WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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MCA

2010-11 Victorian Floods

Rainfall and Streamflow Assessment Project

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Cover Photo: Flooding near Kerang in January 2011 (source: www.weeklytimesnow.com.au).

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GLOSSARY

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small in magnitude. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flash floods occur when soil absorption, runoff or drainage cannot adequately disperse intense rainfall. The most frequent cause of flash flooding is from slow-moving thunderstorms. These systems can deposit extraordinary amounts of water over a small area in a very short time. Flash floods are extremely dangerous weather events as water in creeks, drains and natural watercourses can rise very rapidly.[1]
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood damage	The tangible and intangible costs of flooding.
Flood frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life and limb caused by flooding. A measure of flood hazard often combines the flood depth and velocity.
Flood Warning	The Bureau of Meteorology provides a flood warning service for most major rivers in Australia. Flood warnings of 'Minor', 'Moderate' or 'Major' flooding may be issued for areas with specialised warning systems. These warnings identify the river and the locations expected to be flooded, the likely severity and the timing of flooding. Descriptions of these flood warning categories are provided on the Bureau of Meteorology's website[7] and are summarised below. 'Minor' flooding causes inconvenience. Low-lying areas next to watercourses are inundated which may require the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged. 'Moderate' flooding in addition to the above may require the evacuation of some houses and main traffic routes may be covered. The area of

[1] Bureau of Meteorology website http://reg.bom.gov.au/vic/sevwx/flashfact.shtml

	inundation is substantial in rural areas requiring the removal of stock. 'Major' flooding in addition to the above may result in extensive inundation of rural and/or urban areas. Properties and towns are likely to be isolated and major traffic routes likely to be closed. Evacuation of people from flood affected areas may be required.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Intensity Frequency Duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates. Please refer to the Bureau of Meteorology's website for more information regarding IFD analysis.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.
Risk	A measure of the chance of something happening and the impact. It is measured in terms of consequence and likelihood. For instance flood risk is a measure of the probability of a flood occurring and the impact the flood may have on communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Topography	A surface which defines the ground level of a chosen area.

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1. INTRODUCTION

Over the spring-summer 2010-11 period many communities across Victoria experienced some of the heaviest rainfall and associated flooding ever recorded. Following the floods the Victorian Minister for Water, the Hon Peter Walsh, announced the Flood Warning Network – Repair and Improvement Initiative. This initiative included funding for flood data collection and assessment. This project was funded under the above initiative and collated and analysed rainfall and stream flow data from across Victoria during the 2010-11 floods.

Water Technology was awarded the *2010-11 Victorian Floods Rainfall and Streamflow Assessment Project* by the Department of Sustainability and Environment (DSE), officially commencing on the 24th of November 2011. This is an important project for the Victorian community as it provides not only a summary of the recent floods but will also continue to serve as a useful resource for future flood planning, preparation and response throughout the State.

The project was conducted by Water Technology with review by Michael Cawood and Associates, on behalf of DSE. The project also utilised data and information collated from various studies and enquiries already completed regarding the 2010-11 floods, with all data sources referenced throughout this report.

1.1 Objectives

As discussed above the broad objective of this project is to document the nature of the spring-summer 2010-11 floods in Victoria. More specifically, this documentation is to provide a technical analysis of rainfall and streamflow data over the 2010-11 floods to improving understanding of the recent flood events.

The project included the following:

- **Collation of flood related data** captured during and after the 2010-11 floods. This excluded observed flood levels, aerial photography and satellite imagery, as this was collated in a separate project[2]. Data collated was limited to DSE instantaneous streamflow data, online daily Bureau of Meteorology rainfall data and a flood warning streamflow gauge peak level summary produced by the Bureau of Meteorology. Under instruction from DSE, additional information from other agencies was not sought due to agency commitments to ongoing enquiries at the time.
- **Analysis of rainfall and streamflow data** on a catchment by catchment basis. This analysis included selected Intensity-Frequency-Duration (IFD) analysis, flood frequency analysis, assessment of historic records, and analysis of peak flow travel times.
- **Presentation of data analysis** in a clear and concise manner using plain language so as to facilitate an improved understanding by government agencies.

It must be noted that the intention of this project was not to produce comprehensive flood documentation to the level of detail as that developed post the 1993 floods[3].

[2] Water Technology (2012), Victorian Flood Database Update Project – 2010-11 Floods, Department of Sustainability and Environment.
[3] Hydro Technology (1995), Documentation and Review of 1993 Victorian Floods (vol. 1-5), Department of Conservation and Natural Resources.

1.2 Format of Report

The report is structured in a clear and concise manner and written in plain language to assist government agencies to understand the scale of the 2010-11 flood events. The following sections are included in this report:

- Section 2 – Summary of 2010-11 rainfall and flood warnings
- Section 3 to 8 – Catchment specific hydrological analysis of rainfall and streamflow

1.3 Study Regions

Flooding is generally contained within clearly defined river catchment boundaries. The analysis of rainfall and streamflow can therefore be conducted for individual river catchments. Flood impacts are generally documented at a municipal level, and as municipal boundaries often cross river catchments, the analysis was conducted on wider regions, incorporating multiple river catchments as shown below in Figure 1-1 and described below.

Figure 1-1 Catchment boundaries for rainfall and streamflow analysis and flood impact assessment

- North West region - Wimmera and Mallee catchments.
- North Central region - Avon/Richardson, Avoca, Loddon and Campaspe catchments.

- North East region - Goulburn, Broken, Ovens, King, Kiewa, Mitta Mitta and Upper Murray catchments.
- South West region - Glenelg, Hopkins, Portland Coasts, Barwon, Otway Coasts and Corangamite catchments.
- Port Phillip and Western Port region - Hovells, Moorabool, Werribee, Maribyrnong, Yarra, Patterson and Bunyip catchments.
- Gippsland region - Genoa, Cann, Snowy, Tambo, Mitchell, Avon, Macalister, Thomson, Latrobe, South Gippsland catchments.

2. SUMMARY OF 2010-11 RAINFALL AND FLOOD WARNING

In the spring-summer period of 2010-11, Victoria experienced a number of major rainfall events which led to many communities across Victoria being impacted by floods, some of which were the largest on record. Figure 2-3 shows a summary of the communities impacted by the spring-summer 2010-11 floods. This was provided by the Office of the Emergency Services Commissioner and while it does not include all flood impacted communities, it does provide a good representation of the spatial extent of flooding over this period. Major regional flooding is not uncommon in Victoria. Significant past regional floods includes 1909, 1916, 1917, 1934, 1956, 1974, 1990, 1993 and 1998[4]. The 2010-11 floods were preceded by a long period of sustained drought with the result that in many communities the risk of flooding was not well understood among the general community. Coupled with this long period of drought, the magnitude of some of the floods (largest on record in some instances), came as a surprise to many communities.

Flood events occurred in every month between August 2010 and February 2011. The monthly rainfall totals recorded over this period across Victoria are shown in Figure 2-1, and in more detail in Appendix A. These figures provide an indication of the spatial distribution of rainfall during these events. The discussion below and the summaries provided in Figure 2-1 and Figure 2-2 demonstrate the widespread heavy rainfall and resultant flooding across Victoria.

Given the magnitude, spatial scale and duration of the January 2011 flood event in particular, emergency services were stretched. It was not within the scope of this project to investigate such matters and the reader is directed to the Comrie Review[4] for further discussion and insights into broader issues relating to flooding during this period.

2.1 Rainfall

The Bureau of Meteorology publishes State specific monthly weather reviews which summarise the climatic conditions for the month. The Bureau of Meteorology's monthly reviews were used to describe the rainfall events for each month from August 2010 and February 2011.[5]

2.1.1 August 2010

A succession of frontal systems brought above average rainfall totals to most of Victoria during August 2010. Over half the State recorded rainfall in the highest 10% of previous totals with more than 60 stations recoding their highest August rainfall ever. Several stations also recorded their highest daily August rainfall. Numerous locations recorded rainfall of more than twice the average for August, particularly in the southwest and north central areas. It was the 6th wettest August on record for Victoria and the first individual month with over 100 mm State wide average rainfall since September 1993. Several days of severe weather were experienced across Victoria from Tuesday the 10th to Thursday the 12th of August as a low pressure system which developed over the interior of the continent moved over the State and into Bass Strait. Thunderstorms occurred over the north of Victoria during Tuesday the 10th, with heavy rainfall recorded over the north east region of Victoria. As the low moved into Bass Strait and deepened on Wednesday the 11th, very heavy rainfall was recorded in the south west region of Victoria. The largest two-day rainfall totals were at Weeaproinah (202.2 mm), Haines Junction (135.4 mm), Apollo Bay (105.2 mm) and Lorne (90.4 mm).

[4] Comrie, Neil, *Review of the 2010–11 Flood Warnings & Response*, December 2011.
[5] Bureau of Meteorology http://www.bom.gov.au/climate/mwr/

2.1.2 September 2010

A major rain event affected the north of Victoria on Saturday the 4th and Sunday the 5th as a low pressure system over South Australia deepened and moved into Bass Strait, with an associated trough extending north into NSW. Rain began falling on Friday the 3rd and by 9 am on the Saturday a large proportion of the State had received in excess of 25 mm, with some areas receiving as much as 80 mm. Rainfall continued during the Saturday with the highest 24 hour totals to 9 am on the Sunday centred over the northeast ranges with some places receiving in excess of 130 mm. The highest rainfall totals for the event were 242.8 mm at Falls Creek, 216.4 mm at Whitlands and 181 mm at Myrrhee.

2.1.3 October 2010

Two separate major rainfall events occurred over Victoria in October. Together they delivered more than 1.5 times the October monthly average rainfall over much of central Victoria in the northern regions, in excess of twice the October monthly average. The first of these events occurred in the middle of the month as a trough moved across the State on the 12th and 13th, followed by the rapid development of a low over northern Victoria, which then moved across the State on the 15th and 16th. Significant rainfall totals were recorded across the State, with the highest totals recorded in the north-east and many gauges recording over 120 mm for the 4 day period from the 13th to the 16th. The highest rainfall totals recorded were 174.2 mm at Nariel Creek and 167.0 mm at Bullioh. The second rainfall event occurred at the end of the month. A slow moving low pressure system developed over the west of the State late on the 29th, then gradually moved east on the 30th, and headed south over Tasmania on the 31st. The heaviest rainfalls from this event were recorded in the central and north-east regions, with many gauges recording in excess of 100 mm. Mount Hotham recorded the highest rainfall with 152.0 mm.

2.1.4 November 2010

On the 13th and 14th of November heavy rainfall was recorded as a low developed over Victoria. The highest rainfall totals were recorded in the north-east, with Mt Hotham recording 94.4 mm to 9 am on the 14th. Another trough and low moved across the State on the 27th and 28th leading to more heavy rainfall in the central and north-east regions. 132 mm was recorded at Eildon over the 2 days with numerous places receiving in excess of 80 mm. About half of the rainfall stations in the north-west of the State recorded more than three times their usual November rainfall while in central areas and the north-east many stations recorded their wettest November ever. Humid conditions led to a number of thunderstorms across the State on the 7th, 12th and 26th of the month. Thunderstorms over the western suburbs of Melbourne led to flash flooding on the 26th of November.

2.1.5 December 2010

Victoria started December 2010 with humid north-easterly winds due to a high pressure system in the Tasman Sea and a lingering trough over eastern Australia. All Victorian rainfall districts recorded rainfall in the first few days of the month with the largest falls in the central and northern parts. The high pressure system gradually weakened and moved eastwards and a trough moved in from the southwest on Saturday the 4th. Another high pressure system moved into the Tasman Sea and Victoria returned to north-easterly winds. On Tuesday the 7th, a low pressure system in the Southern Ocean combined with the high pressure system in the Tasman to produce strong northerly flow. The warm northerly winds delivered the hottest night of the month to most parts of the State. A series of cold fronts moved in from the west late on the 7th and crossed the State over the coming days. Large rainfall totals were recorded in the west in the 24 hours to 9 am on 8th, and as the system moved east, large rainfall totals were recorded in the east in the 24 hours to 9 am on the 9th. The highest rainfalls for the 2-day period were 194.0 mm at Falls Creek and 165.2 mm at Tawonga. Another cold

front moved in from the west on the 15th and delivered widespread falls to East Gippsland and other parts of the State. The pattern was repeated again on the 17th, and then again on the 19th. The average rainfall across Victoria during the month was 104.76 mm, making December 2010 the 5th wettest December on record for the State. The last December recording similar rainfall was in 1992. Large parts of the west and the north received above average to highest on record rainfall totals. Some parts of the west and north received more than 100 mm above their average for the month. There were more than a dozen stations with records over 100 years long that recorded their highest ever daily or monthly rainfalls.

2.1.6 January 2011

Significant widespread rainfall in January 2011 affected the majority of Victoria. It was the wettest January on record. The State received almost three times its usual rainfall. More than 150 stations recorded their wettest ever January as well as their highest January daily rainfall on record. The highest monthly total was recorded at Halls Gap with 297.0 mm followed by Mount William with 289.6 mm and Kyneton with 284.2 mm. Gerang Gerung recorded 146.8 mm on the 12th while Halls Gap recorded 146.6 mm on the 14th and 135.0 mm on the 12th. The event was significant enough for the Bureau of Meteorology to publish Special Climate Statement 26.[6] The Special Climate Statement contains a detailed description of the synoptic conditions across Victoria and was used in addition to the January Monthly Weather Review to describe the climate conditions in January 2011. The extreme rainfall observed during January 2011 was generated by the passing of complex and persistent low pressure systems. A broad slow moving trough centred over western Victoria and a ridge of high pressure to the south of Tasmania were the main drivers for the rainfall which commenced on Sunday the 9th of January. The two systems created exceptionally humid conditions and unstable easterly flow across Victoria. The trough strengthened on Wednesday the 12th and developed into a low pressure system over eastern South Australia on Thursday 13th as a high pressure system moved into the Tasman Sea. The low pressure system cleared the State on Friday evening after adding an additional 50 to 100 mm to the deluge already received across Victoria. A broad ridge of high pressure persisted over the State from Saturday 15th through until Thursday 20th, bringing settled and sunny conditions.

2.1.7 February 2011

February 2011 was the third wettest on record across Victoria. Early in the month elevated moisture from ex-Tropical Cyclone Yasi and the remnant of Tropical Cyclone Anthony combined with an approaching trough to deliver heavy rain and thunderstorms to Victoria. Severe thunderstorms affected much of the State during the afternoon and evening of the 4th, with the south eastern suburbs of Melbourne and the north-west (Mildura recorded a record daily rainfall total of 147.4 mm with most of that falling within just a few hours) particularly impacted. The north-east of the State also received significant rainfall with many gauges recording over 140 mm for the 3 days ending on the 6th. Thunderstorms continued in the north of the State on the 10th and 11th with over 100 mm recorded in the north-east.

[6] Bureau of Meteorology http://www.bom.gov.au/climate/current/statements/scs26b.pdf

2.2 Flood Warning & Streamflow

The Bureau of Meteorology issues a variety of flood warning products depending on the type and risk of flooding[7]:

- A 'Flood Watch' to alert of possible flooding may be issued if flood producing rain is expected in the near future;
- A 'Severe Weather Warning' or a 'Severe Thunderstorm Warning' may refer to the possibility of flash flooding when issued for urban areas covered by weather watch radar;
- A 'Generalised Flood Warning' may be issued if flooding is occurring or is expected to occur in a particular region. Specific information regarding severity or location of the flooding is not provided.
- Flood warnings of 'Minor', 'Moderate' or 'Major' flooding may be issued for areas covered by formal flood warning services. These warnings identify the river and the locations expected to be flooded, the likely severity in terms of peak river height, and the timing of flooding. Descriptions of these flood warning categories are provided on the Bureau of Meteorology's website[7] and are summarised below.
    - 'Minor' flooding causes inconvenience. Low-lying areas next to watercourses are inundated which may require the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged.
    - 'Moderate' flooding in addition to the above may require the evacuation of some houses and main traffic routes may be covered. The area of inundation is substantial in rural areas requiring the removal of stock.
    - 'Major' flooding in addition to the above may result in extensive inundation of rural and/or urban areas. Properties and towns are likely to be isolated and major traffic routes likely to be closed. Evacuation of people from flood affected areas may be required.

As well as the meteorological summaries, the Bureau of Meteorology's monthly weather reviews[5] and Special Climate Statement for Janaury 2011[6] also provide a summary of flood warning services issued over the month. Flood warnings issued during the period August 2010 to February 2011 are summarised below in Figure 2-2 and in more detail in Appendix B.

2.2.1 August 2010

A total of 194 flood watches and warnings were issued for the month with warnings current for every day of the month. The majority of the warnings were for 'Minor' flooding and most were for rivers north of the Great Dividing Range. Six of the seven 'Moderate' flood warnings were provided for the Barwon and Leigh River catchments upstream of Geelong. The observed flooding was consistent with the predicted 'Moderate' flooding upstream of Geelong, but only 'Minor' flooding at Geelong was observed on the 15th of the month. The Kiewa catchment had 24 flood warnings with the station at Bandiana at the downstream end of the river near the confluence with the Murray River above 'Minor' flood level for the majority of the month.

2.2.2 September 2010

A total of 331 flood warnings were issued during the September flood event, with 110 of those for 'Major' flooding. Every river basin north of the Great Dividing Range experienced 'Major' flooding except for the Campaspe River which experienced areas of 'Moderate' flooding. Ten river stations in northern Victoria accessed by the Bureau of Meteorology for flood warning purposes recorded their

[7] Bureau of Meteorology http://reg.bom.gov.au/hydro/flood/flooding.shtml

highest ever flood peak. The September 2010 floods caused significant flood damage for numerous Victorian communities.

2.2.3 October 2010

A total of 135 flood warnings were issued across the State, with 122 'Minor', 4 'Moderate' and 9 'Major'. The majority of the flooding occurred in the northern catchments, with the worst of the 'Major' flooding experienced upstream of Hume Dam on the Upper Murray River. As a result of the high flows upstream, controlled releases from Hume Dam resulted in 'Minor' flooding downstream along the Murray River in the Corowa region. The Yarra River was in flood around Yarra Glen and Healesville.

2.2.4 November 2010

Riverine flooding in the north east of the State occurred around the middle of the month, with further rainfall later in the month resulting in 'Major' flooding on the Loddon and Avoca Rivers. Severe thunderstorms over the western suburbs of Melbourne on the 26th resulted in a number of occurrences of flash flooding.

2.2.5 December 2010

'Major' flood warnings were issued for rivers in the north-east, with many other rivers experiencing 'Moderate' flooding. Severe thunderstorms at the start of the month resulted in a number of flash flooding occurrences. Further severe thunderstorms later in the month resulted in a significant amount of damage around the eastern suburbs of Melbourne.

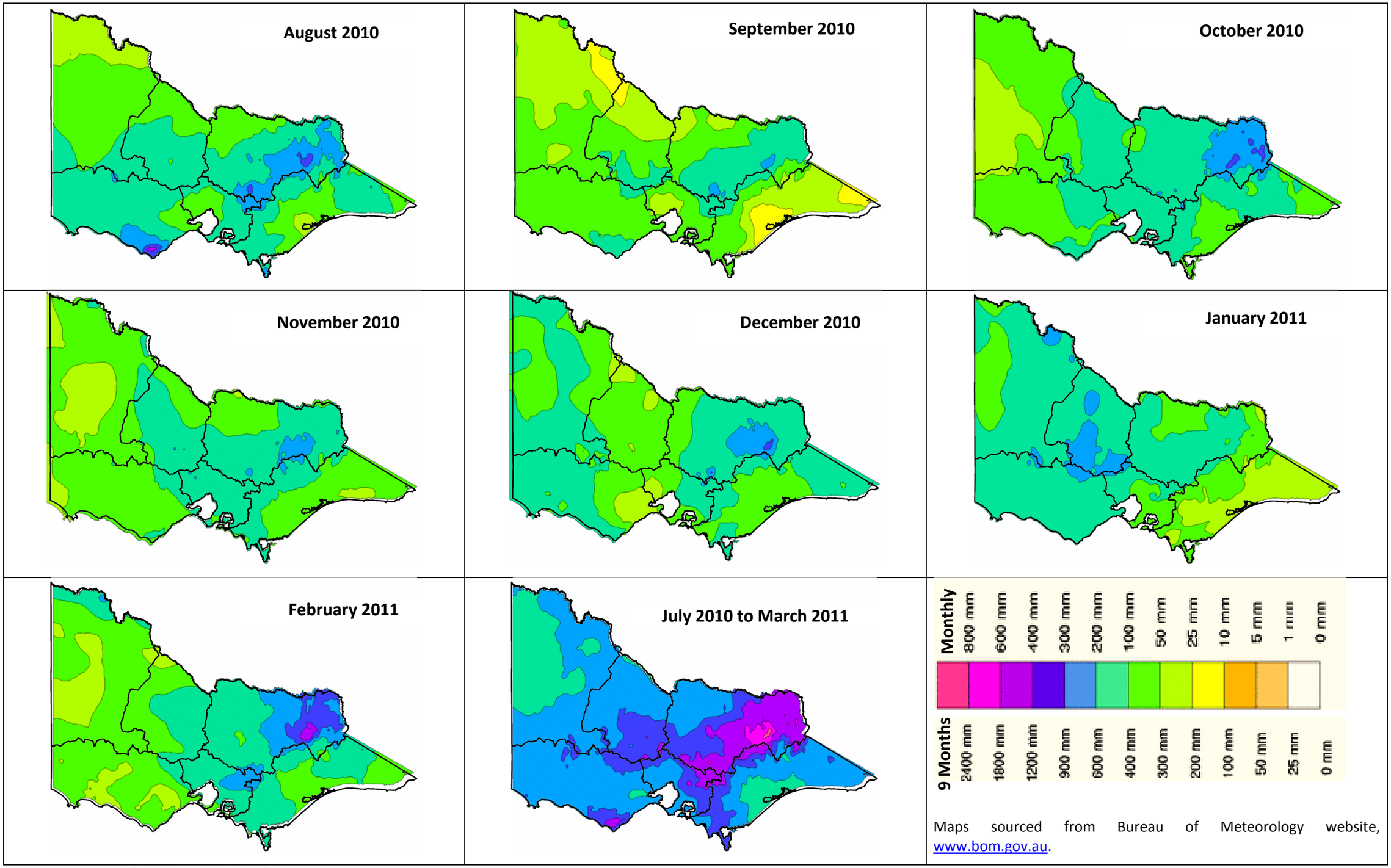
2.2.6 January 2011

'Major' and 'Moderate' flooding was experienced across the north, west and central regions of the State, beginning on or around the 12th of the month and continuing through to the end of the month on some of the bigger northern rivers. Many gauges reached the highest flood levels on record, surpassing the September 2010 flood event. The Avoca River at Quambatook peaked at just over 0.5 m above the previously gauged record height. On the Wimmera River record heights were observed along the length of the river, with the flood estimated by many sources and quoted in the local media as a 0.5% Annual Exceedance Probability (AEP) event.[8] On the Loddon River, the Laanecoorie Reservoir gauge recorded its second highest flow on record, with only the 1909 flood, when the dam failed, recording a larger flow. 'Major' flooding on the Campaspe River led to record flooding, with Rochester severely impacted by flooding.

2.2.7 February 2011

Widespread flash flooding was reported around the Melbourne metropolitan area and in some rural areas on the 4th of the month. Mildura in the State's north-west received heavy rainfall over a short duration causing significant flash flooding issues. Numerous 'Moderate' and 'Major' flood warnings were also issued across the State for the already swollen rivers.

[8] http://www.abc.net.au/news/2011-01-18/nervous-wait-for-flood-affected-horsham/1909204

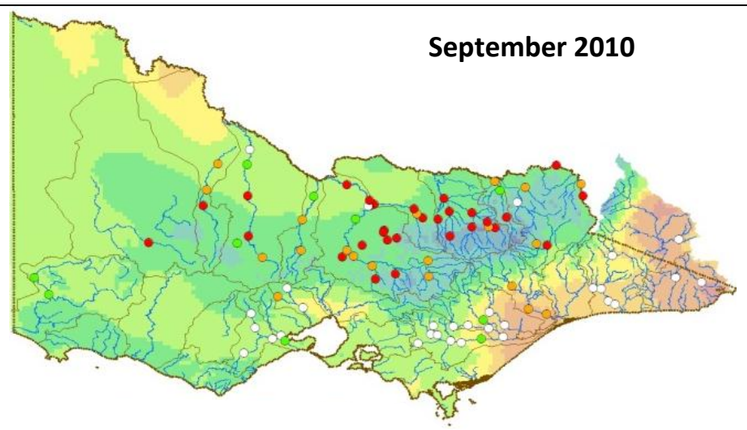


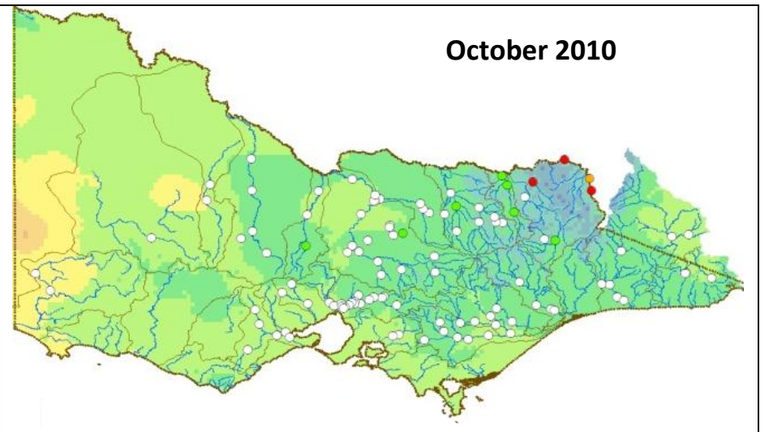
Maps sourced from Bureau of Meteorology website, www.bom.gov.au.

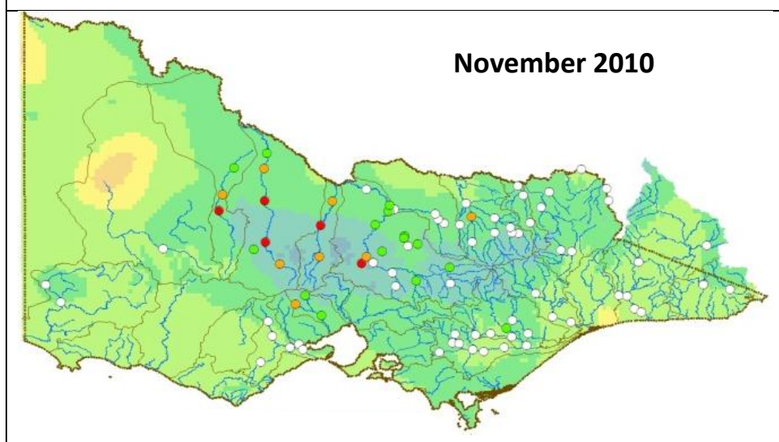
Figure 2-1 Monthly rainfall totals for the 2010-11 spring-summer period

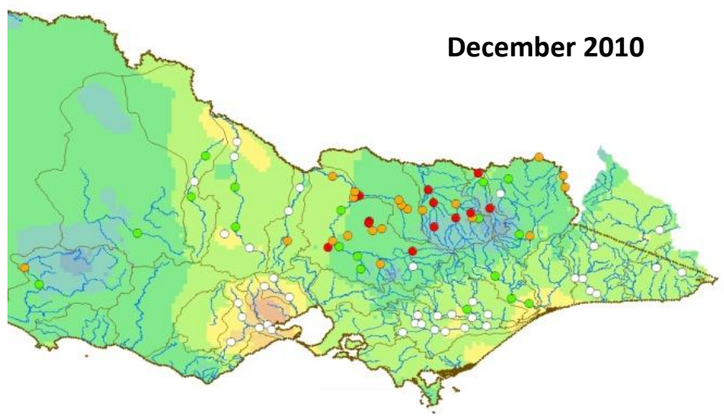
August 2010

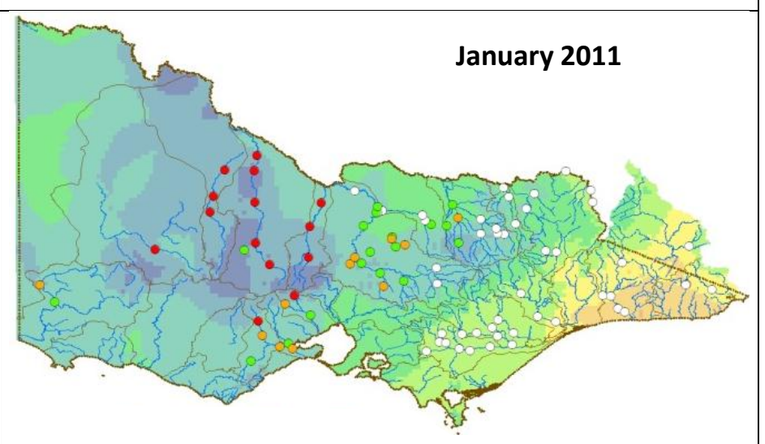
NOT AVAILABLE

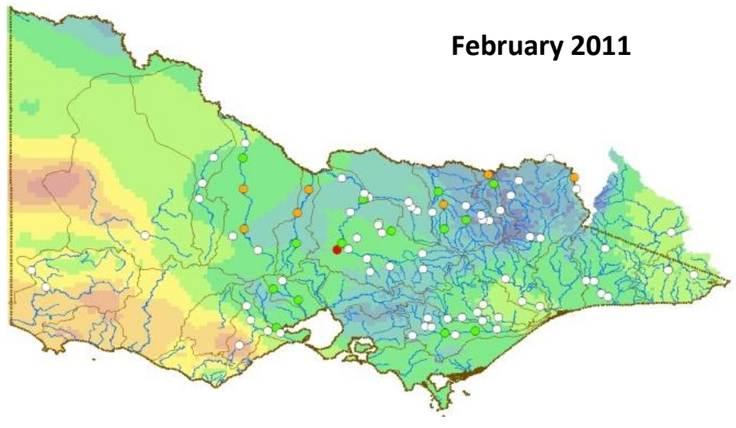


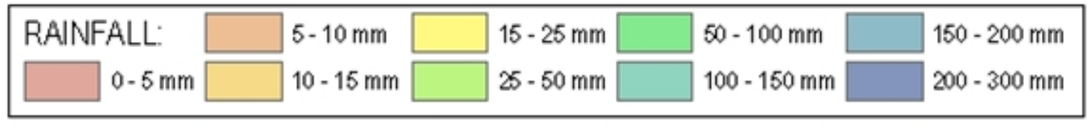












Maps provided by Bureau of Meteorology, with flood warnings only issued at gauge locations where flood class levels have been determined.

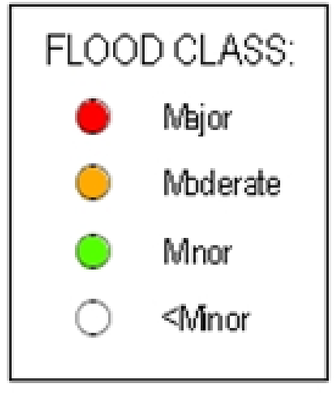


Figure 2-2 Flood warnings for the 2010-11 spring-summer period

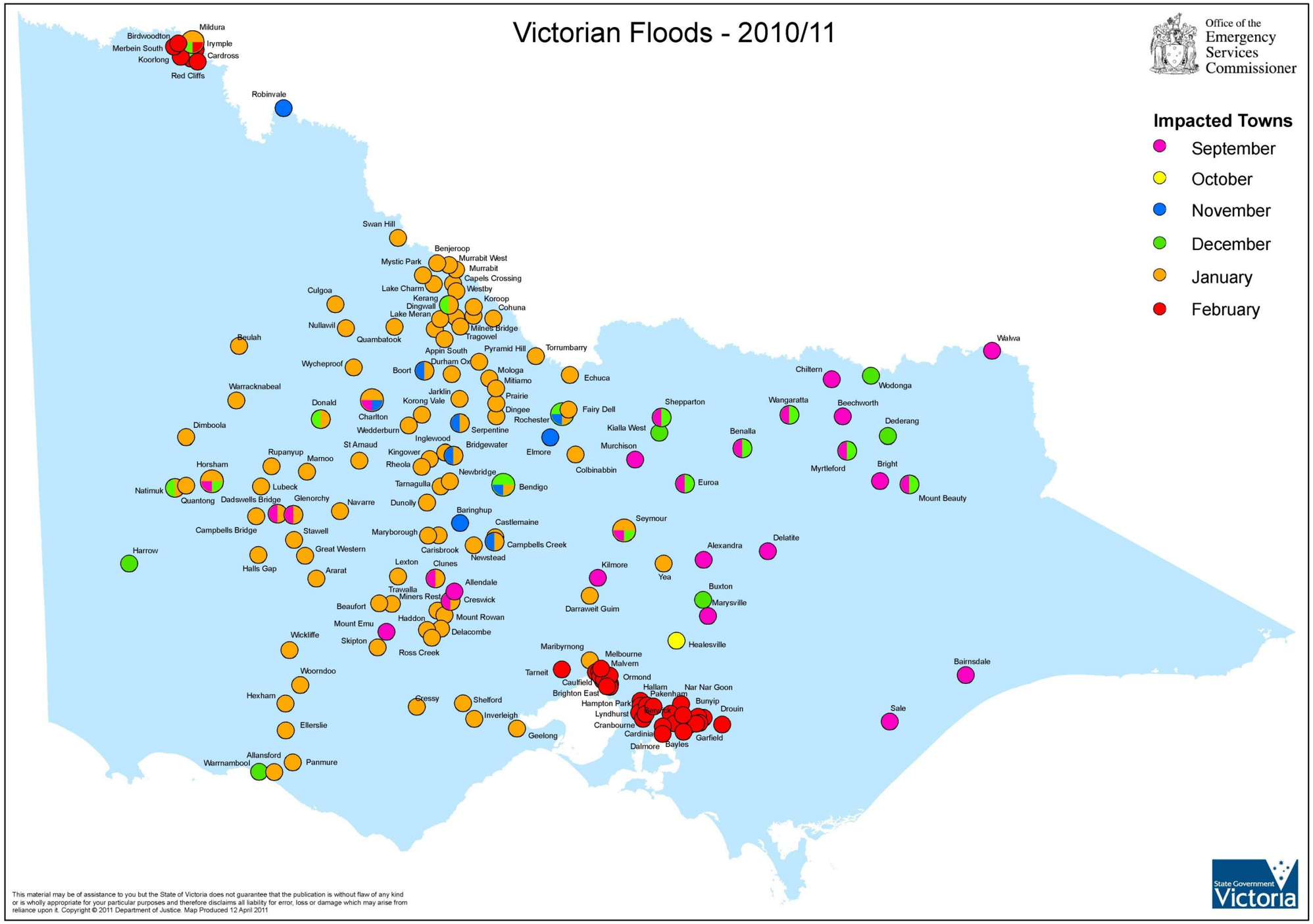


Figure 2-3 Flood impacted communities (supplied by the Office of the Emergency Services Commissioner)

3. NORTH WEST REGION HYDROLOGICAL ANALYSIS

3.1 Overview of Flooding

August 2010 – The North West region was subject to isolated heavy rainfalls which gave rise to reported flash flooding in Warracknabeal.[9] The flood related damage was relatively low compared to subsequent events.

September 2010 – Widespread heavy rainfall was observed with many waterways reaching 'Major' flood levels, with significant flood damage experienced throughout the region.

October 2010 – No known flooding issues, the Wimmera River remained at less than 'Minor' levels.

November 2010 – No known flooding issues. The Wimmera River remained at less than 'Minor' levels.

December 2010 – Heavy rainfall was recorded throughout the region, with 'Major' flooding occurring at Natimuk with many properties flooded below floor level and SES evacuating some homes.[10]

January 2011 – Was the largest flood recorded at most flow gauges along the Wimmera River. The level of flooding and the flood related damage experienced exceeded that of the September 2010 event, with significant above floor flooding and infrastructure damage occurring in communities across the region.[11] No above floor flooding was experienced at Horsham due to good flood intelligence.

February 2011 – Flash flooding was an issue in Mildura, with a significant number of residences impacted by surface runoff and backing up of stormwater drainage systems.[12]

3.2 Regional Description

The North West region includes the Wimmera River and Mallee catchments, Figure 3-1 below shows the major waterways in the region.

The Wimmera River flows north from the Great Dividing Range, with numerous communities situated on the river and its many tributaries in the upper catchment. The Wimmera River then flows through the towns of Glenorchy, Horsham, Dimboola and Jeparit, before flowing into Lake Hindmarsh and Lake Albacutya.

A number of distributary systems characterise the Mallee catchment. Dunmunkle Creek is a major effluent watercourse of the Wimmera River from upstream of Glenorchy. Break outs from the Wimmera River to the Creek occur during high flow events. It flows in a northerly direction through Rupanyup to eventually become part of a channel system that terminates at Lake Tyrell, north of Sea Lake. The Wimmera River also overflows during high flow events into Swedes Creek, a tributary of the Richardson River, from upstream of Glenorchy. The Richardson River catchment is in the North Central region. Yarriambiack Creek is another effluent stream which is fed by breakout flows from the Wimmera River, flowing in a northerly direction through the Mallee townships of Warracknabeal, Brim, Beulah and Hopetoun. A number of distributaries flow from the Avoca River in the North Central region through to the Mallee, including Tyrell Creek which flows through Culgoa.

[9] http://www.abc.net.au/news/2010-08-19/storm-dumps-hail-on-wimmera-mallee/949812
[10] http://www.abc.net.au/local/stories/2010/12/08/3088088.htm
[11] Water Technology (2011), *Wimmera Region Flood Report – January 2011*, Wimmera CMA (in association with Michael Cawood and Associates)
[12] Mildura Rural City Council (2011), *Municipal Flood Recovery Plan 2011-2012*

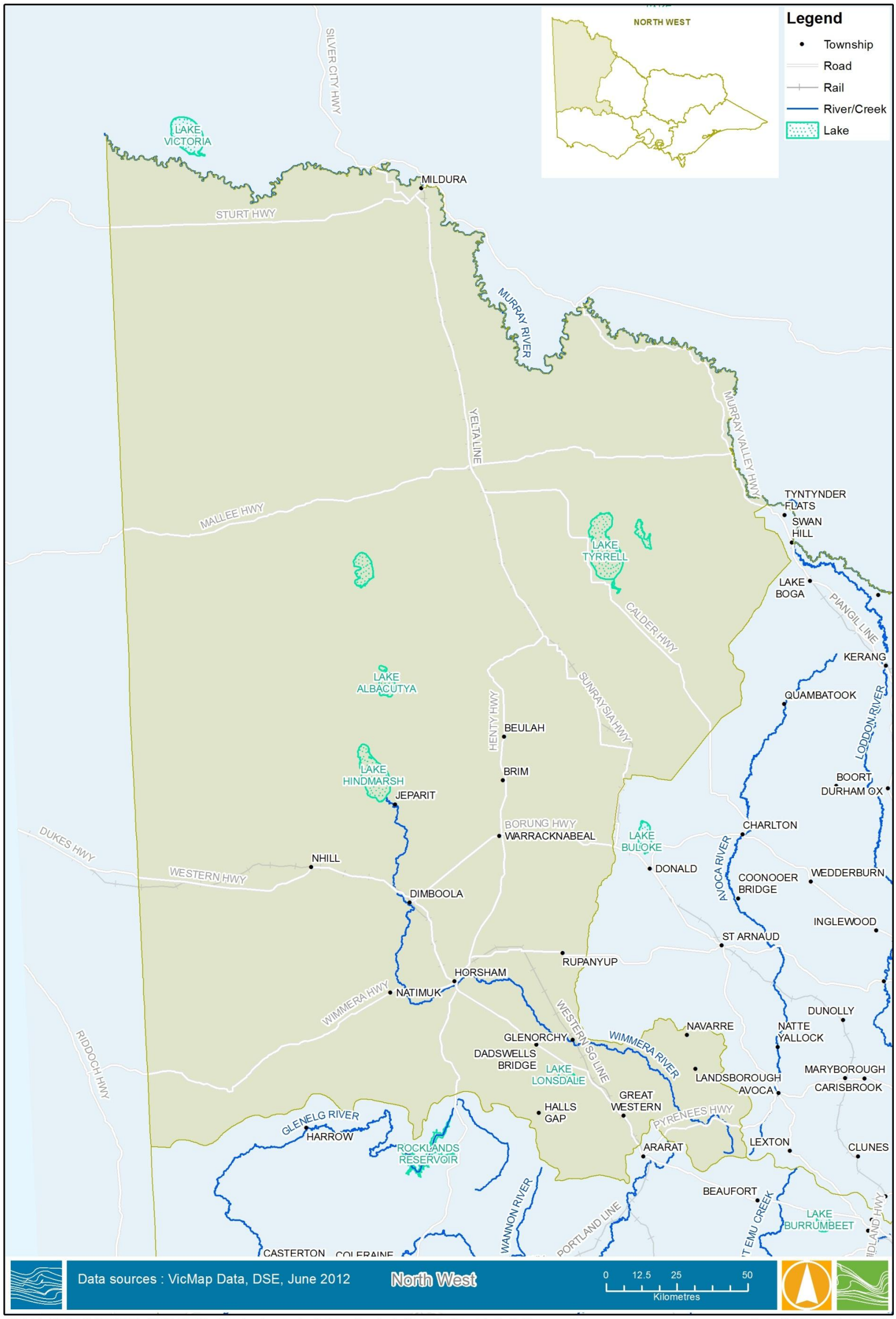


Figure 3-1 North West region

3.3 Rainfall

Section 2.1 provides a broad overview of the synoptic conditions that produced the rainfall events over the spring-summer 2010-11 period. This Section includes more detail about specific rainfall gauges within the North West region. It should be noted that daily rainfall gauges typically record rainfall totals over a 24 hour period to 9 am on the date recorded.

Table 3-1 below summarises the maximum daily rainfall and monthly totals for numerous rainfall gauges across the region. The observed rainfall is compared to historical monthly averages over the spring-summer period as well as against the historical monthly and daily maximum rainfall totals. A high proportion of the gauges selected for analysis broke daily and monthly maximum rainfall records during the spring-summer 2010-11 period.

For a selected number of gauges an Intensity-Frequency-Duration (IFD) analysis was undertaken on the daily rainfall totals at 24, 48 and 72 hour durations. Using the geographical coordinates for the rainfall gauges analysed, the raw polynomial coefficients were taken from the Bureau of Meteorology's online IFD Data System[13], and used as input to an IFD spreadsheet tool developed by Water Technology, plotting the IFD curves for the rainfall gauge site. This was overlayed with the maximum 24, 48 and 72 hour rainfall totals for each month.

The gauges selected were chosen to provide a spread across the region with preference for gauges in proximity to areas of significant flooding. Note that the frequency attributed to the rainfall event does not necessarily correspond to the frequency of the flood event due to antecedent catchment conditions, timing of tributary flows etc. It must also be noted that the frequency of the event may differ when durations shorter than 24 hours are considered, however with daily rainfall gauges these shorter durations can not be assessed. Figure 3-3 to Figure 3-7 below show the IFD analysis undertaken.

Figure 3-2 below shows the location of the rainfall gauges analysed for both daily and monthly totals and also those gauges for which an IFD analysis was completed.

[13] http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml

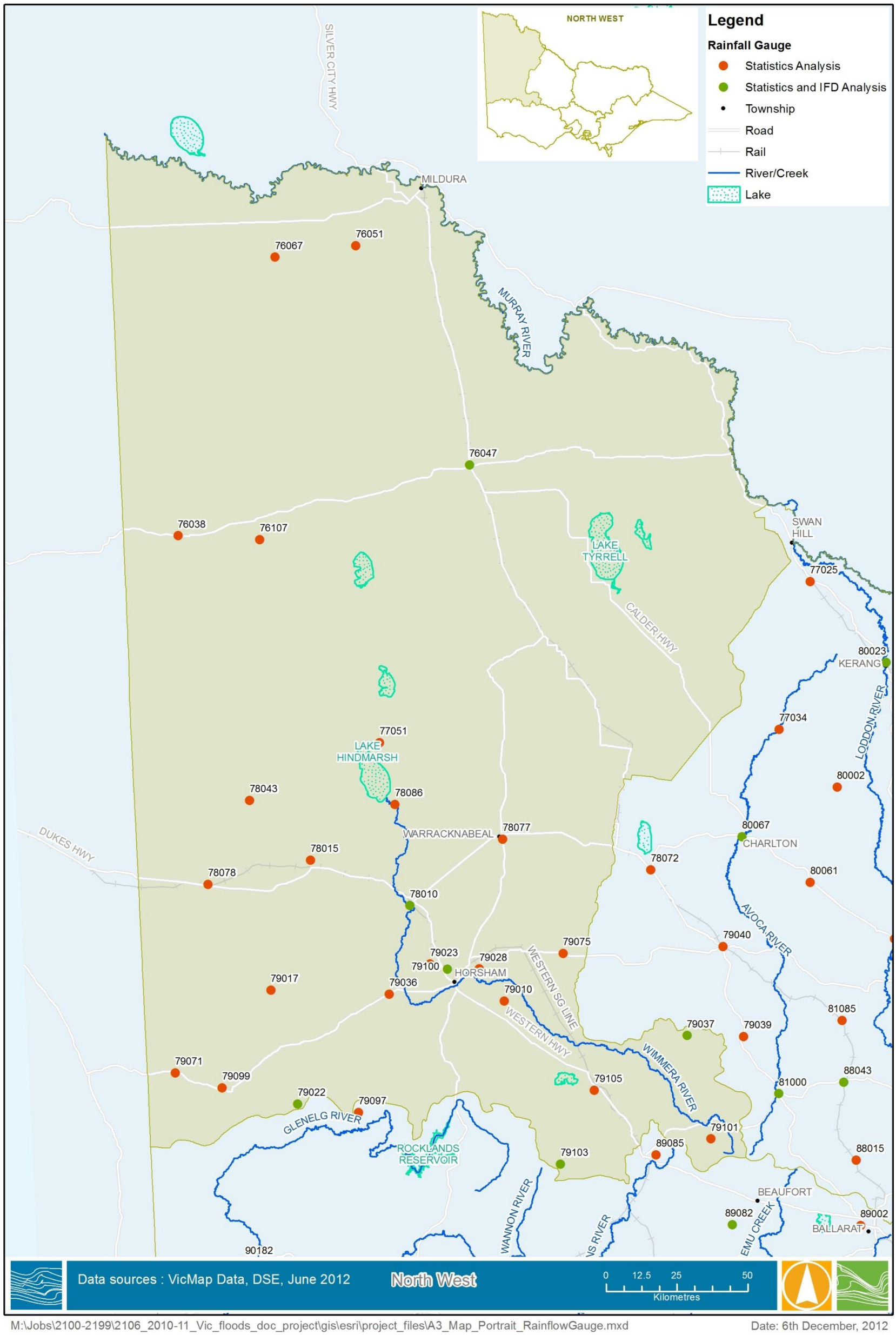
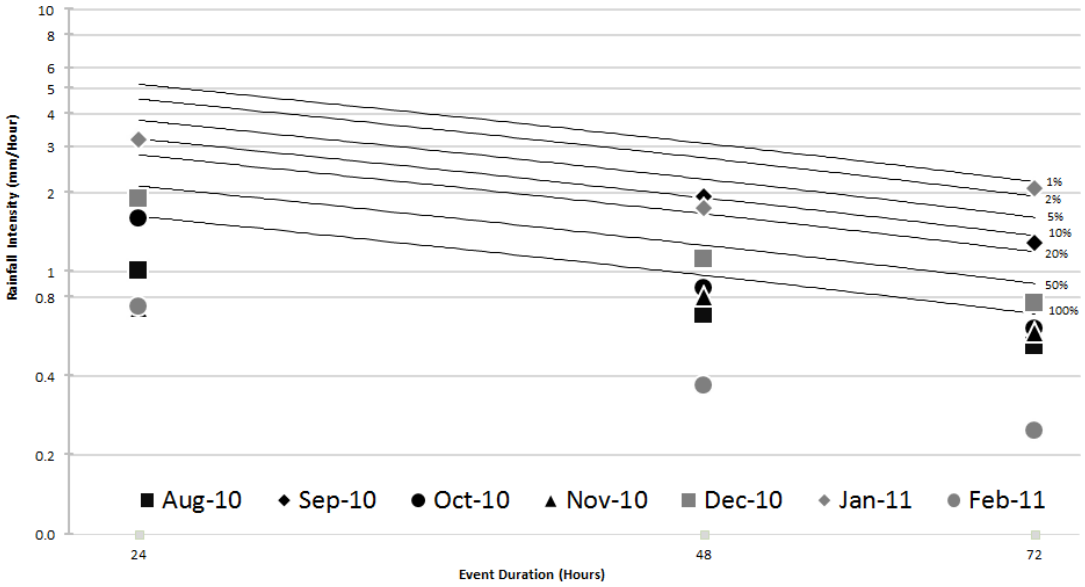


Figure 3-2 North West Region rainfall gauges analysed

Table 3-1 North West region observed rainfall summary

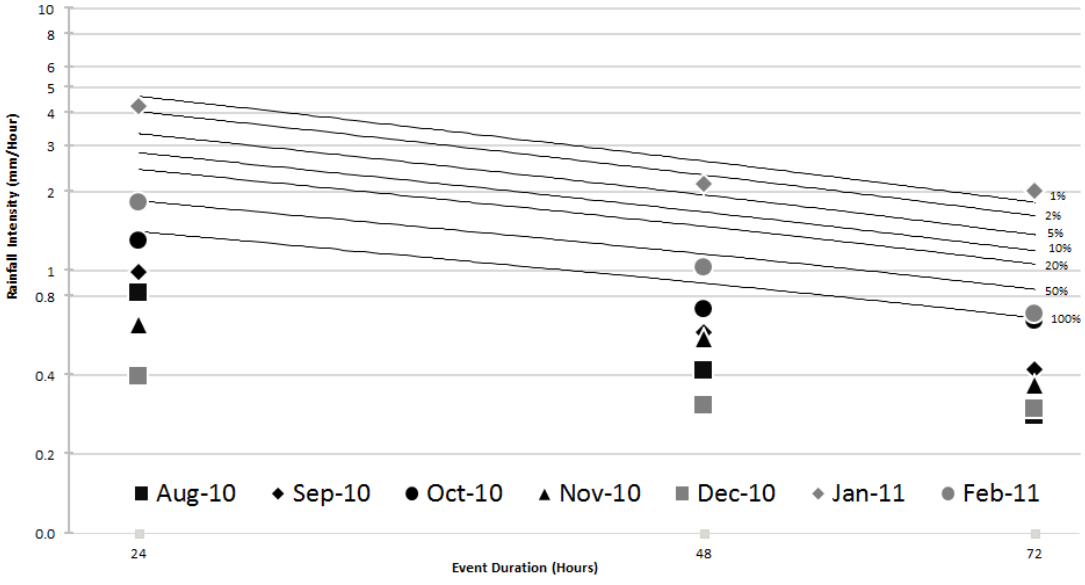
Location	Station Number	August 2010		September 2010		October 2010		November 2010		December 2010		January 2011		February 2011		Record Statistics			
		Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Avg.	Monthly Max.	Daily Max.	Start of record
Apsley (Post Office)	79071	106.7	13.0 (26th)	57.2	10.7 (5th)[1]	28.3	10.6 (30th)[1]	51	23.6 (25th)	135.9	48.4 (8th)	145	115.0 (14th)	59.8	23.5 (19th)[1]	19.9-77.3	193.0 (Jul 1964)	115.0 (14/01/2011)[3]	1953
Dimboola	78010	44.4	13.6 (11th)	77.2	29.4 (14th)	59.2	29.0 (15th)	48.2	14.0 (14th)	141	65.2 (8th)	155	104.2 (12th)	38.4	23.6 (19th)	22.3-43.5	179.7 (Oct 1973)	131.6 (07/02/1957)	1882
Drung Drung	79010	89	24.4 (11th)	44.6	22.0 (4th)	58.6	28.6 (15th)	45.6	14.4 (13th)	142.6	47.6 (8th)	123	57.0 (14th)	85.8	35.2 (28th)	21.6-50.3	203.2 (Oct 1975)	109.5 (07/02/1957)	1905
Edenhope Airport	79099	110.4	18.0 (1st)	63.2	16.4 (4th)	31	11.4 (30th)	56.6	27.4 (25th)	154.2	67.2 (8th)	110.2	62.8 (14th)	66.2	34.0 (11th)	24.0-66.9	154.2 (Dec 2010)[3]	67.2 (08/12/2010)[3]	2005
Goroke (Post Office)	79017	99.2	13.2 (26th)	54.9	18.8 (4th)[1]	34	20.8 (25th)	NA[2]	NA[2]	97.6	35.0 (8th)	94.8	46.4 (12th)	40.2	17.6 (19th)	23.3-62.0	162.6 (Aug 1886)	110.5 (06/03/1910)	1886
Grampians (Mount William)	79103	312	49.0 (11th)	137	35.2 (5th)	109.2	37.0 (15th)	110.8	31.6 (25th)	139	58.4 (8th)	289.6	134.6 (12th)	93.6	35.2 (19th)	39.2-166.2	289.6 (Jan 2011)[3]	134.6 (12/01/2011)[3]	2005
Horsham Aerodrome	79100	73.8	19.6 (11th)	42.8	23.6 (4th)	67.6	31.0 (15th)	49.2	15.0 (25th)	39.2	9.4 (3rd)	159.2	101.4 (12th)	87.6	43.6 (28th)	15.3-40.7	159.2 (Jan 2011)[3]	101.4 (12/01/2011)[3]	1990
Horsham Polkemmet Rd	79023	76.8	17.4 (11th)	41.2	19.0 (4th)	53	23.0 (15th)	58	20.0 (25th)	150.2	60.2 (8th)	146.2	98.0 (12th)	67.8	23.0 (28th)	23.5-49.2	150.2 (Dec 2010)[3]	108.5 (07/02/1957)	1873
Jeparit	78086	77	14.4 (1st)	40.2	27.6 (4th)	36.8	20.0 (15th)	39	14.4 (13th)	84	50.4 (8th)	202.2	160.6 (12th)[1]	34.6	20.4 (19th)	21.1-40.3	202.2 (Jan 2011)[3]	127.3 (06/03/1910)	1898
Kanagulk	79097	98.8	17.2 (26th)	49	15.2 (4th)	46	24.6 (15th)	47.2	20.0 (25th)	156.4	80.4 (8th)	130.2	89.2 (12th)	61.4	26.0 (11th)	28.3-65.9	156.4 (Dec 2010)[3]	89.2 (12/01/2011)[3]	2004
Kaniva	78078	92.4	17.4 (26th)	59.2	21.4 (4th)	37	19.6 (15th)	42	18.6 (25th)	102.2	31.8 (8th)	67	44.8 (14th)	55	35.3 (19th)[1]	21.1-54.5	206.7 (Apr 1889)	158.8 (20/03/1910)	1883
Longerenong	79028	76.2	16.0 (11th)	45.6	29.8 (4th)	48.8	24.0 (15th)	45	15.6 (13th)	126	47.0 (8th)	159.6	97.0 (12th)	69.2	24.6 (19th)	23.1-44.1	171.8 (Oct 1975)	106.7 (07/02/1957)	1860
Murrayville	76038	54.4	8.8 (26th)	43.6	33.4 (4th)	49.4	28.6 (15th)	79.8	42.2 (27th)	122.8	70.0 (8th)	65	32.0 (14th)	61.4	44.8 (5th)	17.2-34.1	142.4 (Jan 1936)	107.2 (07/01/1936)	1910
Natimuk	79036	69.4	15.2 (11th)	42.2	22.8 (4th)	35	19.0 (15th)	51	23.0 (25th)	130.6	54.2 (8th)	150.6	113.6 (12th)[1]	42.8	18.9 (19th)[1]	22.7-50.1	179.6 (Oct 1975)	114.3 (07/02/1957)	1889
Navarre	79037	131.9	24.0 (11th)	109	78.0 (4th)	104.4	38.0 (31st)	75.8	17.4 (14th)	104.1	45.4 (8th)	167.3	76.2 (14th)	49	17.6 (19th)	27.2-62.1	197.6 (Dec 1933)	146.1 (01/12/1933)	1897
Nhill Aerodrome	78015	30.2	14.8 (26th)	49.2	22.4 (4th)	38.6	23.0 (15th)	48.4	14.8 (25th)	99.4	43.8 (8th)	106.6	65.4 (12th)	25.4	13.6 (19th)	11.5-44.1	106.6 (Jan 2011)[3]	65.4 (12/01/2011)[3]	2003
Ouyen (Post Office)	76047	52.2	9.4 (5th)	42.2	30.6 (4th)	71.2	21.2 (15th)	68	19.8 (14th)	168.4	74.2 (8th)	130.6	50.0 (14th)	98.2	44.2 (5th)	20.3-35.2	182.7 (Feb 1969)	83.8 (09/02/1969)	1911
Pirlta	76051	30.8	5.0 (26th)	43.4	28.0 (4th)	86.8	49.4 (15th)	87.6	24.0 (13th)	110.6	33.2 (8th)	106.6	42.0 (14th)	138.2	103.0 (5th)	17.4-28.7	138.2 (Feb 2011)[3]	103.0 (05/02/2011)[3]	1924
Pyrenees (Ben Nevis)	79101	192.2	32.2 (12th)	111	47.2 (4th)	109.6	38.6 (31st)	107.2	26.8 (25th)	109.8	32.2 (8th)	170.2	67.8 (14th)	106.6	57.2 (5th)	46.5-113.9	192.2 (Aug 2010)[3]	67.8 (14/01/2011)[3]	2007
Rainbow (Werrap (Oak-Lea))	77051	82.6	13.2 (11th)	42	31.8 (4th)	49.4	28.4 (15th)	23.4	12.0 (13th)	97	52.6 (8th)	160.2	116.4 (12th)	28.4	15.4 (19th)	19.7-37.8	182.3 (Feb 1911)	116.4 (12/01/2011)[3]	1898
Rupanyup (Post Office)	79075	105.2	22.8 (11th)	59.8	40.0 (4th)	41.6	15.0 (31st)[1]	126.2	42.14 (28th)[1]	148	60.8 (8th)	200.6	90.0 (14th)	47	22.6 (19th)	23.7-45.5	200.6 (Jan 2011)[3]	90.0 (14/01/2011)[3]	1901
Stawell Aerodrome	79105	122.2	35.2 (11th)	66.6	31.0 (4th)	81	39.8 (15th)	79.4	36.8 (25th)	82.6	41.8 (8th)	172.4	86.6 (14th)	61.2	28.0 (19th)	22.4-56.6	172.4 (Jan 2011)[3]	86.6 (14/01/2011)[3]	1996
Tutye (Bunurouk)	76107	62.8	12.6 (26th)	38	26.0 (4th)	52.2	20.0 (15th)	52.2	19.8 (27th)	112.4	65.0 (8th)	92.4	46.2 (12th)	70.2	53.4 (5th)	19.1-34.9	133.2 (Oct 1975)	69.6 (09/02/1969)	1969
Warracknabeal Museum	78077	102	26.4 (19th)	28.2	37.4 (4th)	44.2	17.6 (15th)	39.5	12.0 (13th)	123.4	66.4 (8th)	165.8	77.4 (10th)	57.3	24.4 (5th)	21.5-44.5	165.8 (Jan 2011)[3]	82.0 (21/02/2003)	1969
Werrimull	76067	38.2	6.7 (26th)	33	18.0 (4th)	51.4	20.0 (15th)	89.1	31.0 (25th)	132.2	71.0 (8th)	82.7	26.8 (14th)	109.7	44.6 (5th)[1]	15.9-29.5	139.4 (Feb 2000)	88.4 (26/02/1939)	1926
Yanac North	78043	86.6	17.2 (1st)	48	27.2 (4th)	32.2	19.8 (15th)	60.2	25.2 (27th)	98.4	42.2 (8th)	85.8	43.4 (14th)	37.8	13.4 (19th)	20.2-45.3	220.2 (Mar 1910)	200.9 (06/03/1910)	1889

[1]Note: Gauge recordings were aggregated over a number of days. Daily totals were disaggregated using the daily rainfall pattern from the nearest gauge of complete record.
[2]Note: Records of data were incomplete for the month. The total and highest daily rainfall cannot be determined using incomplete data.
[3]Note: Gauge broke daily or monthly statistical records over the period.
[4]Note: Analysis carried out early May 2012, any events after that not captured in historical records columns.



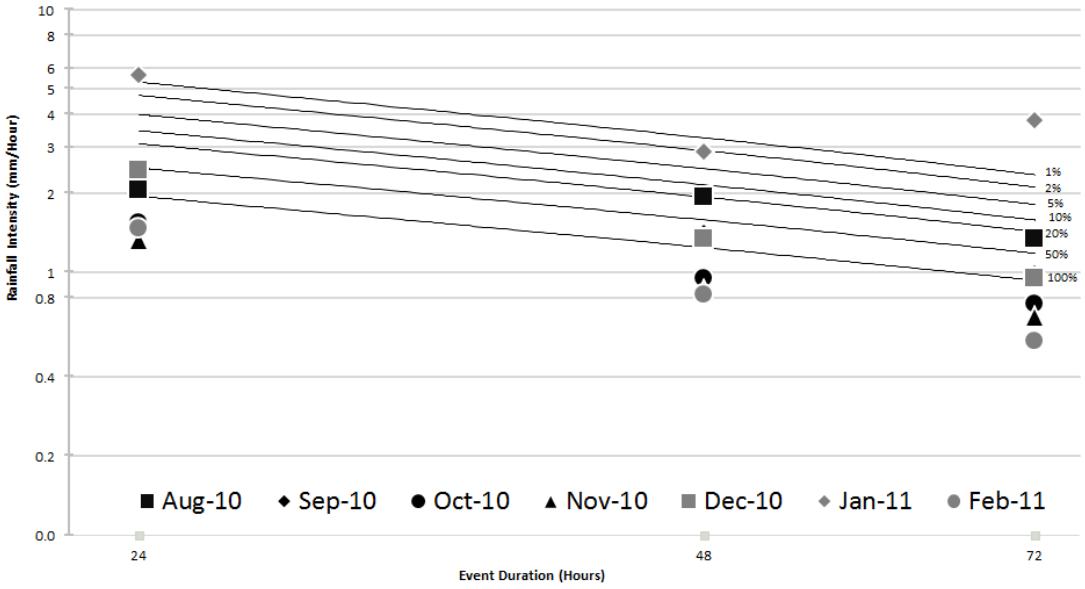
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	24.0	1.0	11/08/2010	>100%	32.6	0.7	12/08/2010	>100%	37.2	0.5	12/08/2010	>100%
Sep 10	78.0	3.3	4/09/2010	10%-5%	92.2	1.9	5/09/2010	10%-5%	92.8	1.3	6/09/2010	10%-20%
Oct 10	38.0	1.6	31/10/2010	>100%	41.6	0.9	31/10/2010	>100%	43.4	0.6	15/10/2010	>100%
Nov 10	17.4	0.7	14/11/2010	>100%	38.4	0.8	1/11/2010	>100%	42.0	0.6	1/11/2010	>100%
Dec 10	45.4	1.9	8/12/2010	100%-50%	53.6	1.1	8/12/2010	100%-50%	54.4	0.8	8/12/2010	100%-50%
Jan 11	76.2	3.2	14/01/2011	10%-20%	83.8	1.7	14/01/2011	10%-20%	149.1	2.1	14/01/2011	2%-1%
Feb 11	17.6	0.7	19/02/2011	>100%	17.6	0.4	19/02/2011	>100%	17.8	0.2	19/02/2011	>100%

Figure 3-3 079037 Navarre Rainfall Intensity-Frequency-Duration Analysis



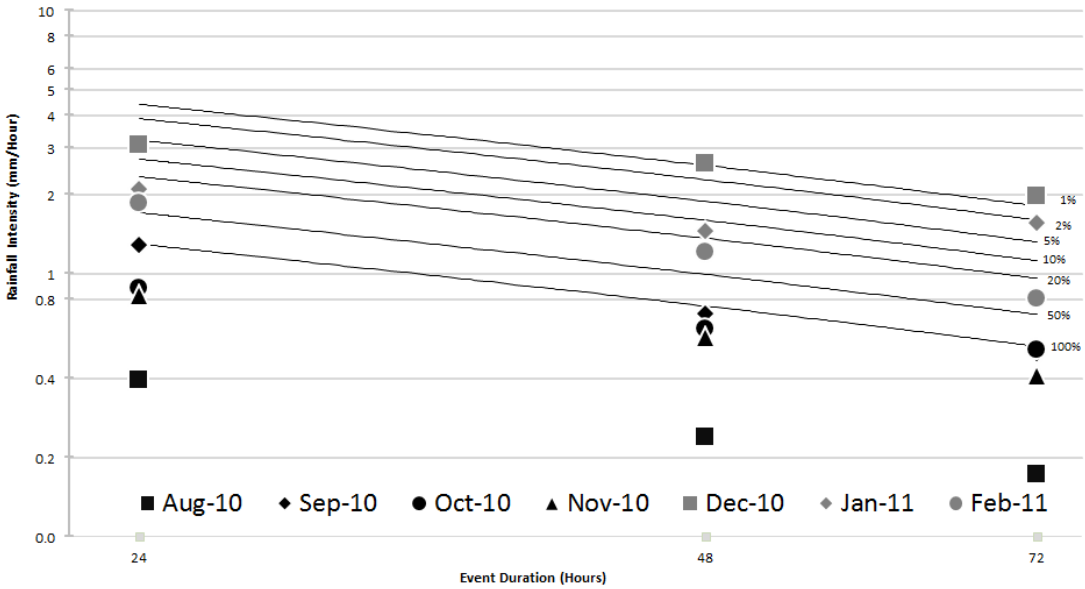
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	19.6	0.8	11/08/2010	>100%	19.8	0.4	12/08/2010	>100%	20.0	0.3	13/08/2010	>100%
Sep 10	23.6	1.0	4/09/2010	>100%	27.8	0.6	5/09/2010	>100%	30.0	0.4	6/09/2010	>100%
Oct 10	31.0	1.3	15/10/2010	>100%	34.2	0.7	16/10/2010	>100%	46.4	0.6	15/10/2010	>100%
Nov 10	15.0	0.6	25/11/2010	>100%	26.4	0.6	14/11/2010	>100%	26.4	0.4	14/11/2010	>100%
Dec 10	9.4	0.4	3/12/2010	>100%	14.6	0.3	3/12/2010	>100%	21.2	0.3	3/12/2010	>100%
Jan 11	101.4	4.2	12/01/2011	2%-1%	102.4	2.1	13/01/2011	5%-2%	144.8	2.0	14/01/2011	<1%
Feb 11	43.6	1.8	28/02/2011	100%-50%	49.0	1.0	28/02/2011	100%-50%	49.0	0.7	28/02/2011	100%-50%

Figure 3-4 079100 Horsham Rainfall Intensity-Frequency-Duration Analysis



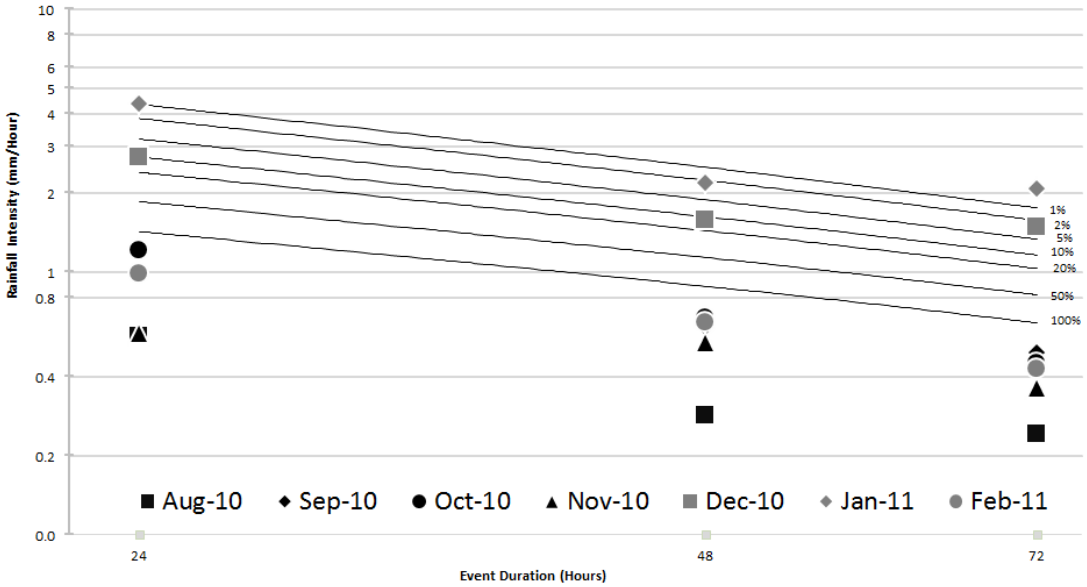
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	49.0	2.0	11/08/2010	100%-50%	92.8	1.9	12/08/2010	50%-20%	96.0	1.3	13/08/2010	50%-20%
Sep 10	35.2	1.5	5/09/2010	>100%	67.8	1.4	5/09/2010	100%-50%	71.0	1.0	6/09/2010	100%-50%
Oct 10	37.0	1.5	15/10/2010	>100%	45.2	0.9	16/10/2010	>100%	54.6	0.8	15/10/2010	>100%
Nov 10	31.6	1.3	25/11/2010	>100%	41.0	0.9	26/11/2010	>100%	48.4	0.7	27/11/2010	>100%
Dec 10	58.4	2.4	8/12/2010	100%-50%	64.4	1.3	8/12/2010	100%-50%	68.0	0.9	9/12/2010	100%-50%
Jan 11	134.6	5.6	12/01/2011	<1%	138.0	2.9	13/01/2011	5%-2%	270.8	3.8	14/01/2011	<1%
Feb 11	35.2	1.5	19/02/2011	>100%	39.2	0.8	12/02/2011	>100%	39.4	0.5	13/02/2011	>100%

Figure 3-5 079103 Grampians Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	9.4	0.4	5/08/2010	>100%	11.4	0.2	26/08/2010	>100%	12.4	0.2	26/08/2010	>100%
Sep 10	30.6	1.3	4/09/2010	>100%	33.8	0.7	5/09/2010	>100%	35.8	0.5	6/09/2010	>100%
Oct 10	21.2	0.9	15/10/2010	>100%	29.6	0.6	16/10/2010	>100%	36.8	0.5	16/10/2010	>100%
Nov 10	19.8	0.8	14/11/2010	>100%	27.4	0.6	14/11/2010	>100%	29.6	0.4	30/11/2010	>100%
Dec 10	74.2	3.1	8/12/2010	10%-5%	125.6	2.6	8/12/2010	<1%	141.8	2.0	9/12/2010	<1%
Jan 11	50.0	2.1	14/01/2011	50%-20%	69.4	1.4	14/01/2011	10%-20%	112.2	1.6	14/01/2011	5%-2%
Feb 11	44.2	1.8	5/02/2011	50%-20%	57.8	1.2	6/02/2011	50%-20%	57.8	0.8	6/02/2011	50%-20%

Figure 3-6 076047 Ouyen Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	13.6	0.6	11/08/2010	>100%	13.6	0.3	11/08/2010	>100%	17.4	0.2	1/08/2010	>100%
Sep 10	29.4	1.2	14/09/2010	>100%	29.4	0.6	14/09/2010	>100%	35.4	0.5	6/09/2010	>100%
Oct 10	29.0	1.2	15/10/2010	>100%	32.2	0.7	16/10/2010	>100%	32.2	0.4	16/10/2010	>100%
Nov 10	14.0	0.6	14/11/2010	>100%	26.0	0.5	14/11/2010	>100%	26.0	0.4	14/11/2010	>100%
Dec 10	65.2	2.7	8/12/2010	10%-20%	75.4	1.6	8/12/2010	10%-20%	106.0	1.5	8/12/2010	5%-2%
Jan 11	104.2	4.3	12/01/2011	<1%	104.2	2.2	12/01/2011	5%-2%	148.4	2.1	14/01/2011	<1%
Feb 11	23.6	1.0	19/02/2011	>100%	30.8	0.6	19/02/2011	>100%	30.8	0.4	19/02/2011	>100%

Figure 3-7 078010 Dimboola Rainfall Intensity-Frequency-Duration Analysis

3.4 Streamflow

Two separate streamflow analyses were undertaken. The first was based on information provided by the Bureau of Meteorology for flood warning gauges over the spring-summer 2010-11 period (excluding August 2010). The second was based on instantaneous flow and level data obtained from DSE for 268 streamflow gauges. These analyses are summarised below in Table 3-2 and Table 3-3.

The streamflow gauge analysis for flood warning gauges included a summary of flood class levels, peak level and flood class and where available frequency of flooding. This analysis was based on information provided by the Bureau of Meteorology, with no attempt to infill missing data. The frequency of flooding was provided for gauges where a flood frequency analysis had been undertaken in the past and as documented in the Victorian Strategic Flood Intelligence Report[14]. The flood frequency analysis included in the above mentioned VICSES document includes flood frequency analysis from two distinct sources. The first source included flood frequency analysis undertaken by Thiess for the Victorian Flood Warning Station Information Manual[15], covering the majority of flood warning gauges. The second source of flood frequency analysis was for gauges analysed as part of recent flood studies. The accuracy of the flood frequencies may differ given the source and the length of data record available.

The DSE instantaneous streamflow gauge analysis concentrated on peak levels and flows and timing of peaks. Travel times were calculated between peaks. These travel times were found to be inconsistent in some cases (i.e. downstream gauges sometimes peaking earlier). Each case was assessed and it is likely that this was due to the spatial and temporal distribution of rainfall, the effect of storages attenuating or totally storing upstream flows, the timing of tributary flows or the occurrence of multiple peaks within a month obscuring the analysis. This analysis was only conducted on months where a significant flow event occurred (generally above Minor flood levels).

[14] Water Technology (2012), *Victorian Strategic Flood Intelligence Report*, Victorian State Emergency Service (in association with Michael Cawood and Associates)

[15] Thiess (1999), Flood Warning Station Information Manual, Department of Natural Resources and Environment

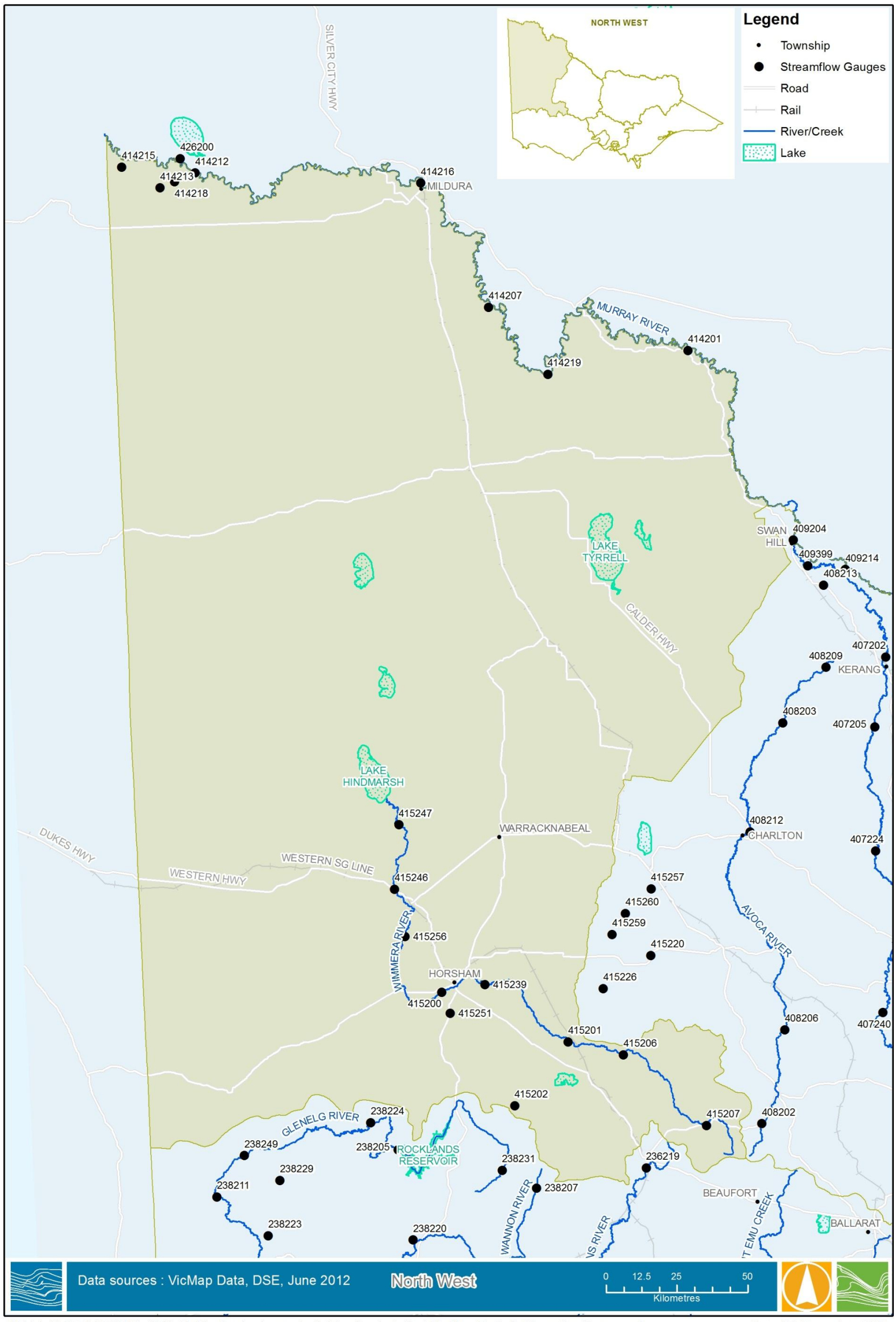


Figure 3-8 North West region streamflow gauges analysed

Table 3-2 Wimmera River Bureau of Meteorology flood warning gauge summary

River Basin		Wimmera	Wimmera	Wimmera	Wimmera
Location		Glenorchy	Horsham (Walmer)	Quantong Bridge	U/S Dimboola
Flood Class Level	Minor	4.00	-	-	-
	Moderate	4.75	-	-	-
	Major	4.90	-	-	-
Sep-2010	Peak (m)	4.93	-	-	-
	Warning	Major	<Minor	<Minor	<Minor
	AEP (%)	~10%			
Oct-2010	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Dec-2010	Peak (m)	4.53	-	-	-
	Warning	Minor	<Minor	<Minor	<Minor
Jan-2011	Peak (m)	5.04	4.27	7.31	5.84
	Warning	Major	Major	Major	Major
	AEP (%)	<1%	2 to 1%		
Feb-2011	Peak (m)	1.15	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Historic Record	Peak (m)	4.97	3.87	-	-
	Date	Sep-1988	Aug-1909	-	-
	Start Of Record	1946	1881	-	-
	New Record Set	Yes	Yes	-	-
	New Record Date	Jan-2011	Jan-2011	-	-
	Peak (m)	5.04	4.27	-	-
	Increase (m)	0.07	0.40	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 3-3 Wimmera River instantaneous flow and level gauge summary

River Basin		Mackenzie	Mackenzie	Wimmera	Wimmera	Wimmera	Wimmera	Wimmera	Wimmera	Wimmera
Gauge Number		415202	415251	415207	415206	415239	415200	415256	415246	415247
Gauge Location		Wartook Reservoir	McKenzie Creek	Eversley	Glynwylln	Drung Drung	Horsham	U/S of Dimboola	Lochiel Railway Bridge	Tarrenyurk
August 2010	Date/Time of Peak			12/08/2010 3:45 AM	13/08/2010 4:30 AM	18/08/2010 1:15 AM	18/08/2010 5:45 PM	21/08/2010 2:39 AM	21/08/2010 8:30 AM	22/08/2010 11:15 PM
	Time Diff. (hrs)				25	117	17	57	6	39
	Peak Level (m)			263.23	4.85	132.45	122.66	2.97	3.44	3.08
	Peak Flow (m3/s)			74	82		38	38	53	
September 2010	Date/Time of Peak	4/09/2010 4:00 PM	6/09/2010 7:15 AM	4/09/2010 9:15 AM	5/09/2010 4:15 AM	7/09/2010 6:00 PM	9/09/2010 12:00 PM	10/09/2010 11:35 PM	12/09/2010 2:45 AM	14/09/2010 6:30 AM
	Time Diff. (hrs)		39		19	62	42	36	27	52
	Peak Level (m)	426.53	1.43	264.61	8.31	133.68	123.71	4.69	4.15	4.80
	Peak Flow (m3/s)	5	8	245	395		136	136	116	
December 2010	Date/Time of Peak	8/12/2010 6:00 PM	10/12/2010 2:45 PM	9/12/2010 1:15 AM	8/12/2010 11:45 PM	11/12/2010 7:15 PM	12/12/2010 4:00 PM	9/12/2010 7:30 PM	10/12/2010 1:30 PM	16/12/2010 11:30 AM
	Time Diff. (hrs)		45		-2	68	21	-68	18	142
	Peak Level (m)	426.49	1.23	261.89	5.19	132.79	122.98	3.74	3.75	3.81
	Peak Flow (m3/s)	5	5	13	100		52	70	73	
January 2011	Date/Time of Peak		15/01/2011 8:30 AM	14/01/2011 8:15 AM	14/01/2011 10:15 PM	16/01/2011 6:15 PM	18/01/2011 11:30 AM	19/01/2011 4:00 PM	20/01/2011 3:00 PM	21/01/2011 2:15 PM
	Time Diff. (hrs)				14	44	41	29	23	23
	Peak Level (m)		2.36	265.70	8.80	133.54	124.66	5.75	4.62	5.75
	Peak Flow (m3/s)		19	357	464		382	340	335	

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

3.5 Summary

The North West region recorded significant widespread rainfall during the January 2011 storm event, with IFD analysis estimating a 2% to greater than 1% AEP for the rainfall event at 24 to 72 hour durations. In the north of the region, the December 2010 event also recorded significant rainfall with the 24 to 72 hour rainfall estimated at between 5% to greater than 1% AEP. The upper Wimmera River catchment recorded some significant rainfall at individual gauges in September 2010. Reasonable rainfall totals were recorded at individual gauges during the other spring-summer months, but not enough to cause any significant riverine flooding.

The streamflow gauges along the Wimmera River accessed by the Bureau of Meteorology for flood warning purposes all remained at less than 'Minor' flood level for all months with the exception of January 2011 and at the Glenorchy gauge during September 2010, when in both instances 'Major' flood levels were exceeded. The January 2011 event was larger than the previous highest recorded flood levels at Glenorchy and Horsham. Using available flood frequency information, the September 2010 event at Glenorchy was estimated as approximately a 10% AEP event. The January 2011 event at Glenorchy was estimated at less than a 1% AEP event while at Horsham it was estimated at between 2% and 1% AEP event. The frequency for the January 2011 flood on the Wimmera River near Horsham was widely publicised in local and national media as a 0.5% AEP event, significantly different from the available gauged data and flood frequency information. The provided peak flows recorded in the DSE instantaneous record are approximately 55 m^3/s lower than manual flows measured by Thiess just prior to the peak of the flood. In addition the rating curve at this location was currently under review at the time of writing this report. Given these issues at this gauge, no further accuracy can be placed on the frequency of the January 2011 flood at this time.

4. NORTH CENTRAL REGION HYDROLOGICAL ANALYSIS

4.1 Overview of Flooding

August 2010 – Widespread rainfall, with higher totals recorded in the southern half of the region, but no known flooding issues.

September 2010 – Widespread heavy rainfall was observed with many waterways reaching 'Moderate' and 'Major' flood levels, with significant flood damage experienced throughout the region.

October 2010 – No known flooding issues, with most rivers within the region remaining at less than 'Minor' flood levels.

November 2010 – Widespread heavy rainfall was observed with many waterways reaching 'Moderate' and 'Major' flood levels, with significant flood damage experienced throughout the region.

December 2010 – Rainfall recorded in the North Central region in December was generally less than in other regions. Localised thunderstorms caused some local flash flooding issues. Riverine flooding was observed in early December as the flows from the late November storm flowed downstream through the systems.

January 2011 – Was the largest flood recorded at many streamflow gauges throughout the region. The level of flooding and the flood related damage experienced exceeded that of the September 2010 event in most cases, with significant above floor flooding occurring in communities throughout the region.

February 2011 – Flash flooding was an issue in a number of communities, particularly in the south-east of the region.

4.2 Regional Description

The North Central region includes the Avon/Richardson, Avoca, Loddon and Campaspe catchments. Figure 4-1 below shows the major waterways in the region.

The Avon and Richardson rivers flow north from the Pyrenees ranges through the York and Avon Plains, terminating at Lake Buloke. In the upper catchment the rivers flow through a number of small communities. They merge around Banyena and then flow through Donald, upstream of Lake Buloke. The Richardson River receives breakout flows from the Wimmera River in large floods through the Swedes Creek distributary system.

The Avoca River flows northwards from its headwaters near Amphitheatre on the Great Dividing Range through a relatively confined valley, before opening out to a flatter wider floodplain around Yawong. Further downstream around Glenloth the river splits into a series of distributaries flow into a number of terminal lakes. In large floods the lakes fill and flood flows continue downstream to the Little Murray River through the Avoca Floodway and Lake Boga. The river passes through a number of communities including Avoca, Natte Yallock, Archdale, Charlton and Quambatook.

The Loddon River flows northwards from the Great Dividing Range near Daylesford through to the Little Murray River near Benjeroop. A number of storages are located in the upper catchment. In the upper catchment the river passes through Newstead, Baringhup, Eddington, Laanecoorie, Newbridge and Bridgewater. Around Serpentine the river and its complex of tributaries, anabranches and distributaries have created a floodplain that is almost 50 km wide and that supports a number of rural communities. These tributaries, anabranches and distributaries meet around Kerang before flowing on to the Little Murray River.

The Campaspe River flows northwards from the Great Dividing Range near Woodend, through Kyneton and on to Lake Eppalock, a significantly large storage. Downstream from Lake Eppalock the Campaspe River flows through Barnadown, Elmore and Rochester, before joining the Murray River at Echuca.

Figure 4-1 North Central region

4.3 Rainfall

Section 2.1 provides a broad overview of the synoptic conditions that produced the rainfall events over the spring-summer 2010-11 period. This Section includes more detail about specific rainfall gauges within the North Central region. It should be noted that daily rainfall gauges typically record rainfall totals over a 24 hour period to 9 am on the date recorded.

Table 4-1 below summarises the maximum daily rainfall and monthly totals for numerous rainfall gauges across the region and compares it against the historical monthly average over the spring-summer period as well as against the historical monthly and daily maximum rainfall totals. A high proportion of the gauges selected for analysis broke daily and monthly maximum rainfall records during the spring-summer 2010-11 period.

For a selected number of gauges an Intensity-Frequency-Duration (IFD) analysis was undertaken on the daily rainfall totals at 24, 48 and 72 hour durations. Using the geographical coordinates for the rainfall gauges analysed, the raw polynomial coefficients were taken from the Bureau of Meteorology's online IFD Data System[13], and used as input to an IFD spreadsheet tool developed by Water Technology, plotting the IFD curves for the rainfall gauge site. This was overlayed with the maximum 24, 48 and 72 hour rainfall totals for each month.

The gauges selected were chosen to provide a spread across the region with preference for gauges in proximity to areas of significant flooding. Note that the frequency attributed to the rainfall event does not necessarily correspond to the frequency of the flood event due to antecedent catchment conditions, timing of tributary flows etc. It must also be noted that the frequency of the event may differ when durations shorter than 24 hours are considered, however with daily rainfall gauges these shorter durations can not be assessed. Figure 4-3 to Figure 4-9 below show the IFD analysis undertaken.

Figure 4-2 below shows the location of the rainfall gauges analysed for both daily and monthly totals and also those gauges for which an IFD analysis was completed.

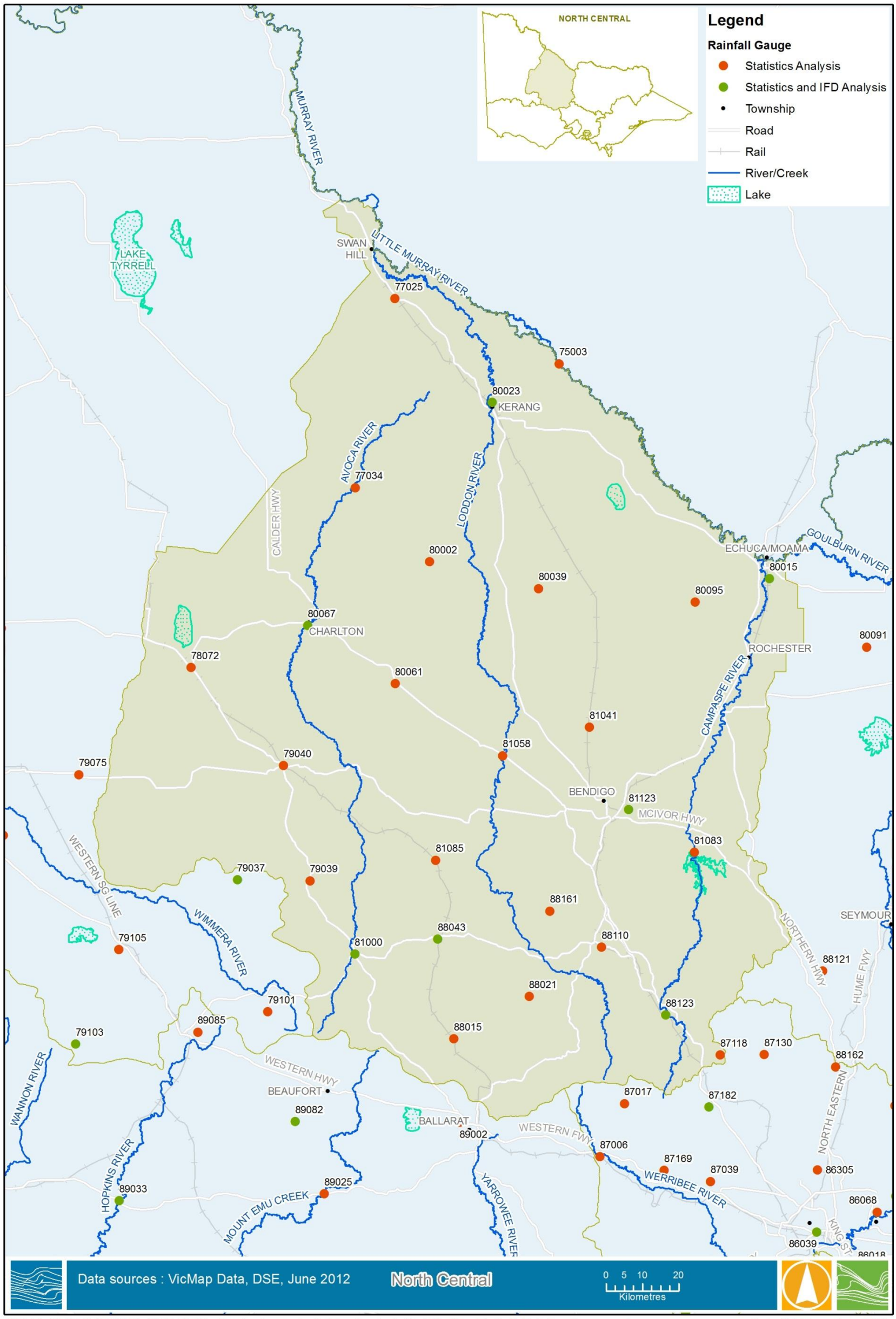
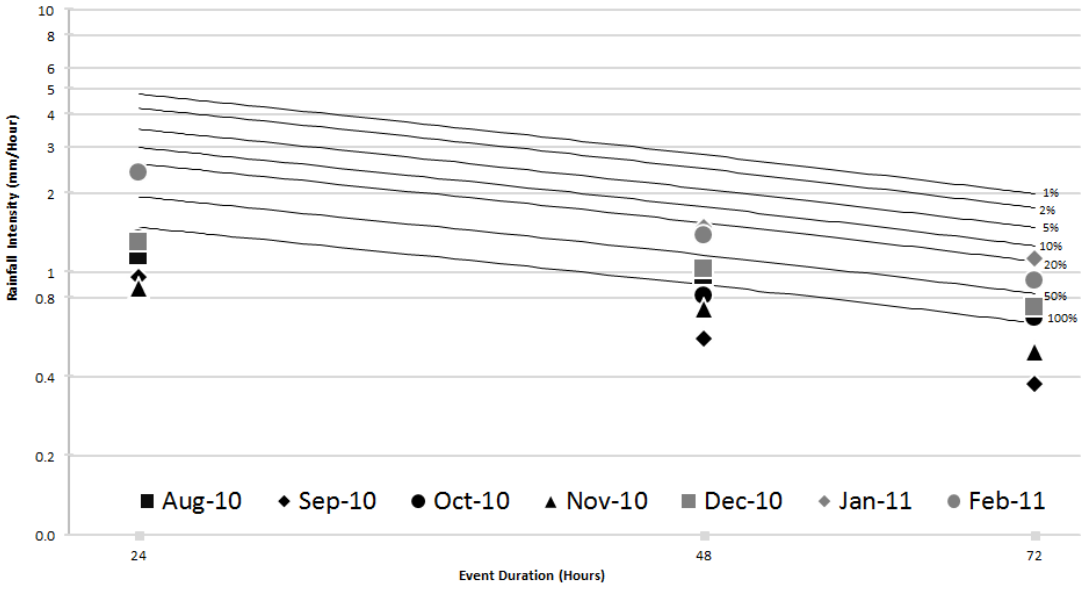


Figure 4-2 North Central region rainfall gauges analysed

Table 4-1 North Central region observed rainfall summary

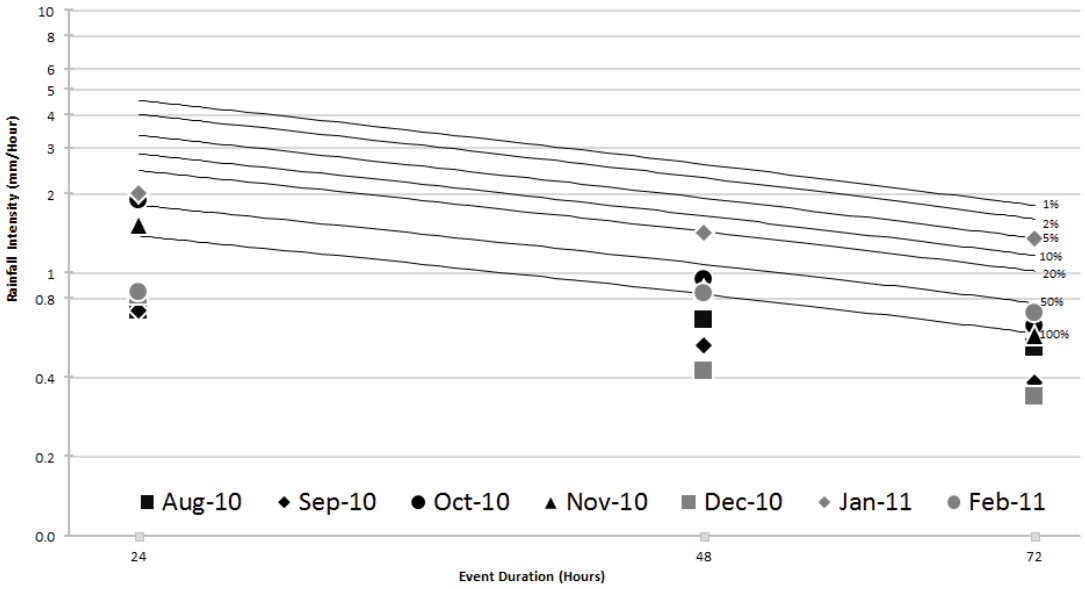
Location	Station Number	August 2010		September 2010		October 2010		November 2010		December 2010		January 2011		February 2011		Record Statistics			
		Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Avg.	Monthly Max.	Daily Max.	Start of record
Avoca (Post Office)	81000	103.4	19.0 (19th)	104.2	69.7 (4th)	110.8	52.0 (31st)	81.4	23.7 (28th)	99.4	34.8 (3rd)[1]	225	87.4 (14th)	55.8	24.6 (21st)	28.7-60.4	286.9 (Apr 1939)	124.5 (07/04/1939)	1884
Barham (Thule Street)	75003	62.5	16.5 (10th)	30.4	17.0 (4th)	99.5	37.8 (31st)	80.1	24.0 (28th)	64.4	22.0 (9th)	146	44.6 (14th)[1]	56.4	19.0 (5th)	24.3-36.8	146.0 (Jan 2011)	90.4 (12/11/1968)	1897
Bendigo Airport	81123	139	27.8 (19th)	96.2	50.6 (4th)	137.6	53.8 (31st)	115.2	38.2 (28th)	103.6	22.0 (7th)	177.8	64.2 (14th)	152.2	66.4 (5th)	29.2-52.8	177.8 (Jan 2011)	66.4 (05/02/2011)	1991
Boort	80002	131.4	33.2 (11th)	29	16.0 (4th)	129	56.0 (31st)[1]	112.2	42.3 (28th)[1]	103.4	56.0 (7th)	202.8	65.4 (14th)	102.2	62.2 (5th)[1]	24.2-41.8	205.8 (Dec 1930)	83.8 (08/09/1921)	1881
Bridgewater (Post Office)	81058	108.2	25.4 (19th)	59	28.8 (4th)	168.2	57.4 (31st)	131.4	44.6 (28th)	78.2	25.4 (7th)	220.2	55.2 (14th)	141.4	63.0 (5th)	27.1-44.9	220.2 (Jan 2011)	81.5 (24/10/2000)	1894
Castlemaine Prison	88110	122	14.8 (12th)	88.4	37.2 (4th)	146.2	64.0 (31st)	177.8	50.6 (27th)	70.5	13.4 (9th)	201	64.8 (14th)	137.4	101.2 (5th)	34.8-67.4	203.9 (Feb 2012)	101.2 (05/02/2011)	1966
Charlton (Donald St)	80067	99.8	16.4 (19th)	57.2	43.0 (4th)	83	25.0 (31st)	119.4	50.4 (28th)	66.8	17.6 (8th)	184.2	64.0 (14th)	86.6	52.0 (5th)	24.3-46.5	230.4 (Feb 1973)	77.0 (19/02/1973)	1951
Clunes	88015	136.8	30.2 (12th)	103.2	64.0 (4th)	92.2	27.0 (31st)	105.2	28.0 (28th)	57.6	14.4 (8th)	217.2	94.0 (14th)	60.8	19.6 (19th)	32.8-64.5	217.2 (Jan 2011)	96.5 (08/01/1897)	1878
Donald	78072	116.8	25.2 (19th)	60.8	43.0 (4th)	65	22.0 (31st)	111.2	61.2 (27th)	116	38.4 (8th)	194.8	81.0 (14th)	64.4	33.8 (5th)	22.8-43.0	211.4 (Feb 1973)	94.0 (27/01/1993)	1996
Dunolly	81085	111.4	18.2 (19th)	100.8	76.7 (4th)[1]	112.6	53.8 (31st)	188.8	53.4 (28th)	62.6	15.6 (1st)	224.6	71.2 (14th)	98.4	66.6 (5th)[1]	28.4-52.8	224.6 (Jan 2011)	91.9 (18/02/1919)	1882
Eberys	88021	105.6	20.2 (12th)	90.6	61.4 (4th)	115.7	36.6 (31st)	144	36.4 (25th)	61.8	19.8 (6th)	191.8	73.0 (14th)	58.4	19.0 (5th)	30.2-64.1	196.0 (Oct 1975)	104.1 (18/02/1919)	1913
Echuca Aerodrome	80015	104	27.4 (11th)	42	22.8 (4th)	112	32.2 (31st)	76.8	21.0 (14th)	74.2	31.2 (9th)	126.6	58.0 (14th)	111.8	57.4 (5th)	27.9-42.5	224.9 (Jan 1974)	94.0 (01/03/2012)	1859
Eppalock Reservoir	81083	109.2	24.6 (11th)	71.4	31.0 (4th)	115.6	65.6 (31st)	170.4	61.0 (28th)	73.2	20.8 (9th)	162.8	68.4 (14th)	150.6	59.4 (5th)	30.5-59.2	162.8 (Jan 2011)	91.2 (17/02/1972)	1965
Hesket (Straws Lane)	87118	153.6	28.0 (12th)	96	33.0 (5th)	178.4	68.6 (31st)	158.4	43.4 (28th)	83.8	24.2 (9th)	210.6	68.2 (14th)	125	62.2 (5th)	50.4-97.3	335.2 (Sep 1993)	118.4 (03/01/1970)	1968
Kerang	80023	88.6	17.2 (10th)	33.4	17.2 (5th)	100	45.2 (31st)	97.4	36.6 (28th)	53	19.6 (9th)	160.8	48.2 (14th)	62.8	20.2 (4th)	23.8-37.8	180.8 (Dec 1992)	125.2 (18/01/1928)	1880
Kotta	80095	98.4	17.0 (11th)[1]	34	20.0 (4th)	113.4	34.8 (31st)[1]	61	17.0 (28th)	41	21.0 (9th)	100.2	36.7 (14th)[1]	127.2	75.0 (5th)	27.9-42.3	185.9 (Feb 1973)	92.2 (01/03/2012)	1967
Kyneton	88123	115.2	14.0 (19th)	119.8	49.0 (4th)	152.2	70.6 (31st)	162.6	44.2 (28th)	79	16.8 (9th)	284.2	109.0 (13th)	112.6	61.6 (5th)	39.7-85.6	284.2 (Jan 2011)	109.0 (13/01/2011)	1969
Lake Boga	77025	64.6	13.0 (10th)	30.7	21.5 (4th)	106.8	51.4 (31st)	86.2	21.0 (14th)	37.4	12.0 (9th)	133.6	46.0 (14th)	43	20.0 (5th)	20.7-34.7	220.8 (May 1974)	150.4 (15/05/1974)	1903
Maldon (Stump St)	88161	118.4	15.8 (19th)	94.2	36.4 (4th)	158.6	52.0 (31st)	183.2	54.6 (28th)	70.6	14.0 (6th)	206.4	84.6 (14th)	126.2	83.0 (5th)	38.7-80.6	206.4 (Jan 2011)	84.6 (14/01/2011)	2003
Maryborough	88043	114.1	19.3 (12th)	112.9	79.6 (4th)	109.1	39.1 (31st)	155.3	40.8 (27th)	54.7	12.0 (3rd)	240.7	90.4 (14th)	52.3	17.6 (5th)	30.9-56.5	240.7 (Jan 2011)	99.3 (30/11/1933)	1878
Quambatook South	77034	82.8	15.0 (19th)	23	9.0 (4th)	125.8	44.0 (31st)	119.8	44.0 (28th)	63.8	13.4 (9th)	168.2	85.0 (10th)	81.4	60.0 (5th)	19.9-37.1	193.1 (Nov 1887)	86.0 (05/05/1988)	1887
Raywood	81041	102.4	20.0 (19th)	61.2	36.2 (4th)	129.4	48.2 (31st)	112.2	51.4 (28th)	86	20.6 (9th)	165.2	63.2 (14th)	199.2	47.0 (5th)	27.3-44.9	213.5 (Feb 1911)	108.0 (19/02/1973)	1898
Redbank	79039	122	20.7 (11th)[1]	105.5	72.0 (4th)	106.5	38.5 (31st)	109.5	54.0 (27th)	75	15.0 (9th)	230.5	92.0 (12th)	78	29.0 (5th)	29.9-70.0	230.5 (Jan 2011)	100.3 (07/02/1957)	1897
St Arnaud	79040	122.6	27.8 (11th)	107.2	65.0 (4th)	88.8	54.0 (31st)[1]	98.8	25.0 (27th)	70.6	22.5 (8th)	225.8	93.8 (14th)	83.8	59.8 (5th)	27.4-57.4	263.6 (Oct 1975)	146.1 (09/01/1897)	1880
Wedderburn (Post Office)	80061	111.9	20.0 (19th)	73.2	57.0 (4th)	99.5	43.1 (31st)[1]	151	48.0 (29th)[1]	42	16.0 (7th)[1]	206	84.0 (14th)	164.6	111.0 (5th)[1]	27.6-52.1	206.0 (Jan 2011)	84.0 (14/01/2011)	1882
Yarrawalla South	80039	89	19.0 (19th)	29.8	20.0 (4th)	108	40.0 (31st)	102.2	42.2 (28th)	46.4	14.0 (9th)	145	53.2 (14th)	123.6	76.0 (5th)	23.4-37.0	233.7 (Feb 1911)	106.2 (09/02/1911)	1886

[1]*Note: Gauge recordings were aggregated over a number of days. Daily totals were disaggregated using the daily rainfall pattern from the nearest gauge of complete record.*
[2]*Note: Records of data were incomplete for the month. The total and highest daily rainfall cannot be determined using incomplete data.*
[3]*Note: Gauge broke daily or monthly statistical records over the period.*
[4]*Note: Analysis carried out early May 2012, any events after that not captured in historical records columns.*



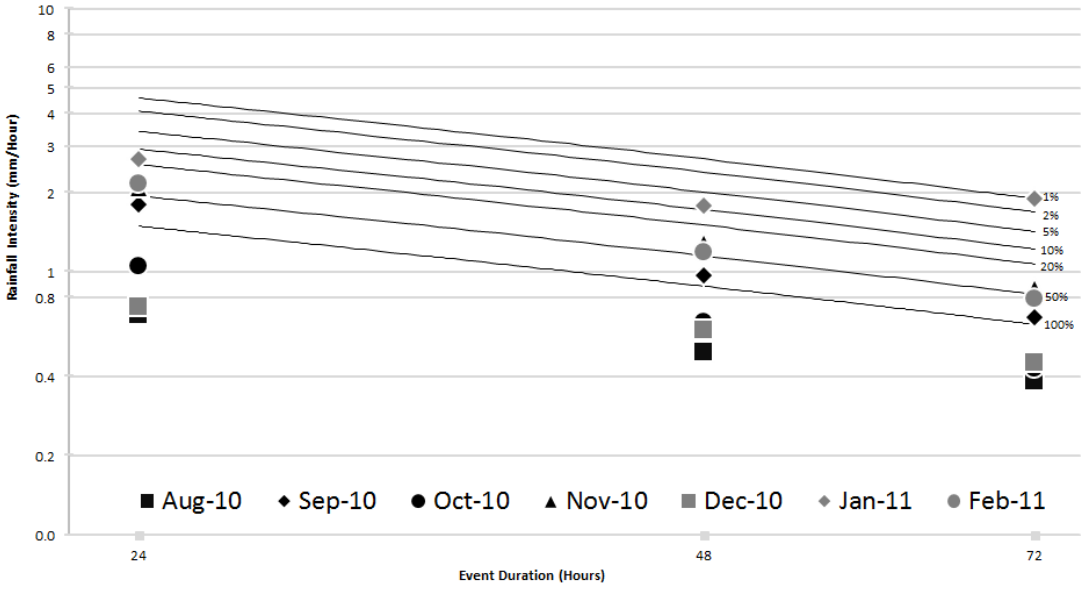
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	27.4	1.1	12/08/2010	>100%	46.4	1.0	12/08/2010	100%-50%	52.8	0.7	12/08/2010	100%-50%
Sep 10	22.8	1.0	4/09/2010	>100%	26.6	0.6	5/09/2010	>100%	26.8	0.4	6/09/2010	>100%
Oct 10	32.2	1.3	31/10/2010	>100%	39.0	0.8	31/10/2010	>100%	48.2	0.7	31/10/2010	100%-50%
Nov 10	21.0	0.9	27/11/2010	>100%	34.8	0.7	28/11/2010	>100%	35.8	0.5	28/11/2010	>100%
Dec 10	31.2	1.3	3/12/2010	>100%	49.4	1.0	4/12/2010	100%-50%	52.8	0.7	3/12/2010	100%-50%
Jan 11	58.0	2.4	14/01/2011	50%-20%	71.0	1.5	12/01/2011	50%-20%	80.8	1.1	14/01/2011	10%-20%
Feb 11	57.4	2.4	5/02/2011	50%-20%	66.4	1.4	5/02/2011	50%-20%	66.4	0.9	6/02/2011	50%-20%

Figure 4-3 080015 Echuca Rainfall Intensity-Frequency-Duration Analysis



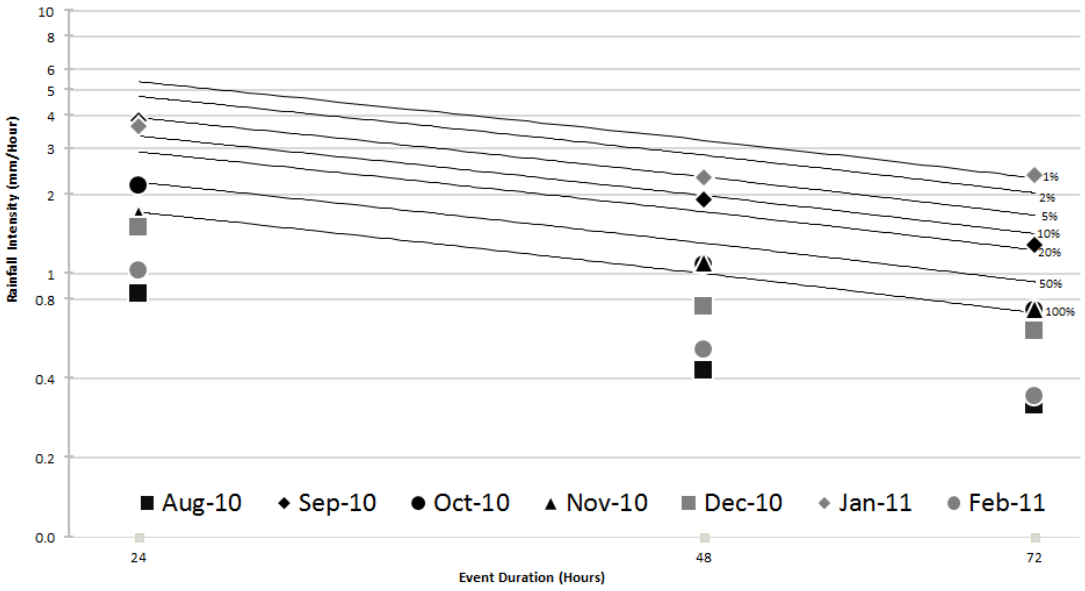
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	17.2	0.7	12/08/2010	>100%	31.8	0.7	12/08/2010	>100%	37.2	0.5	12/08/2010	>100%
Sep 10	17.2	0.7	4/09/2010	>100%	25.4	0.5	5/09/2010	>100%	27.4	0.4	6/09/2010	>100%
Oct 10	45.2	1.9	31/10/2010	50%-20%	45.2	0.9	31/10/2010	100%-50%	45.2	0.6	31/10/2010	100%-50%
Nov 10	36.6	1.5	27/11/2010	100%-50%	41.6	0.9	28/11/2010	100%-50%	41.6	0.6	28/11/2010	>100%
Dec 10	19.6	0.8	3/12/2010	>100%	20.2	0.4	4/12/2010	>100%	24.4	0.3	3/12/2010	>100%
Jan 11	48.2	2.0	14/01/2011	50%-20%	68.2	1.4	12/01/2011	50%-20%	97.6	1.4	14/01/2011	10%-5%
Feb 11	20.2	0.8	5/02/2011	>100%	40.0	0.8	5/02/2011	100%-50%	50.4	0.7	6/02/2011	100%-50%

Figure 4-4 080023 Kerang Rainfall Intensity-Frequency-Duration Analysis



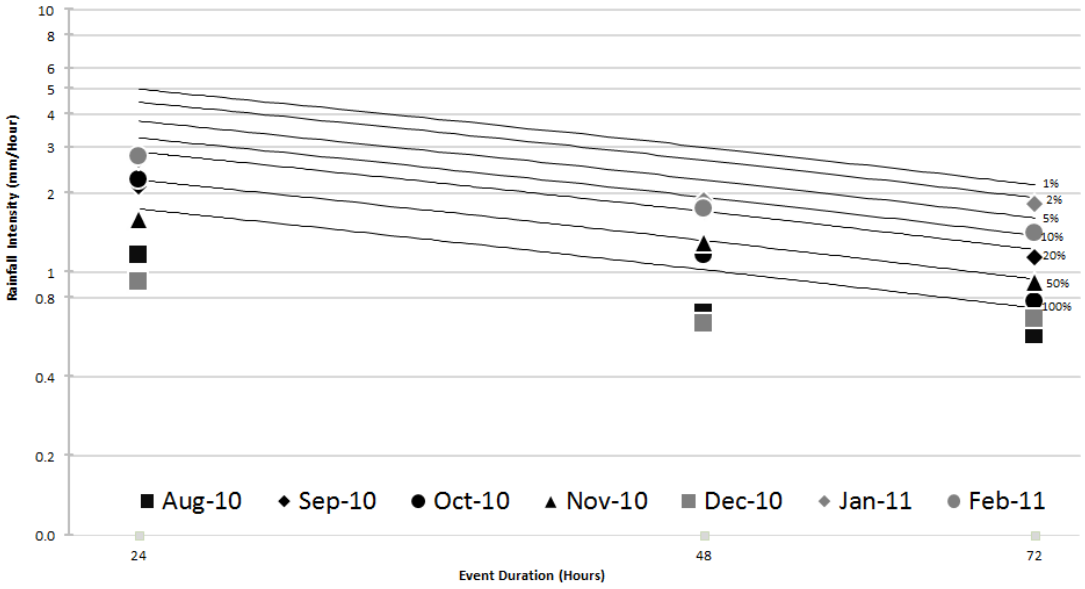
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	16.4	0.7	12/08/2010	>100%	23.6	0.5	12/08/2010	>100%	27.6	0.4	12/08/2010	>100%
Sep 10	43.0	1.8	4/09/2010	100%-50%	46.4	1.0	5/09/2010	100%-50%	48.2	0.7	6/09/2010	100%-50%
Oct 10	25.0	1.0	31/10/2010	>100%	30.8	0.6	31/10/2010	>100%	30.8	0.4	31/10/2010	>100%
Nov 10	50.4	2.1	27/11/2010	50%-20%	61.8	1.3	28/11/2010	50%-20%	61.8	0.9	28/11/2010	50%-20%
Dec 10	17.6	0.7	3/12/2010	>100%	28.6	0.6	4/12/2010	>100%	32.2	0.4	3/12/2010	>100%
Jan 11	64.0	2.7	14/01/2011	10%-20%	85.0	1.8	12/01/2011	10%-5%	136.0	1.9	14/01/2011	2%-1%
Feb 11	52.0	2.2	5/02/2011	50%-20%	56.6	1.2	5/02/2011	50%-20%	56.6	0.8	6/02/2011	100%-50%

Figure 4-5 080067 Charlton Rainfall Intensity-Frequency-Duration Analysis



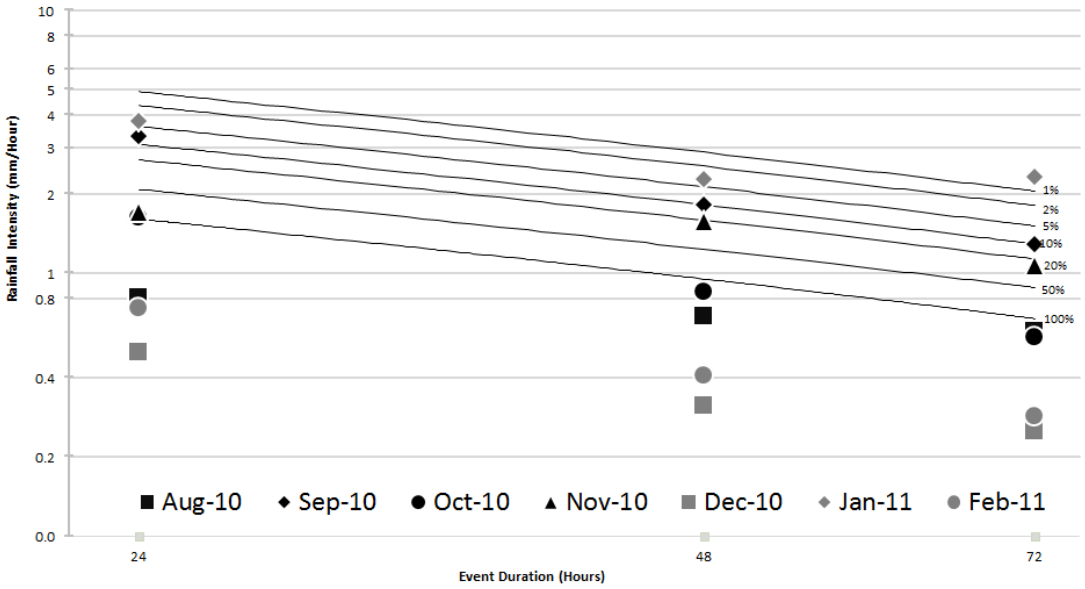
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	20.0	0.8	16/08/2010	>100%	20.6	0.4	11/08/2010	>100%	22.6	0.3	11/08/2010	>100%
Sep 10	91.2	3.8	6/09/2010	10%-5%	92.0	1.9	7/09/2010	10%-20%	92.0	1.3	7/09/2010	10%-20%
Oct 10	52.0	2.2	31/10/2010	100%-50%	52.0	1.1	31/10/2010	100%-50%	52.0	0.7	31/10/2010	100%-50%
Nov 10	40.0	1.7	29/11/2010	>100%	53.0	1.1	1/11/2010	100%-50%	53.0	0.7	1/11/2010	100%-50%
Dec 10	35.8	1.5	3/12/2010	>100%	35.8	0.7	3/12/2010	>100%	43.4	0.6	1/12/2010	>100%
Jan 11	87.4	3.6	14/01/2011	10%-5%	111.0	2.3	12/01/2011	10%-5%	171.0	2.4	14/01/2011	<1%
Feb 11	24.6	1.0	21/02/2011	>100%	24.6	0.5	21/02/2011	>100%	24.6	0.3	21/02/2011	>100%

Figure 4-6 081000 Avoca Rainfall Intensity-Frequency-Duration Analysis



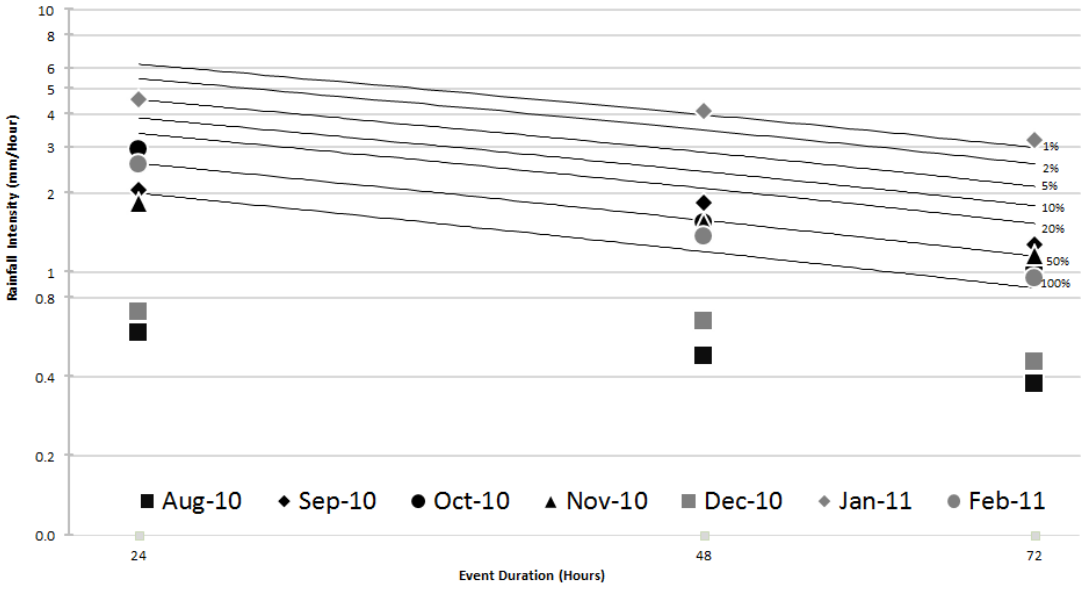
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	27.8	1.2	19/08/2010	>100%	33.4	0.7	20/08/2010	>100%	41.2	0.6	12/08/2010	>100%
Sep 10	50.6	2.1	4/09/2010	100%-50%	81.6	1.7	5/09/2010	50%-20%	81.8	1.1	6/09/2010	50%-20%
Oct 10	53.8	2.2	31/10/2010	100%-50%	55.4	1.2	31/10/2010	100%-50%	55.4	0.8	31/10/2010	100%-50%
Nov 10	38.2	1.6	28/11/2010	>100%	62.2	1.3	28/11/2010	100%-50%	66.0	0.9	28/11/2010	100%-50%
Dec 10	22.0	0.9	7/12/2010	>100%	30.6	0.6	8/12/2010	>100%	47.8	0.7	9/12/2010	>100%
Jan 11	64.2	2.7	14/01/2011	50%-20%	89.4	1.9	14/01/2011	10%-20%	130.2	1.8	14/01/2011	5%-2%
Feb 11	66.4	2.8	5/02/2011	50%-20%	84.0	1.8	5/02/2011	10%-20%	101.6	1.4	6/02/2011	10%-5%

Figure 4-7 081123 Bendigo Airport Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	19.3	0.8	12/08/2010	>100%	32.6	0.7	12/08/2010	>100%	43.2	0.6	12/08/2010	>100%
Sep 10	79.6	3.3	4/09/2010	10%-5%	87.4	1.8	5/09/2010	10%-20%	91.9	1.3	6/09/2010	10%-20%
Oct 10	39.1	1.6	31/10/2010	100%-50%	40.7	0.8	31/10/2010	>100%	40.7	0.6	31/10/2010	>100%
Nov 10	40.8	1.7	27/11/2010	100%-50%	75.5	1.6	28/11/2010	50%-20%	77.2	1.1	28/11/2010	50%-20%
Dec 10	12.0	0.5	3/12/2010	>100%	15.0	0.3	4/12/2010	>100%	17.9	0.2	3/12/2010	>100%
Jan 11	90.4	3.8	14/01/2011	5%-2%	109.3	2.3	12/01/2011	5%-2%	166.1	2.3	14/01/2011	<1%
Feb 11	17.6	0.7	5/02/2011	>100%	19.4	0.4	5/02/2011	>100%	20.4	0.3	6/02/2011	>100%

Figure 4-8 088043 Maryborough Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	14.0	0.6	19/01/2010	>100%	23.0	0.5	2/01/2010	>100%	26.8	0.4	27/01/2010	>100%
Sep 10	49.0	2.0	4/02/2010	100%-50%	88.0	1.8	5/02/2010	50%-20%	91.0	1.3	6/02/2010	50%-20%
Oct 10	70.6	2.9	2/09/2010	50%-20%	73.6	1.5	2/09/2010	100%-50%	73.6	1.0	2/09/2010	100%-50%
Nov 10	44.2	1.8	30/09/2010	>100%	74.0	1.5	30/09/2010	100%-50%	83.4	1.2	30/09/2010	50%-20%
Dec 10	16.8	0.7	11/10/2010	>100%	31.2	0.7	11/10/2010	>100%	32.8	0.5	12/10/2010	>100%
Jan 11	109.0	4.5	15/11/2010	5%-2%	197.0	4.1	16/11/2010	<1%	229.8	3.2	16/11/2010	<1%
Feb 11	61.6	2.6	8/12/2010	100%-50%	65.6	1.4	8/12/2010	100%-50%	67.8	0.9	9/12/2010	100%-50%

Figure 4-9 088123 Kyneton Rainfall Intensity-Frequency-Duration Analysis

4.4 Streamflow

Two separate streamflow analyses were undertaken. The first was based on information provided by the Bureau of Meteorology for flood warning gauges over the spring-summer 2010-11 period (excluding August 2010), the second based on instantaneous flow and level data obtained from DSE on 268 streamflow gauges. These analyses are summarised below in Table 4-2 to Table 4-9.

The streamflow gauge analysis for flood warning gauges included a summary of flood class levels, peak level and flood class and where available frequency of flooding. This analysis was based on information provided by the Bureau of Meteorology, with no attempt to infill missing data. The frequency of flooding was provided for gauges where a flood frequency analysis had been undertaken in the past and as documented in the Victorian Strategic Flood Intelligence Report[14]. The flood frequency analysis included in the above mentioned VICSES document includes flood frequency analysis from two distinct sources. The first source included flood frequency analysis undertaken by Thiess for the Victorian Flood Warning Station Information Manual[15], covering the majority of flood warning gauges. The second source of flood frequency analysis was for gauges analysed as part of recent flood studies. The accuracy of the flood frequencies may differ given the source and the length of data record available.

The DSE instantaneous streamflow gauge analysis concentrated on peak levels and flows and timing of peaks. Travel times were calculated between peaks. These travel times were found to be inconsistent in some cases (i.e. downstream gauges sometimes peaking earlier). Each case was assessed and it is likely that this was due to the spatial and temporal distribution of rainfall, the effect of storages attenuating or totally storing upstream flows, the timing of tributary flows or the occurrence of multiple peaks within a month obscuring the analysis. This analysis was only conducted on months where a significant flow event occurred (generally above Minor flood levels).

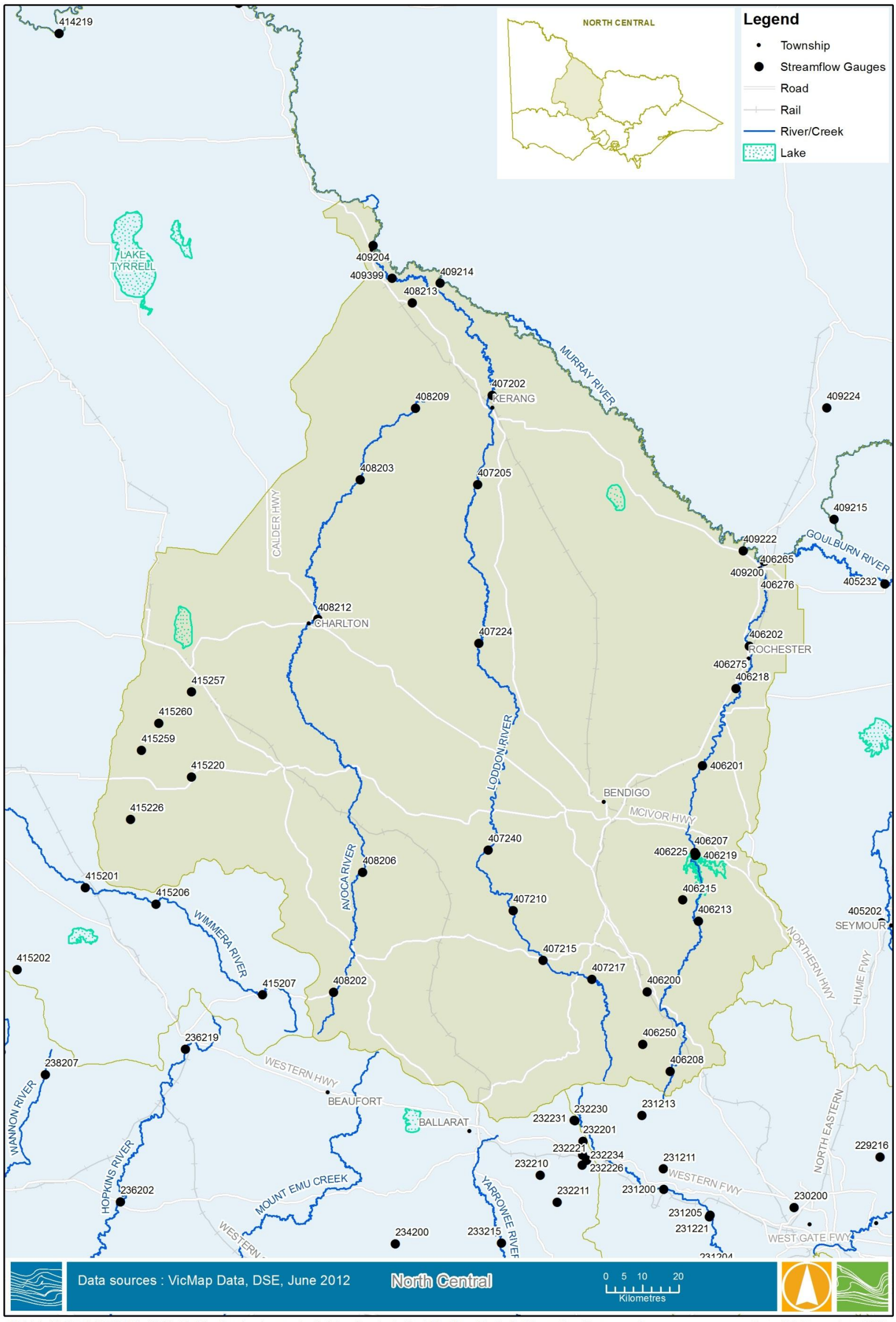


Figure 4-10 North Central region streamflow gauges analysed

Table 4-2 Campaspe River Bureau of Meteorology flood warning gauge summary

River Basin		Campaspe	Campaspe	Campaspe	Campaspe
Location		Redesdale	Barnadown	Rochester Syphon	Echuca
Flood Class Level	Minor	2.00	4.00	8.00	-
	Moderate	4.00	4.60	8.80	-
	Major	6.00	5.50	9.10	-
Sep-2010	Peak (m)	5.80	4.82	8.25	-
	Warning	Moderate	Moderate	Minor	-
	AEP (%)	<1%	20-10%	~33%	
Oct-2010	Peak (m)	2.52	1.75	2.63	-
	Warning	Minor	<Minor	<Minor	Major
Nov-2010	Peak (m)	4.34	5.99	9.00	-
	Warning	Moderate	Major	Moderate	-
	AEP (%)	10-5%	10-4%	~10%	
Dec-2010	Peak (m)	3.99	3.69	7.29	-
	Warning	Minor	<Minor	<Minor	-
Jan-2011	Peak (m)	6.30	7.59	9.17	95.75
	Warning	Major	Major	Major	-
	AEP (%)	<1%	<1%	4-2%	
Feb-2011	Peak (m)	3.64	5.44	8.93	-
	Warning	Minor	Moderate	Moderate	<Minor
	AEP (%)	~20%	~10%	~20%	
Historic Record	Peak (m)	4.87	6.15	9.15	-
	Date	Sep-1975	Sep-1983	Sep-1983	-
	Start Of Record	1953	1977	1963	-
	New Record Set	Yes	Yes	Yes	-
	New Record Date	Jan-2011	Jan-2011	Jan-2011	-
	Peak (m)	6.30	7.59	9.17	-
	Increase (m)	1.43	1.44	0.02	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 4-3 Loddon River Bureau of Meteorology flood warning gauge summary

River Basin		Bet Bet	Loddon	Loddon	Loddon	Loddon	Loddon
Location		Bet Bet*	Newstead	Laanecoorie Reservoir	Loddon Weir DS	Appin South	Kerang Weir
Flood Class Level	Minor	4.00	3.00	1.50	3.30	2.80	77.00
	Moderate	-	4.50	3.00	6.00	3.10	77.50
	Major	-	6.00	5.50	7.00	3.30	77.80
Sep-2010	Peak (m)	6.18	4.91	6.10	7.03	3.07	76.95
	Warning	Minor	Moderate	Major	Major	Minor	<Minor
	AEP (%)		~20%	20-10%			
Oct-2010	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	4.71	5.60	6.30	7.18	3.20	77.44
	Warning	Minor	Moderate	Major	Major	Moderate	Minor
	AEP (%)		~10%	20-10%		10-4%	
Dec-2010	Peak (m)	3.25	1.80	2.64	5.96	-	-
	Warning	<Minor	<Minor	Minor	Minor	Major	Major
	AEP (%)					<1%	<1%
Jan-2011	Peak (m)	6.86	5.86	7.50	7.29	3.52	78.03
	Warning	Minor	Moderate	Major	Major	Major	Major
	AEP (%)		10-7%	~2%		<1%	<1%
Feb-2011	Peak (m)	2.76	2.79	3.08	6.25	3.07	76.92
	Warning	<Minor	<Minor	Moderate	Moderate	Minor	<Minor
	AEP (%)			>50%			
Historic Record	Peak (m)	5.66	5.35	7.79	2.26	3.19	-
	Date	Aug-1999	Jul-1990	-	Dec-2004	Oct-1996	-
	Start Of Record	1990	1967	1891	1965	1927	-
	New Record Set	Yes	Yes	No	Yes	Yes	-
	New Record Date	Jan-2011	Jan-2011	-	Jan-2011	Jan-2011	-
	Peak (m)	6.86	5.86	-	7.29	3.52	-
	Increase (m)	1.20	0.51	-	5.03	0.33	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 4-4 Avoca River Bureau of Meteorology flood warning gauge summary

River Basin		Avoca	Avoca	Avoca	Avoca	Avoca
Location		Archdale Junction	Yawong Weir	Charlton Town	Charlton DS	Quambatook
Flood Class Level	Minor	-	3.00	5.00	5.00	2.00
	Moderate	-	4.30	7.00	7.00	2.20
	Major	-	5.00	7.50	7.50	2.40
Sep-2010	Peak (m)	5.14	5.64	-	7.30	2.23
	Warning	Major	Major	-	Moderate	Moderate
	AEP (%)	20-10%	4-2%			25-20%
Oct-2010	Peak (m)	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	1.70	5.07	-	7.09	2.17
	Warning	Major	Major	<Minor	Moderate	Minor
	AEP (%)	>20%	14-10%			
Dec-2010	Peak (m)	3.56	3.08	-	4.76	2.00
	Warning	Major	Minor	-	<Minor	Minor
	AEP (%)	>20%				
Jan-2011	Peak (m)	5.32	6.09	-	8.05	3.02
	Warning	Major	Major	-	Major	Major
	AEP (%)	~4%	<1%			<1%
Feb-2011	Peak (m)	0.78	2.59	-	4.00	1.67
	Warning	Major	<Minor	<Minor	<Minor	<Minor
	AEP (%)	>20%				
Historic Record	Peak (m)	5.15	5.59	-	7.20	2.50
	Date	Sep-1988	Aug-1909	-	Oct-1992	Sep-1983
	Start Of Record	1966	1931	-	-	1967
	New Record Set	Yes	Yes	-	Yes	Yes
	New Record Date	Jan-2011	Jan-2011	-	Jan-2011	Jan-2011
	Peak (m)	5.32	6.09	-	8.05	3.02
	Increase (m)	0.17	0.50	-	0.85	0.52

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 4-5 Avon and Richardson Rivers instantaneous flow and level gauge summary

River Basin		Avon	Richardson	Richardson	Richardson	Richardson
Gauge Number		415220	415226	415259	415260	415257
Gauge Location		Wimmera Highway	Carrs Plains	Banyena	U/S RichAvon Weir	Donald
August 2010	Date/Time of Peak	13/08/2010 2:00 AM		16/08/2010 11:45 PM	17/08/2010 12:45 AM	23/08/2010 4:00 PM
	Time Diff. (hrs)				1	159
	Peak Level (m)	4.18		1.80	2.82	1.68
	Peak Flow (m3/s)	18		15	0	4
September 2010	Date/Time of Peak	5/09/2010 1:00 AM	4/09/2010 9:19 AM	6/09/2010 8:00 AM	6/09/2010 8:00 PM	7/09/2010 8:00 AM
	Time Diff. (hrs)			47	12	12
	Peak Level (m)	5.25	3.19	4.47	3.80	3.90
	Peak Flow (m3/s)	66	114	93	0	149
December 2010	Date/Time of Peak	9/12/2010 8:00 AM		11/12/2010 3:15 AM	11/12/2010 10:45 PM	12/12/2010 8:00 AM
	Time Diff. (hrs)				20	9
	Peak Level (m)	5.24		4.21	3.49	3.72
	Peak Flow (m3/s)	62		83	0	89
January 2011	Date/Time of Peak	14/01/2011 3:45 PM	14/01/2011 10:26 AM	15/01/2011 9:00 AM		
	Time Diff. (hrs)			23		
	Peak Level (m)	5.31	3.39	4.99		
	Peak Flow (m3/s)	93	181	115		

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

Table 4-6 Avoca River instantaneous flow and level gauge summary

River Basin		Avoca	Avoca	Avoca	Avoca	Avoca	Avoca
Gauge Number		408202	408206	408212	408203	408209	408213
Gauge Location		Amphitheatre	Archdale Junction	Charlton	Quambatook	Sandhill Lake Road	Outfall Tresco Pumphouse
August 2010	Date/Time of Peak	12/08/2010 3:00 AM	13/08/2010 12:00 AM	22/08/2010 1:00 AM	26/08/2010 12:00 AM	1/08/2010 12:00 AM	
	Time Diff. (hrs)		21	217	95		
	Peak Level (m)	267.44	199.16	4.77	1.75		
	Peak Flow (m3/s)		50	53	9		
September 2010	Date/Time of Peak	4/09/2010 5:15 AM	4/09/2010 7:15 PM	6/09/2010 10:30 PM	11/09/2010 3:00 AM	16/09/2010 12:25 PM	
	Time Diff. (hrs)		14	51	101	129	
	Peak Level (m)	268.45	200.12	7.30	2.23	78.04	
	Peak Flow (m3/s)		138	250	31	15	
November to December 2010	Date/Time of Peak		28/11/2010 12:15 PM	30/11/2010 1:15 AM	4/12/2010 7:00 AM	6/12/2010 9:30 PM	
	Time Diff. (hrs)			37	102	63	
	Peak Level (m)		196.69	7.09	2.18	78.60	
	Peak Flow (m3/s)		8	202	27	30	
January 2011	Date/Time of Peak		14/01/2011 2:45 PM	15/01/2011 2:30 AM	18/01/2011 7:50 AM	22/01/2011 10:30 AM	25/01/2011 4:00 PM
	Time Diff. (hrs)			12	77	99	77
	Peak Level (m)		200.30	8.05	2.99	79.35	0.99
	Peak Flow (m3/s)		185	277	149	53	5

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

Table 4-7 Loddon River instantaneous flow and level gauge summary

River Basin		Loddon	Loddon	Loddon	Loddon
Gauge Number		407217	407215	407224	407205
Gauge Location		Vaughan	Newstead	Loddon Weir	Appin South
September 2010	Date/Time of Peak	5/09/2010 2:45 AM	4/09/2010 8:30 PM	6/09/2010 12:30 PM	11/09/2010 11:15 PM
	Time Diff. (hrs)		-6	40	131
	Peak Level (m)	260.50	212.85	107.56	3.07
	Peak Flow (m3/s)	114	322	320	54
November to December 2010	Date/Time of Peak	27/11/2010 4:00 PM	27/11/2010 8:15 PM	29/11/2010 7:15 PM	6/12/2010 1:44 PM
	Time Diff. (hrs)		4	47	162
	Peak Level (m)	261.78	213.56	107.71	3.21
	Peak Flow (m3/s)	230	562	418	131
January 2011	Date/Time of Peak	14/01/2011 10:45 AM	14/01/2011 3:30 PM	15/01/2011 2:15 AM	17/01/2011 11:30 PM
	Time Diff. (hrs)		5	11	69
	Peak Level (m)	261.59	213.83	107.82	3.58
	Peak Flow (m3/s)	212	696	523	584
February 2011	Date/Time of Peak	5/02/2011 9:45 AM	5/02/2011 2:30 PM	7/02/2011 5:45 PM	12/02/2011 1:45 AM
	Time Diff. (hrs)		5	51	104
	Peak Level (m)	259.16	210.75	106.79	3.07
	Peak Flow (m3/s)	20	89	87	72

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to localised storms in the upper catchment with spatial and temporal variability in rainfall impacting on tributary flows.*

Table 4-8 Coliban River instantaneous flow and level gauge summary

River Basin		Coliban	Coliban	Coliban
Gauge Number		406250	406200	406215
Gauge Location		Springhill-Tylden Road	Malmsbury	Lyal
September 2010	Date/Time of Peak	4/09/2010 11:15 PM	4/09/2010 10:00 AM	4/09/2010 1:45 PM
	Time Diff. (hrs)		-13	4
	Peak Level (m)	2.61	432.58	209.08
	Peak Flow (m3/s)	35	11	420
November 2010	Date/Time of Peak	27/11/2010 7:00 PM	28/11/2010 4:45 AM	28/11/2010 2:00 AM
	Time Diff. (hrs)		10	-3
	Peak Level (m)	2.63	434.84	208.59
	Peak Flow (m3/s)	36	115	351
January 2011	Date/Time of Peak	14/01/2011 9:13 AM	14/01/2011 2:30 PM	14/01/2011 1:15 PM
	Time Diff. (hrs)		5	-1
	Peak Level (m)	2.94	435.55	210.51
	Peak Flow (m3/s)	46	167	695
February 2011	Date/Time of Peak	5/02/2011 7:49 AM	5/02/2011 3:45 PM	5/02/2011 5:15 PM
	Time Diff. (hrs)		8	2
	Peak Level (m)	1.06	432.63	206.03
	Peak Flow (m3/s)	5	11	119

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to storages attenuating or totally storing upstream flows, with downstream tributary flows contributing to earlier downstream peaks.*

Table 4-9 Campaspe River instantaneous flow and level gauge summary

River Basin		Campaspe	Campaspe	Campaspe	Campaspe	Campaspe	Campaspe	Campaspe
Gauge Number		406208	406213	406207	406201	406218	406275	406276
Gauge Location		Ashbourne	Redesdale	Eppalock	Barnadown	Campaspe Weir (Head Gauge)	Burnewang-Bonn River	Fehrings Lane
September 2010	Date/Time of Peak	4/09/2010 4:15 PM	4/09/2010 1:15 PM	4/09/2010 11:00 AM	5/09/2010 12:00 AM	5/09/2010 3:45 PM	5/09/2010 7:05 PM	6/09/2010 6:30 PM
	Time Diff. (hrs)		-3	-2	13	16	3	23
	Peak Level (m)	0.93	218.19	153.40	137.32	121.39	8.17	5.99
	Peak Flow (m3/s)	12	260	3	258			
November 2010	Date/Time of Peak	27/11/2010 7:00 PM	28/11/2010 12:30 AM	29/11/2010 6:30 PM	28/11/2010 8:00 AM	29/11/2010 12:15 AM	29/11/2010 3:35 AM	30/11/2010 10:45 AM
	Time Diff. (hrs)		6	42	-35	16	3	31
	Peak Level (m)	1.05	217.44	156.83	138.49	121.72	8.99	5.91
	Peak Flow (m3/s)	19	216	72	384			
December 2010	Date/Time of Peak	8/12/2010 1:00 PM	8/12/2010 3:00 PM	9/12/2010 8:30 AM	9/12/2010 8:15 AM	9/12/2010 11:45 PM	10/12/2010 5:05 AM	11/12/2010 3:45 AM
	Time Diff. (hrs)		2	17	0	16	5	23
	Peak Level (m)	0.62	217.09	156.92	136.18	121.21	7.17	5.91
	Peak Flow (m3/s)	2	194	65	166			
January 2011	Date/Time of Peak	14/01/2011 10:30 AM	14/01/2011 12:00 PM	14/01/2011 8:15 PM	15/01/2011 12:15 AM	15/01/2011 10:45 AM	15/01/2011 11:35 AM	16/01/2011 10:45 PM
	Time Diff. (hrs)		2	8	4	11	1	35
	Peak Level (m)	1.37	219.35	162.49	140.08	122.46	11.05	9.20
	Peak Flow (m3/s)	40	322	65	715			
February 2011	Date/Time of Peak	5/02/2011 8:15 AM	5/02/2011 12:45 PM	6/02/2011 4:30 AM	5/02/2011 9:45 PM	6/02/2011 10:30 AM	6/02/2011 12:05 PM	7/02/2011 11:30 PM
	Time Diff. (hrs)		5	16	-7	13	2	35
	Peak Level (m)	0.41	216.75	156.41	137.95	121.62	10.62	6.55
	Peak Flow (m3/s)	1	172	65	315			

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to storages attenuating or totally storing upstream flows, with downstream tributary flows contributing to earlier downstream peaks.*

4.5 Summary

The North Central region experienced numerous significant rainfall events over the spring-summer 2010-11 period, including September and November 2010, and January and February 2011. The January 2011 rainfall event generally recorded the lowest AEPs at the 72 hour duration, ranging from just 20% AEP at Echuca to around 1% AEP at Charlton and Avoca, and less than 1% AEP at Maryborough and Kyneton. The September 2010 event registered between a 10 to 5% AEP at Avoca and Maryborough for the 24 to 48 hour durations, but had a higher AEP in other areas. The November 2010 rainfall event was estimated to have a 20% AEP at Maryborough for the 48 hour duration. The February 2011 rainfall event was estimated as 10% AEP event at Bendigo for the 72 hour duration.

In January 2011 the streamflow gauges accessed by the Bureau of Meteorology for flood warning purposes recorded peak levels in excess of major flood levels in all the significant river systems in the region. The flooding during this event was typically less than 1% AEP from available flood frequency information for the Campaspe, Loddon and Avoca rivers. Analysis of peak water levels from the September 2010 flood was estimated at approximately 20 to 10% AEP on the Loddon, between 25 to 2% AEP on the Avoca and 33 to less than 1% AEP on the Campaspe. The November 2010 flood event was estimated at between 10 to 4% AEP on the Campaspe, 20 to 4% AEP on the Loddon and 20 to 10% AEP on the Avoca. The February 2010 flood event was estimated at between 20 to 10% AEP for the Campaspe River.

A number of flood studies currently underway will most likely produce different estimates of the AEP of these flood events as a result of the application of a much more rigorous approach to design flood estimation.

5. NORTH EAST REGION HYDROLOGICAL ANALYSIS

5.1 Overview of Flooding

August 2010 – Widespread rainfall, with high totals recorded in the upper catchment, but no known flooding issues.

September 2010 – Widespread heavy rainfall was observed with most waterways reaching 'Moderate' and 'Major' flood levels, with significant flood damage experienced throughout the region.

October 2010 – Most rivers within the region remained at or less than 'Minor' flood levels, with the exception of the Upper Murray, which recorded 'Moderate' and 'Major' flooding.

November 2010 – Most rivers within the region remained at or less than 'Minor' flood levels, with the exception of the Upper Murray and Sunday Creek, a tributary of the Goulburn River near Seymour.

December 2010 – Most river systems recorded significant flooding throughout the region, with 'Moderate' and 'Major' flooding.

January 2011 – Compared to other regions, January 2011 was not overly significant for most of the river systems in the region, with only 'Minor' to 'Moderate' flood levels recorded. It is understood that the Corop Lakes area did receive some significant inundation. However as this area is not covered by any formal flood warning arrangements and it does not include any major river systems, there is limited data to assist this study.

February 2011 – Most rivers remained at or below 'Minor' flood levels even though intense rainfall was recorded over the far east of the region with large rainfall totals.

5.2 Regional Description

The North East region includes the Goulburn, Broken, Ovens, Kiewa Mitta Mitta and Upper Murray catchments, Figure 5-1 below shows the major waterways in the region.

The Goulburn River flows north from the Great Dividing Range near Woods Point, through Jamieson and into Lake Eildon. Downstream from Lake Eildon the river flows through Molesworth, Kerrisdale, Seymour and Nagambie where it enters a small pondage (Lake Nagambie). The river then flows through Shepparton and Mooroopna before opening out to the lower Goulburn River floodplain and flowing into the Murray River upstream of Echuca.

The Broken River is a major tributary of the Goulburn River, flowing northwards from the Great Dividing Range near Mansfield, through Lake Nillahcootie in the upper catchment, through Benalla and to the Goulburn River at Shepparton. Between Benalla and Shepparton the Broken River breaks out in large floods and flows into the Broken Creek catchment. Broken Creek drains a large area including the Muckatah Depression and flows through numerous small rural communities including Numurkah and Nathalia before flowing to the Murray River through the Barmah State Forest upstream of Barmah.

The Ovens, King and Kiewa rivers all flow to the north from the Great Dividing Range through relatively confined valleys and passing through many small communities. The Ovens River passes through Bright, Porepunkah, Myrtleford and Wangaratta before flowing on to the Murray River at the upstream end of Lake Mulwala. The King River flows into the Ovens River at Wangaratta. The Kiewa River passes through Mount Beauty, Mongans Bridge and Kiewa before flowing into the Murray River a short distance upstream of Wodonga.

The Mitta Mitta River flows from the Great Dividing Range near Anglers Rest through to Lake Dartmouth. It then flows through Mitta Mitta, Eskdale and Tallandoon, before passing through Tallangatta and flowing into Lake Hume. The Upper Murray River and its tributaries also flow into Lake Hume.

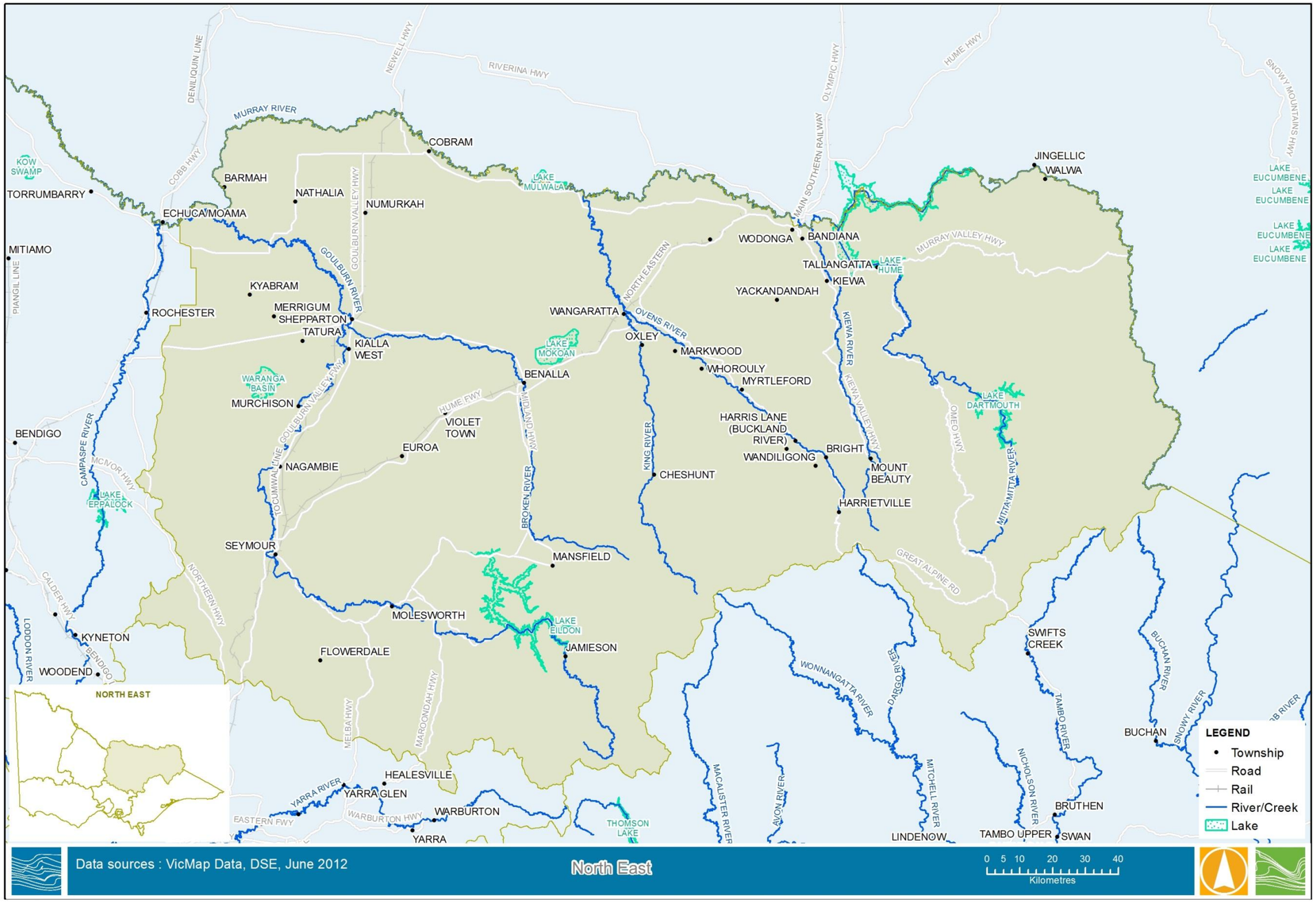


Figure 5-1 North East region

5.3 Rainfall

Section 2.1 provides a broad overview of the synoptic conditions that produced the rainfall events over the spring-summer 2010-11 period. This Section includes more detail about specific rainfall gauges within the North East region. It should be noted that daily rainfall gauges typically record rainfall totals over a 24 hour period to 9 am on the date recorded.

Table 5-1 below summarises the maximum daily rainfall and monthly totals for numerous rainfall gauges across the region and compares it against the historical monthly average over the spring-summer period as well as against the historical monthly and daily maximum rainfall totals. A high proportion of the gauges selected for analysis broke daily and monthly maximum rainfall records during the spring-summer 2010-11 period.

For a selected number of gauges an Intensity-Frequency-Duration (IFD) analysis was undertaken on the daily rainfall totals at 24, 48 and 72 hour durations. Using the geographical coordinates for the rainfall gauges analysed, the raw polynomial coefficients were taken from the Bureau of Meteorology's online IFD Data System[13], and used as input to an IFD spreadsheet tool developed by Water Technology, plotting the IFD curves for the rainfall gauge site. This was overlayed with the maximum 24, 48 and 72 hour rainfall totals for each month.

The gauges selected were chosen to provide a spread across the region with preference for gauges in proximity to areas of significant flooding. Note that the frequency attributed to the rainfall event does not necessarily correspond to the frequency of the flood event due to antecedent catchment conditions, timing of tributary flows etc. It must also be noted that the frequency of the event may differ when durations shorter than 24 hours are considered, however with daily rainfall gauges these shorter durations can not be assessed. Figure 5-3 to Figure 5-9 below show the IFD analysis undertaken.

Figure 5-2 below shows the location of the rainfall gauges analysed for both daily and monthly totals and also those gauges for which an IFD analysis was completed.

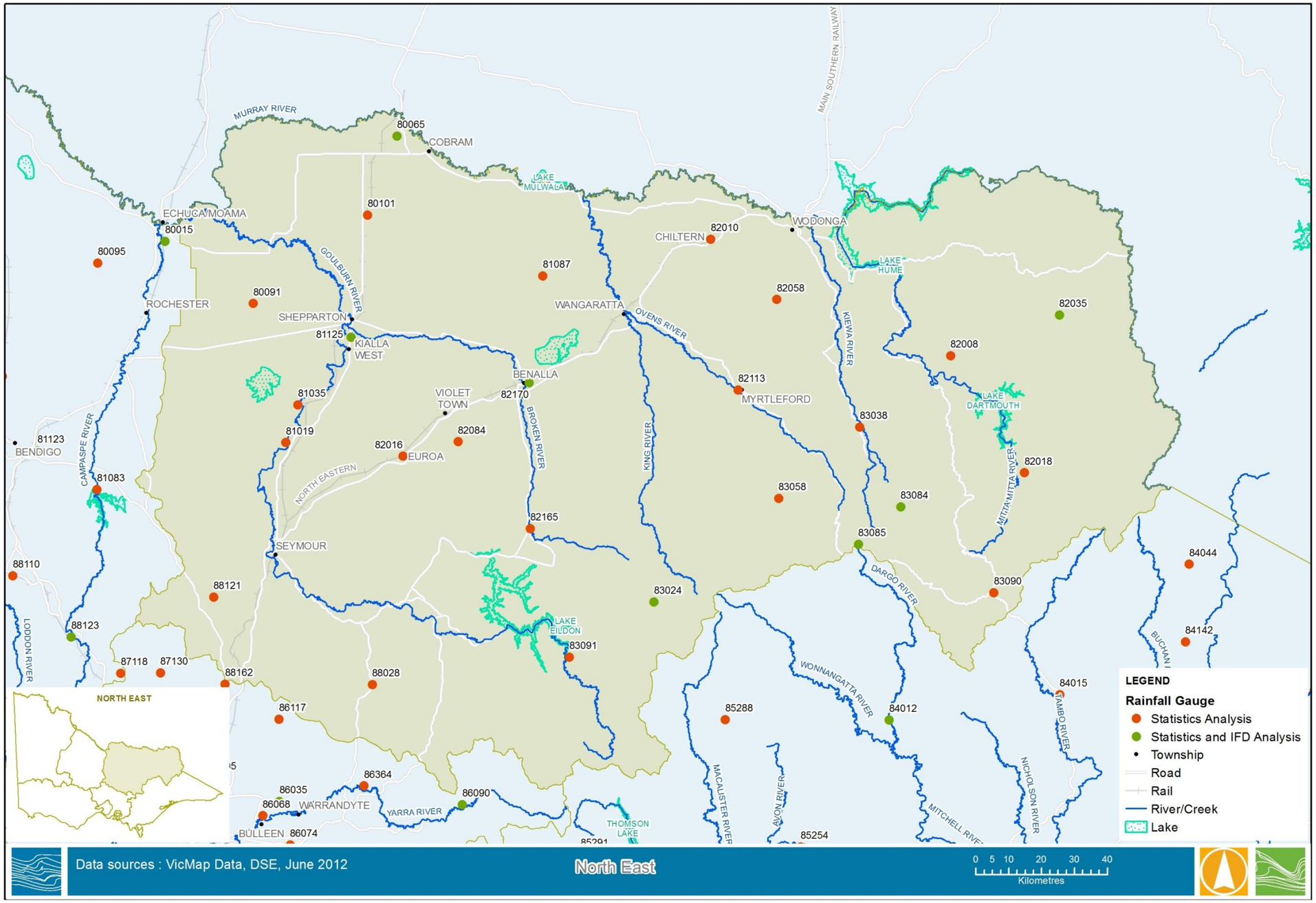
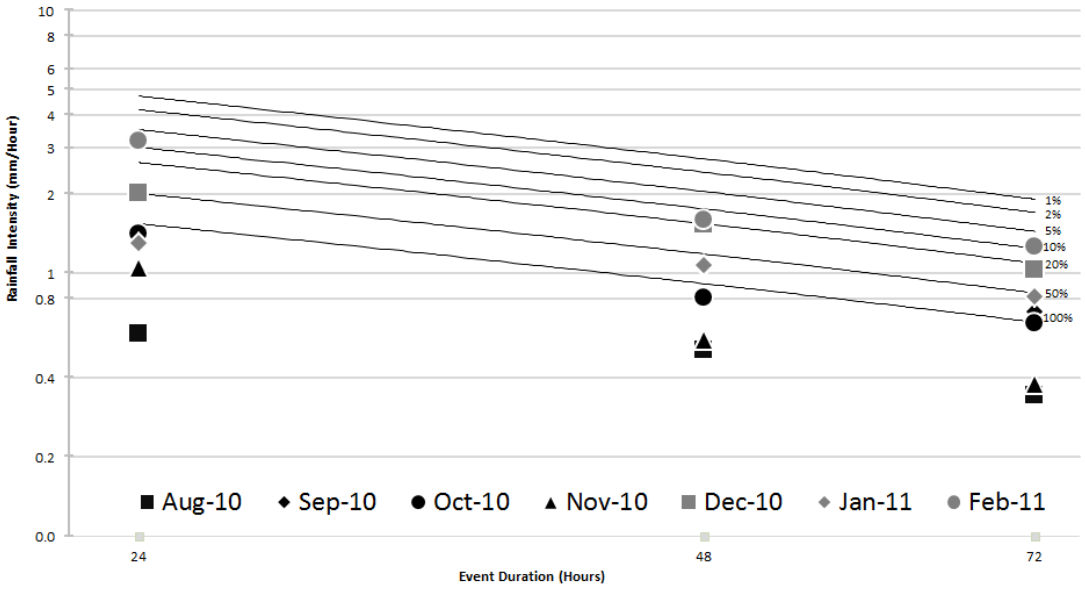


Figure 5-2 North East region rainfall gauges analysed

Table 5-1 North East region observed rainfall summary

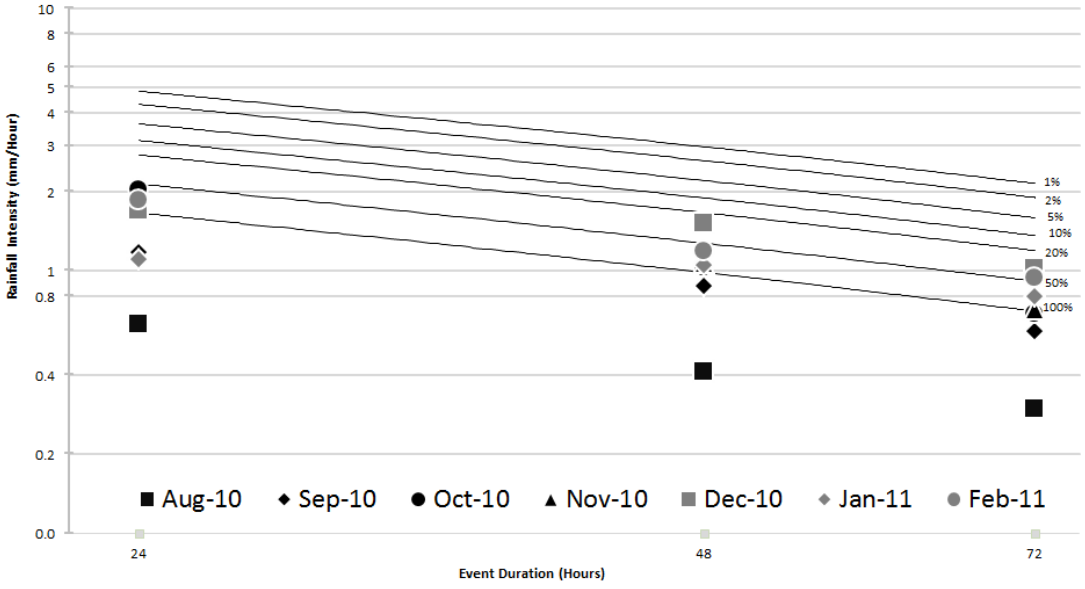
Location	Station Number	August 2010		September 2010		October 2010		November 2010		December 2010		January 2011		February 2011		Record Statistics			
		Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Avg.	Monthly Max.	Daily Max.	Start of record
Benalla Airport	82170	118.3	33.7 (11th)	68.7	30.6 (4th)	108.1	23.8 (16th)	86.7	48.8 (28th)	117.6	42.6 (9th)	78.8	24.2 (15th)	183.1	52.6 (5th)	38.5-80.9	191.4 (Mar 2012)	87.9 (01/03/2012)	2006
Boho (Honeysuckle Ck U/S Violet Town)	82084	158	21.4 (26th)	107.2	41.2 (4th)	112.6	55.2 (31st)	100.2	51.8 (28th)	168	61.6 (9th)	131.8	49.6 (15th)	216.8	58.6 (5th)	44.0-89.9	216.8 (Feb 2011)	105.0 (03/02/2005)	2000
Bungeet (Highlands)	81087	109	36.2 (11th)	71.8	28.8 (4th)	134.8	27.8 (31st)	93.8	45.4 (28th)	172	71.8 (9th)	46.2	23.6 (15th)	26.2	5.4 (6th)	26.1-61.1	219.4 (Mar 2012)	109.8 (01/03/2012)	2002
Callaghan Creek Station	82008	187.6	35.8 (26th)	142.8	69.0 (5th)	226	66.6 (31st)	133.4	42.0 (14th)	99	37.2 (9th)	111.6	32.0 (13th)	270.8	82.2 (5th)	53.6-123.4	334.0 (Aug 1981)	167.5 (04/08/1981)	1912
Chiltern (Post Office)	82010	100.4	16.4 (12th)	33.1	31.0 (4th)	184.1	46.0 (31st)[1]	131.9	66.2 (14th)	148.4	60.3 (9th)	106.2	33.0 (15th)	245.9	111.4 (5th)	42.3-75.4	305.3 (Feb 1928)	117.0 (01/03/2012)	1885
Euroa	82016	116.4	20.2 (19th)	82.8	34.0 (4th)	130	44.0 (31st)	120.2	61.0 (28th)	134.8	45.2 (9th)	93	28.6 (15th)	122.8	36.0 (6th)	33.5-75.1	270.1 (Apr 1939)	100.3 (04/01/1941)	1883
Falls Creek	83084	143.2	28.8 (3rd)	164.4	96.6 (5th)	236.4	87.0 (31st)	240.6	71.6 (14th)	112.4	19.4 (20th)	124.8	53.6 (15th)	492.8	104.2 (5th)	81.0-141.9	492.8 (Feb 2011)	131.4 (01/01/2010)	1990
Glenburn	88028	151.4	27.4 (12th)	124.4	33.4 (5th)	169.8	65.4 (31st)	135.2	53.4 (28th)	140	42.8 (9th)	161.8	46.8 (14th)	142.4	40.4 (6th)	46.8-94.4	271.5 (Aug 1954)	106.6 (03/02/2005)	1936
Halls (Buckland River at Twelve Mile)	83058	247.6	40.4 (26th)	209.8	113.2 (5th)	232.6	103.0 (31st)	246.2	90.2 (28th)	259	97.8 (9th)	141	53.2 (13th)	333.4	75.8 (12th)	49.0-147.8	333.4 (Feb 2011)	127.2 (28/02/2012)	2001
High Camp (Lannermoor)	88121	116.4	22.0 (19th)	81	34.0 (4th)	107.6	39.0 (31st)	192.2	58.2 (27th)	107.8	42.4 (9th)	135.6	48.6 (14th)	135.6	42.0 (5th)	33.8-67.1	192.2 (Nov 2010)	80.5 (17/02/1972)	1969
Jamieson Licola Rd	83091	231.8	30.2 (26th)	168.9	69.6 (5th)	132.4	97.0 (14th)	171.6	74.4 (28th)	134	46.6 (9th)	129.8	33.4 (15th)	195.6	49.4 (6th)	56.4-141.0	231.8 (Aug 2010)	106.0 (28/02/2012)	2004
Kyabram	80091	88	18.8 (19th)	48.4	20.6 (4th)	70	27.0 (31st)	26	5.4 (26th)	55	23.4 (2nd)	113.4	30.8 (14th)	146.8	65.8 (5th)	29.3-43.5	162.8 (Oct 1975)	105.9 (04/10/1993)	1964
Mount Bulla	83024	257.6	36.2 (1st)	234.6	90.8 (5th)	193	70.2 (31st)	197.4	75.2 (28th)	274.2	102.8 (9th)	182.6	63.6 (13th)	291.8	84.0 (6th)	75.2-162.8	431.6 (Jul 1990)	128.0 (09/09/1949)	1948
Mount Hotham	83085	202	34.4 (19th)	227.2	131.4 (5th)	269.6	130.2 (31st)	300.8	96.4 (14th)	232.6	95.6 (9th)	121.8	50.2 (15th)	419	90.8 (5th)	95.0-150.4	567.0 (Aug 1990)	131.4 (05/09/2010)	1990
Murchison	81035	77.4	22.0 (19th)	42.2	18.0 (4th)	100.2	41.0 (31st)	71.2	40.6 (28th)	76.4	20.0 (9th)	97.2	21.6 (13th)	100	36.0 (5th)	33.6-60.2	307.8 (Mar 1950)	147.3 (18/03/1950)	1883
Myrtleford	82113	159.4	32.4 (26th)	63.1	20.0 (5th)	172.3	36.4 (31st)	114	48.4 (14th)	162.6	49.0 (9th)	95.4	24.8 (13th)	198.6	63.7 (5th)[1]	52.3-99.5	232.0 (Feb 1973)	80.8 (20/02/1973)	1969
Nagambie (Goulburn Weir)	81019	108.4	24.4 (19th)	70.2	28.6 (5th)	91	31.0 (31st)	110.8	43.6 (28th)	86.4	27.8 (9th)	133.4	45.6 (13th)	109.8	46.0 (5th)	32.2-55.0	286.1 (Mar 1950)	143.5 (18/03/1950)	1908
Nariel Creek (Simpson)	82035	192	29.4 (11th)	161.8	83.2 (5th)	290	88.0 (16th)	126.2	32.0 (14th)	150.2	90.4 (9th)	58.6	21.8 (15th)	255.2	61.4 (5th)	53.1-120.6	352.9 (Jul 1964)	110.4 (04/03/2012)	1884
Numurkah	80101	56.6	10.2 (19th)	41.8	27.8 (4th)	105.4	30.2 (31st)	61	30.4 (28th)	110	62.4 (9th)	77.4	25.0 (11th)	145.2	49.4 (11th)	28.4-43.0	159.0 (Dec 1975)	103.0 (26/11/1985)	1968
Omeo	83090	77.8	14.2 (11th)	42.8	27.4 (5th)	107	48.8 (16th)	89.6	36.4 (14th)	132.2	69.0 (9th)	50.4	17.6 (23rd)	126.2	35.2 (5th)	25.5-82.3	175.8 (Mar 2012)	69.0 (09/12/2010)	2004
Shepparton Airport	81125	77.8	15.0 (19th)	64.2	28.2 (4th)	104.4	48.8 (31st)	60	44.4 (28th)	122.8	40.6 (9th)	100.8	26.4 (10th)	137.6	44.6 (5th)	27.5-53.5	137.6 (Feb 2011)	83.0 (12/11/1998)	1996
Stump Hill (Barjarg)	82165	154.2	34.4 (11th)	128.8	54.0 (5th)	116	32.0 (31st)	134.6	77.4 (28th)	142.6	41.0 (9th)	123	36.2 (15th)	163.4	51.6 (6th)	41.0-83.0	184.2 (Mar 2012)	125.0 (22/12/2007)	2003
Tawonga	83038	224.8	39.0 (26th)	130.4	68.0 (5th)	187.6	55.1 (31st)[1]	186.6	82.0 (14th)	247.8	144.2 (9th)	86.8	27.0 (13th)	288.6	85.0 (5th)	57.6-143.0	386.7 (Jul 1964)	144.2 (09/12/2010)	1942
Uplands (Gibbo River Park)	82018	208	30.4 (26th)	118.4	66.0 (5th)	255.2	98.0 (31st)	141.2	44.6 (14th)	97.2	32.0 (9th)	79.6	27.4 (23rd)	258.4	66.0 (5th)	52.2-134.6	350.2 (Jun 1920)	120.1 (25/08/1924)	1904
Yackandandah	82058	135.4	19.6 (26th)	114	45.4 (5th)	188.4	62.5 (31st)	152.9	62.5 (14th)	173.6	84.2 (9th)	137	39.2 (10th)	22.4	90.4 (5th)	47.2-115.2	360.4 (Jun 1981)	169.7 (27/02/1939)	1886
Yarroweyah	80065	60.3	10.4 (12th)	70.1	24.8 (4th)[1]	130	29.4 (7th)	43	25.0 (28th)	116.2	48.0 (9th)	88.4	31.2 (10th)	136.6	40.7 (5th)[1]	28.8-45.0	225.8 (Apr 1926)	144.0 (06/04/1926)	1890

[1] *Note: Gauge recordings were aggregated over a number of days. Daily totals were disaggregated using the daily rainfall pattern from the nearest gauge of complete record.*
[2] *Note: Records of data were incomplete for the month. The total and highest daily rainfall cannot be determined using incomplete data.*
[3] *Note: Gauge broke daily or monthly statistical records over the period.*
[4] *Note: Analysis carried out early May 2012, any events after that not captured in historical records columns.*



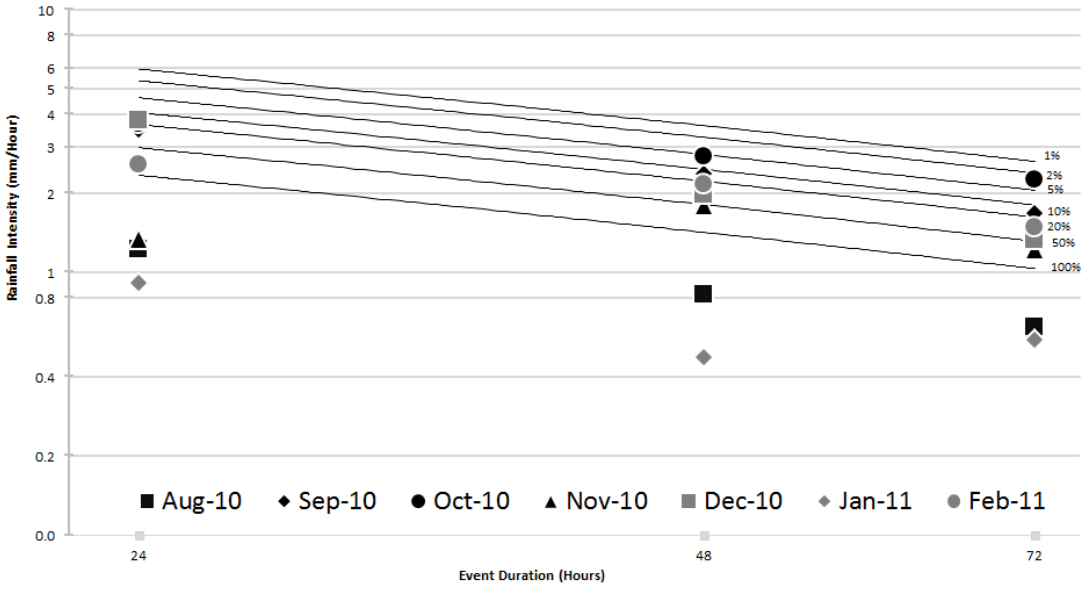
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	14.0	0.6	11/08/2010	>100%	24.4	0.5	12/08/2010	>100%	24.6	0.3	13/08/2010	>100%
Sep 10	49.6	2.1	5/09/2010	50%-20%	51.0	1.1	6/09/2010	100%-50%	51.2	0.7	7/09/2010	100%-50%
Oct 10	33.8	1.4	16/10/2010	>100%	38.6	0.8	14/10/2010	>100%	46.4	0.6	16/10/2010	>100%
Nov 10	25.0	1.0	28/11/2010	>100%	26.8	0.6	1/11/2010	>100%	27.2	0.4	28/11/2010	>100%
Dec 10	48.0	2.0	9/12/2010	100%-50%	73.0	1.5	9/12/2010	50%-20%	74.0	1.0	9/12/2010	50%-20%
Jan 11	31.2	1.3	10/01/2011	>100%	51.2	1.1	11/01/2011	100%-50%	58.4	0.8	12/01/2011	100%-50%
Feb 11	76.2	3.2	6/02/2011	10%-5%	76.2	1.6	6/02/2011	10%-20%	90.6	1.3	6/02/2011	10%-5%

Figure 5-3 080065 Yarroweyah Rainfall Intensity-Frequency-Duration Analysis



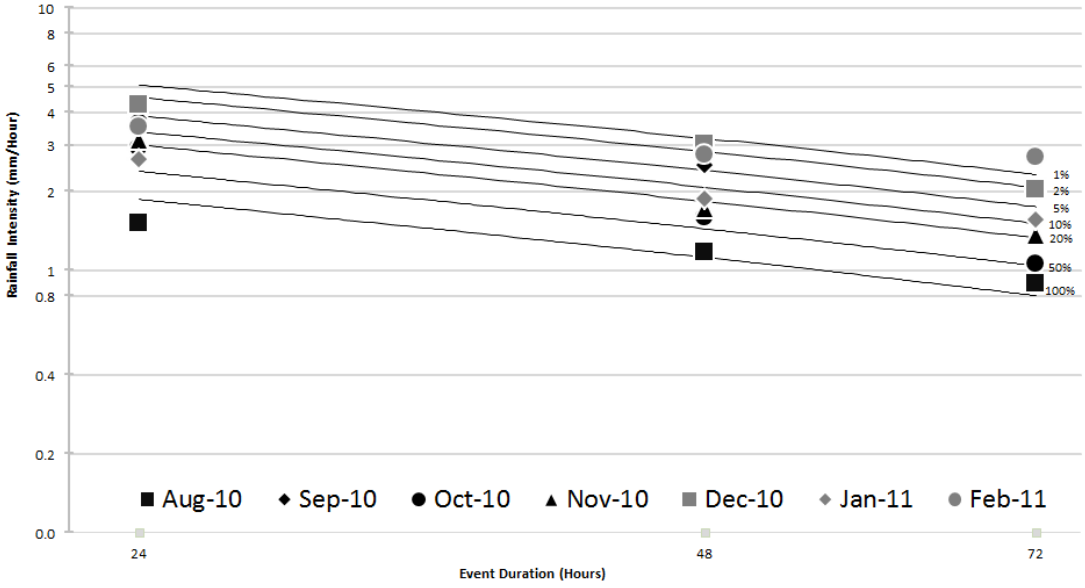
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	15.0	0.6	19/08/2010	>100%	19.6	0.4	26/08/2010	>100%	21.2	0.3	27/08/2010	>100%
Sep 10	28.2	1.2	4/09/2010	>100%	41.8	0.9	5/09/2010	>100%	42.0	0.6	6/09/2010	>100%
Oct 10	48.8	2.0	31/10/2010	100%-50%	49.0	1.0	31/10/2010	100%-50%	49.0	0.7	31/10/2010	>100%
Nov 10	44.4	1.9	28/11/2010	100%-50%	51.2	1.1	1/11/2010	100%-50%	51.4	0.7	1/11/2010	100%-50%
Dec 10	40.6	1.7	9/12/2010	100%-50%	72.8	1.5	9/12/2010	50%-20%	72.8	1.0	9/12/2010	50%-20%
Jan 11	26.4	1.1	10/01/2011	>100%	50.2	1.0	11/01/2011	100%-50%	57.4	0.8	12/01/2011	100%-50%
Feb 11	44.6	1.9	5/02/2011	100%-50%	56.6	1.2	12/02/2011	100%-50%	67.6	0.9	6/02/2011	50%-20%

Figure 5-4 081125 Shepparton Airport Rainfall Intensity-Frequency-Duration Analysis



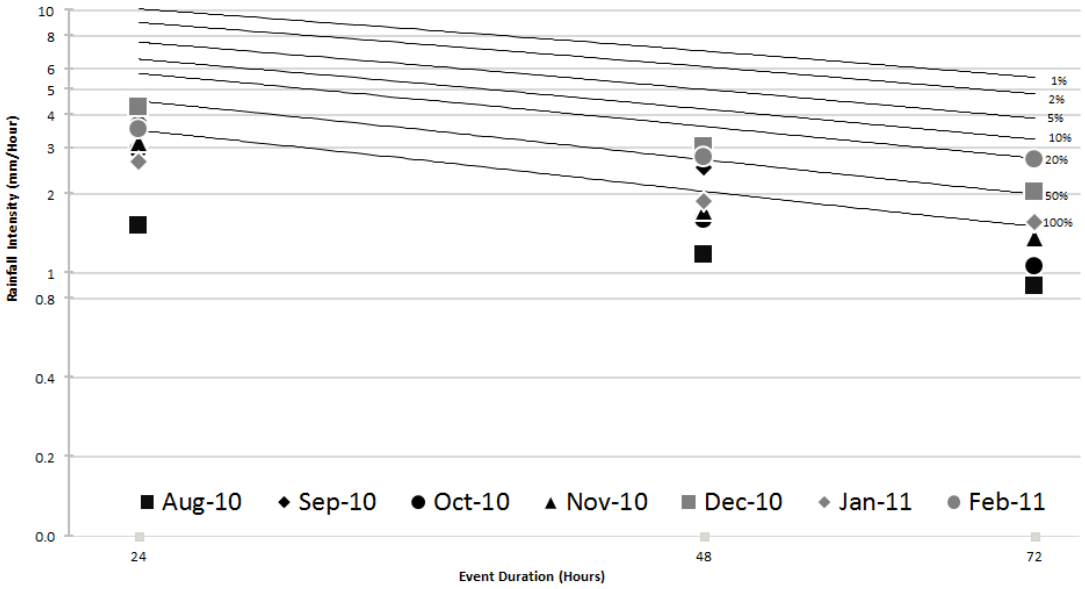
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	29.4	1.2	11/08/2010	>100%	39.2	0.8	12/08/2010	>100%	44.2	0.6	12/08/2010	>100%
Sep 10	83.2	3.5	5/09/2010	50%-20%	113.2	2.4	5/09/2010	10%-20%	120.4	1.7	6/09/2010	10%-20%
Oct 10	88.0	3.7	16/10/2010	10%-20%	131.6	2.7	16/10/2010	10%-5%	161.6	2.2	16/10/2010	5%-2%
Nov 10	32.0	1.3	14/11/2010	>100%	86.6	1.8	1/11/2010	100%-50%	87.6	1.2	2/11/2010	100%-50%
Dec 10	90.4	3.8	9/12/2010	10%-20%	94.0	2.0	9/12/2010	50%-20%	94.8	1.3	10/12/2010	50%-20%
Jan 11	21.8	0.9	15/01/2011	>100%	22.8	0.5	15/01/2011	>100%	39.8	0.6	15/01/2011	>100%
Feb 11	61.4	2.6	5/02/2011	100%-50%	103.4	2.2	6/02/2011	50%-20%	106.4	1.5	6/02/2011	50%-20%

Figure 5-5 082035 Nariel Creek (Simpson) Rainfall Intensity-Frequency-Duration Analysis



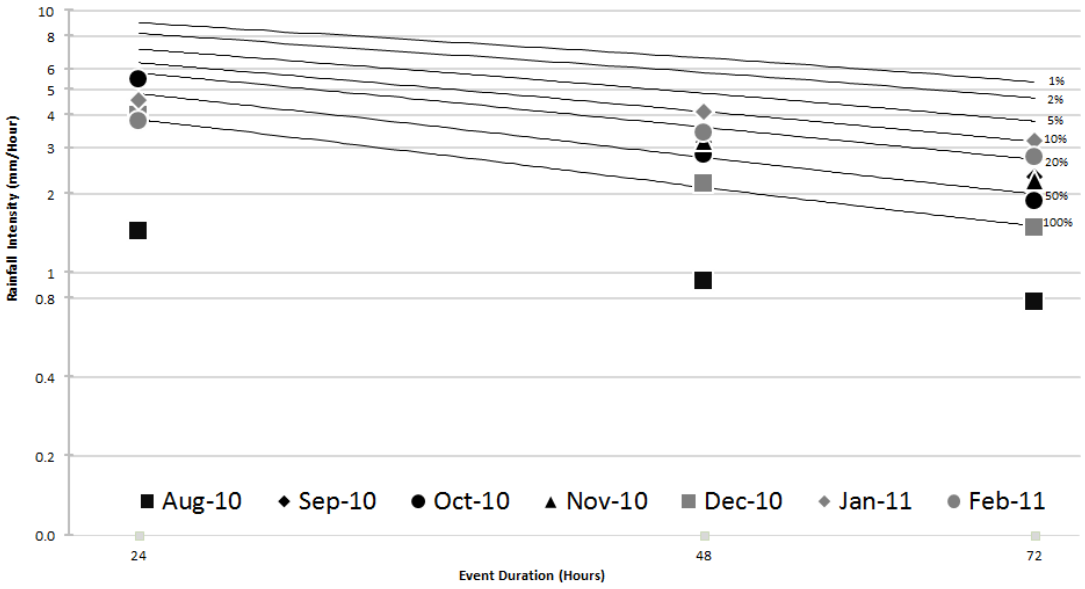
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	36.2	1.5	1/08/2010	>100%	56.2	1.2	2/08/2010	100%-50%	64.2	0.9	3/08/2010	100%-50%
Sep 10	90.8	3.8	5/09/2010	10%-5%	120.6	2.5	6/09/2010	5%-2%	143.0	2.0	6/09/2010	5%-2%
Oct 10	70.2	2.9	31/10/2010	50%-20%	76.4	1.6	31/10/2010	50%-20%	76.4	1.1	31/10/2010	50%-20%
Nov 10	75.2	3.1	28/11/2010	10%-20%	82.4	1.7	1/11/2010	50%-20%	98.4	1.4	28/11/2010	10%-20%
Dec 10	102.8	4.3	9/12/2010	5%-2%	145.4	3.0	9/12/2010	2%-1%	145.4	2.0	9/12/2010	5%-2%
Jan 11	63.6	2.7	13/01/2011	50%-20%	89.8	1.9	14/01/2011	10%-20%	111.6	1.6	14/01/2011	10%-5%
Feb 11	84.0	3.5	6/02/2011	10%-5%	131.8	2.7	6/02/2011	5%-2%	195.0	2.7	6/02/2011	<1%

Figure 5-6 082170 Benalla Airport Rainfall Intensity-Frequency-Duration Analysis



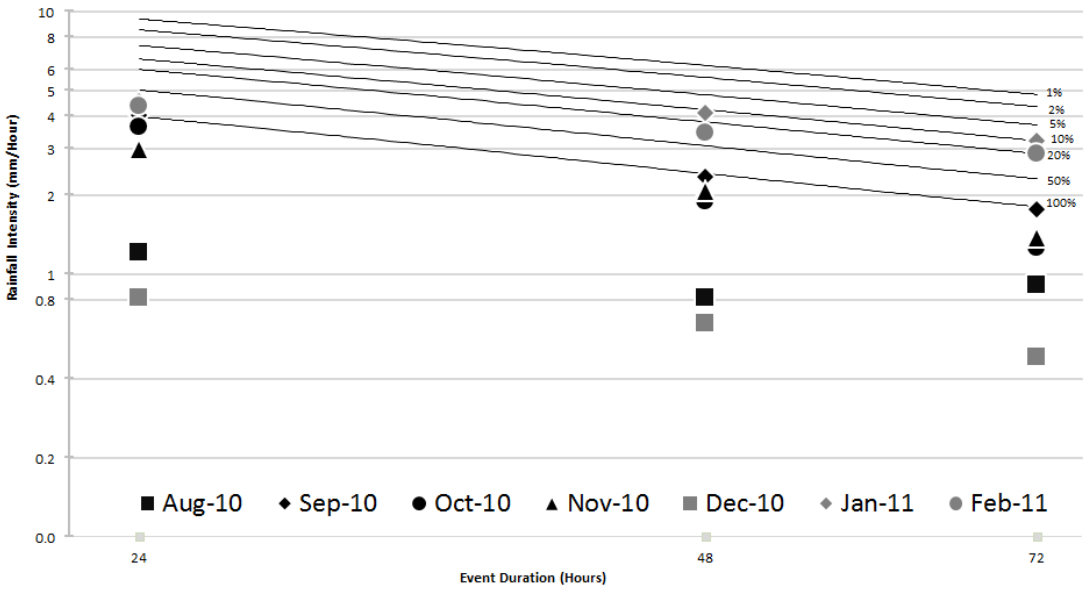
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	36.2	1.5	1/08/2010	>100%	56.2	1.2	2/08/2010	>100%	64.2	0.9	3/08/2010	>100%
Sep 10	90.8	3.8	5/09/2010	100%-50%	120.6	2.5	6/09/2010	100%-50%	143.0	2.0	6/09/2010	100%-50%
Oct 10	70.2	2.9	31/10/2010	>100%	76.4	1.6	31/10/2010	>100%	76.4	1.1	31/10/2010	>100%
Nov 10	75.2	3.1	28/11/2010	>100%	82.4	1.7	1/11/2010	>100%	98.4	1.4	28/11/2010	>100%
Dec 10	102.8	4.3	9/12/2010	100%-50%	145.4	3.0	9/12/2010	50%-20%	145.4	2.0	9/12/2010	50%-20%
Jan 11	63.6	2.7	13/01/2011	>100%	89.8	1.9	14/01/2011	>100%	111.6	1.6	14/01/2011	100%-50%
Feb 11	84.0	3.5	6/02/2011	100%-50%	131.8	2.7	6/02/2011	50%-20%	195.0	2.7	6/02/2011	50%-20%

Figure 5-7 083024 Mount Buller Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	34.4	1.4	19/08/2010	>100%	44.6	0.9	1/08/2010	>100%	55.4	0.8	1/08/2010	>100%
Sep 10	131.4	5.5	5/09/2010	50%-20%	150.4	3.1	6/09/2010	50%-20%	166.2	2.3	6/09/2010	50%-20%
Oct 10	130.2	5.4	31/10/2010	50%-20%	134.6	2.8	31/10/2010	50%-20%	134.6	1.9	31/10/2010	100%-50%
Nov 10	96.4	4.0	14/11/2010	100%-50%	152.0	3.2	1/11/2010	50%-20%	162.2	2.3	2/11/2010	50%-20%
Dec 10	95.6	4.0	9/12/2010	100%-50%	104.2	2.2	9/12/2010	100%-50%	106.8	1.5	10/12/2010	>100%
Jan 11	109.0	4.5	13/01/2011	100%-50%	197.0	4.1	14/01/2011	10%-20%	229.8	3.2	14/01/2011	10%-5%
Feb 11	90.8	3.8	5/02/2011	>100%	164.0	3.4	6/02/2011	50%-20%	199.0	2.8	6/02/2011	10%-20%

Figure 5-8 083085 Mount Hotham Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	28.8	1.2	3/08/2010	>100%	38.8	0.8	3/08/2010	>100%	65.2	0.9	3/08/2010	>100%
Sep 10	96.6	4.0	5/09/2010	100%-50%	112.0	2.3	6/09/2010	>100%	127.0	1.8	6/09/2010	>100%
Oct 10	87.0	3.6	31/10/2010	>100%	90.4	1.9	31/10/2010	>100%	90.4	1.3	31/10/2010	>100%
Nov 10	71.6	3.0	14/11/2010	>100%	99.0	2.1	15/11/2010	>100%	99.4	1.4	1/11/2010	>100%
Dec 10	19.4	0.8	20/12/2010	>100%	31.2	0.7	9/12/2010	>100%	34.6	0.5	4/12/2010	>100%
Jan 11	109.0	4.5	13/01/2011	100%-50%	197.0	4.1	14/01/2011	10%-20%	229.8	3.2	14/01/2011	10%-20%
Feb 11	104.2	4.3	5/02/2011	100%-50%	165.8	3.5	6/02/2011	50%-20%	206.2	2.9	6/02/2011	50%-20%

Figure 5-9 083084 Falls Creek Rainfall Intensity-Frequency-Duration Analysis

5.4 Streamflow

Two separate streamflow analyses were undertaken. The first was based on information provided by the Bureau of Meteorology for flood warning gauges over the spring-summer 2010-11 period (excluding August 2010), the second based on instantaneous flow and level data obtained from DSE on 268 streamflow gauges. These analyses are summarised below in Table 5-2 to Table 5-18.

The streamflow gauge analysis for flood warning gauges included a summary of flood class levels, peak level and flood class and where available frequency of flooding. This analysis was based on information provided by the Bureau of Meteorology, with no attempt to infill missing data. The frequency of flooding was provided for gauges where a flood frequency analysis had been undertaken in the past and as documented in the Victorian Strategic Flood Intelligence Report[14]. The flood frequency analysis included in the above mentioned VICSES document includes flood frequency analysis from two distinct sources. The first source included flood frequency analysis undertaken by Thiess for the Victorian Flood Warning Station Information Manual[15], covering the majority of flood warning gauges. The second source of flood frequency analysis was for gauges analysed as part of recent flood studies. The accuracy of the flood frequencies may differ given the source and the length of data record available.

The DSE instantaneous streamflow gauge analysis concentrated on peak levels and flows and timing of peaks. Travel times were calculated between peaks. These travel times were found to be inconsistent in some cases (i.e. downstream gauges sometimes peaking earlier). Each case was assessed and it is likely that this was due to the spatial and temporal distribution of rainfall, the effect of storages attenuating or totally storing upstream flows, the timing of tributary flows or the occurrence of multiple peaks within a month obscuring the analysis. This analysis was only conducted on months where a significant flow event occurred (generally above Minor flood levels).

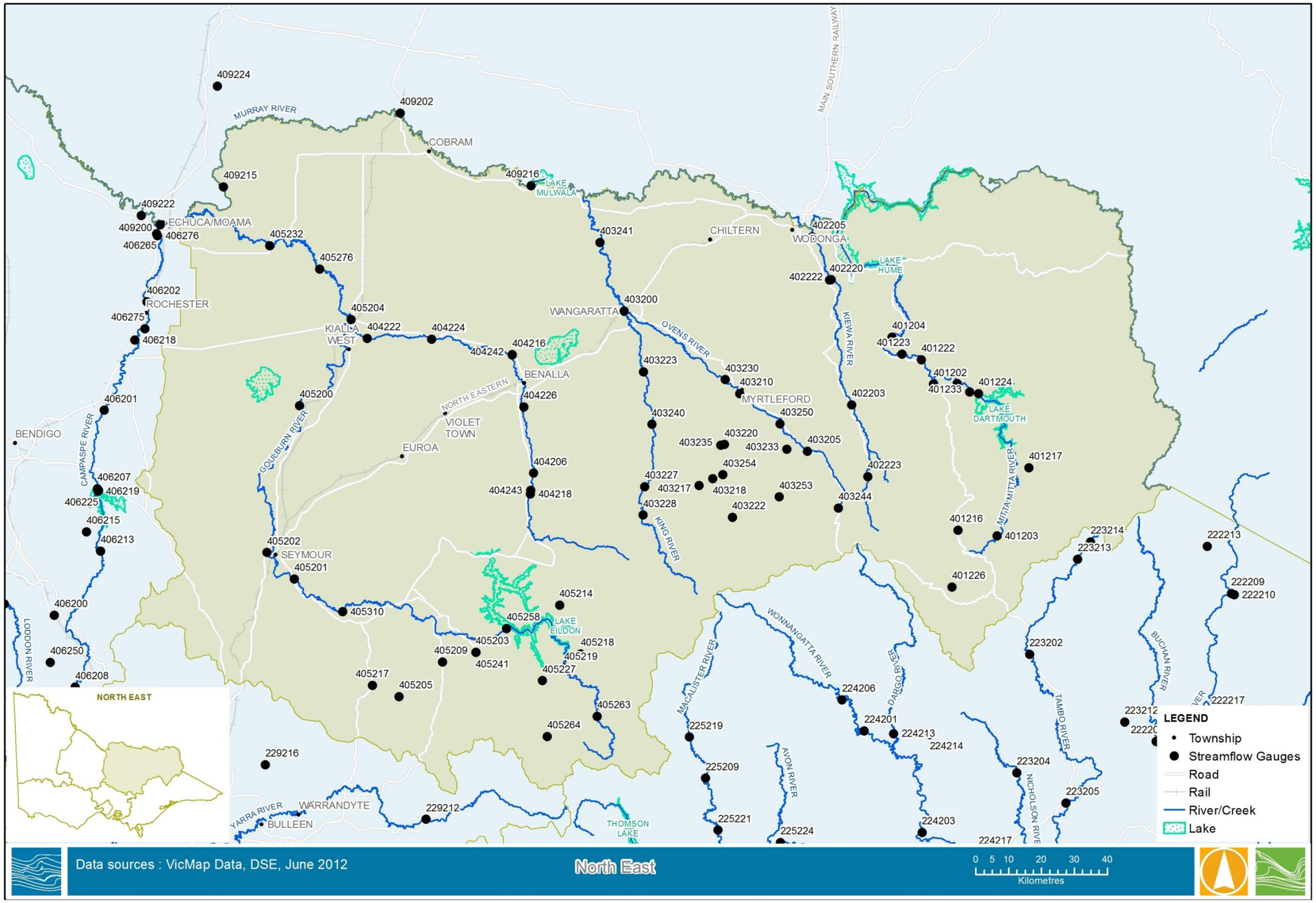


Figure 5-10 North East region streamflow gauges analysed

Table 5-2 Mitta Mitta River Bureau of Meteorology flood warning gauge summary

River Basin		Big	Mitta Mitta	Mitta Mitta
Location		Joker Creek	Hinnomunjie	Tallandoon
Flood Class Level	Minor	2.80	1.80	4.20
	Moderate	3.70	2.50	4.90
	Major	-	3.00	5.60
Sep-2010	Peak (m)	3.73	3.51	4.11
	Warning	Moderate	Major	<Minor
	AEP (%)	6-4%	10-4%	
Oct-2010	Peak (m)	2.40	2.07	2.93
	Warning	<Minor	Minor	<Minor
Nov-2010	Peak (m)	2.53	2.18	2.64
	Warning	<Minor	Minor	<Minor
Dec-2010	Peak (m)	3.15	2.89	2.78
	Warning	Minor	Moderate	<Minor
	AEP (%)		>25%	
Jan-2011	Peak (m)	-	-	-
	Warning	<Minor	<Minor	<Minor
Feb-2011	Peak (m)	1.34	1.72	2.83
	Warning	<Minor	<Minor	<Minor
Historic Record	Peak (m)	4.56	4.04	5.97
	Date	Sep-1998	Sep-1998	Aug-1955
	Start Of Record	1934	1925	1934
	New Record Set	No	No	No
	New Record Date	-	-	-
	Peak (m)	-	-	-
	Increase (m)	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 5-3 Upper Murray River Bureau of Meteorology flood warning gauge summary

River Basin		Tallangatta	Murray	Murray	Murray
Location		McCallums	Bringenbrong	Biggara	Jingellic
Flood Class Level	Minor	1.60	3.00	2.00	4.00
	Moderate	2.00	3.40	2.60	5.50
	Major	2.30	-	3.00	7.00
Sep-2010	Peak (m)	2.12	3.53	3.38	7.03
	Warning	Moderate	Moderate	Major	Major
	AEP (%)	20-10%	5-2%		~6%
Oct-2010	Peak (m)	2.68	3.45	3.17	7.63
	Warning	Major	Moderate	Major	Major
	AEP (%)	5-2%	10-5%		~3%
Nov-2010	Peak (m)	1.46	3.41	2.02	4.22
	Warning	<Minor	Moderate	Minor	Minor
	AEP (%)		~10%		
Dec-2010	Peak (m)	1.89	3.45	2.93	5.73
	Warning	Minor	Moderate	Moderate	Moderate
	AEP (%)		10-5%		25-20%
Jan-2011	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Feb-2011	Peak (m)	1.56	3.40	1.66	3.71
	Warning	<Minor	Minor	<Minor	<Minor
Historic Record	Peak (m)	2.86	-	3.01	7.62
	Date	Oct-1992	-	Sep-1998	Oct-1974
	Start Of Record	1976	-	1968	1890
	New Record Set	No	-	Yes	Yes
	New Record Date	-	-	Sep-2010	Oct-2010
	Peak (m)	-	-	3.38	7.63
	Increase (m)	-	-	0.37	0.01

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 5-4 Kiewa River Bureau of Meteorology flood warning gauge summary

River Basin		Kiewa	Kiewa	Kiewa
Location		Mongan's Bridge	Kiewa	Bandiana
Flood Class Level	Minor	2.40	3.30	2.70
	Moderate	3.50	3.70	3.10
	Major	4.50	4.00	3.30
Sep-2010	Peak (m)	5.23	3.62	3.28
	Warning	Major	Minor	Moderate
	AEP (%)	5-2%		20-10%
Oct-2010	Peak (m)	2.54	3.37	2.99
	Warning	Minor	Minor	Minor
Nov-2010	Peak (m)	2.82	3.33	2.99
	Warning	Minor	Minor	Minor
Dec-2010	Peak (m)	4.64	3.62	3.32
	Warning	Major	Minor	Major
	AEP (%)	10-5%		~10%
Jan-2011	Peak (m)	-	-	2.72
	Warning	<Minor	<Minor	Minor
Feb-2011	Peak (m)	2.28	3.37	3.15
	Warning	<Minor	Minor	Moderate
	AEP (%)			~20%
Historic Record	Peak (m)	6.69	3.76	3.58
	Date	Sep-1998	Sep-1998	Sep-1998
	Start Of Record	1955	1937	1965
	New Record Set	No	No	No
	New Record Date	-	-	-
	Peak (m)	-	-	-
	Increase (m)	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 5-5 Fifteen Mile Creek and King River Bureau of Meteorology flood warning gauge summary

River Basin		Fifteen Mile	King	King
Location		Greta South	Cheshunt	Docker Road
Flood Class Level	Minor	3.20	1.80	3.70
	Moderate	5.00	2.30	3.95
	Major	6.00	2.60	4.30
Sep-2010	Peak (m)	6.08	2.79	4.30
	Warning	Major	Major	Moderate
	AEP (%)	~4%	10-4%	~10%
Oct-2010	Peak (m)	1.96	1.16	3.85
	Warning	<Minor	<Minor	Minor
Nov-2010	Peak (m)	2.54	1.53	3.79
	Warning	<Minor	<Minor	Minor
Dec-2010	Peak (m)	5.88	2.79	4.51
	Warning	Moderate	Major	Major
	AEP (%)	~5%	10-4%	4-2%
Jan-2011	Peak (m)	3.74	2.15	4.03
	Warning	Minor	Minor	Moderate
Feb-2011	Peak (m)	2.51	1.89	3.95
	Warning	<Minor	Minor	Minor
Historic Record	Peak (m)	8.54	3.50	4.76
	Date	Oct-1993	Sep-1998	Oct-1993
	Start Of Record	1958	1967	1966
	New Record Set	No	No	No
	New Record Date	-	-	-
	Peak (m)	-	-	-
	Increase (m)	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 5-6 Ovens River Bureau of Meteorology flood warning gauge summary

River Basin		Ovens	Buckland	Ovens	Buffalo	Ovens	Ovens
Location		Bright	Harris Lane	Eurobin	Lake Buffalo	Rocky Point	Wangaratta
Flood Class Level	Minor	3.00	2.80	4.50	3.00	3.20	11.90
	Moderate	3.60	3.50	5.00	4.00	4.40	12.40
	Major	4.30	4.20	5.50	5.00	5.20	12.70
Sep-2010	Peak (m)	5.00	4.15	7.06	7.68	5.73	12.81
	Warning	Major	Moderate	Major	Major	Major	Major
	AEP (%)	~4%	2-1%		~4%		>10%
Oct-2010	Peak (m)	2.17	2.25	3.50	2.50	2.81	11.77
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	2.08	2.53	3.74	2.25	2.52	11.25
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Dec-2010	Peak (m)	3.26	3.75	5.82	5.98	4.79	12.76
	Warning	Minor	Moderate	Major	Major	Moderate	Major
	AEP (%)		4-2%		~20%		>10%
Jan-2011	Peak (m)	1.86	2.47	3.78	2.82	2.61	11.94
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	Minor
Feb-2011	Peak (m)	2.03	2.13	3.40	3.75	2.96	12.03
	Warning	<Minor	<Minor	<Minor	Minor	<Minor	Minor
Historic Record	Peak (m)	6.14	3.89	4.87	8.65	6.18	12.98
	Date	Oct-1993	Oct-1993	Oct-2000	Oct-1993	Oct-1993	Oct-1993
	Start Of Record	1972	1972	2000	1967	1965	1891
	New Record Set	No	Yes	Yes	No	No	No
	New Record Date	-	Sep-2010	Sep-2010	-	-	-
	Peak (m)	-	4.15	7.06	-	-	-
	Increase (m)	-	0.26	0.26	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 5-7 Broken River Bureau of Meteorology flood warning gauge summary

River Basin		Holland	Broken	Broken	Broken
Location		Kelfeera	Benalla	Casey Weir	Orrvale
Flood Class Level	Minor	3.70	2.50	2.10	6.80
	Moderate	4.10	3.70	2.60	7.20
	Major	4.90	4.50	3.00	7.90
Sep-2010	Peak (m)	5.01	4.26	3.32	8.15
	Warning	Major	Moderate	Major	Major
	AEP (%)	~4%	10-8%	10-4%	
Oct-2010	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	2.87	2.17	1.15	5.25
	Warning	<Minor	<Minor	<Minor	<Minor
Dec-2010	Peak (m)	4.76	3.87	2.73	7.92
	Warning	Moderate	Moderate	Moderate	Major
	AEP (%)	10-4%	20-10%	15-10%	
Jan-2011	Peak (m)	3.99	-	-	-
	Warning	Minor	<Minor	<Minor	<Minor
Feb-2011	Peak (m)	3.43	2.24	1.23	5.75
	Warning	<Minor	<Minor	<Minor	<Minor
Historic Record	Peak (m)	6.07	5.50	4.18	8.41
	Date	Oct-1993	Oct-1993	Oct-1993	Oct-1993
	Start Of Record	1960	1978	1888	1977
	New Record Set	No	No	No	No
	New Record Date	-	-	-	-
	Peak (m)	-	-	-	-
	Increase (m)	-	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 5-8 Seven and Castle Creeks Bureau of Meteorology flood warning gauge summary

River Basin		Seven	Seven	Seven	Castle	Seven
Location		Strathbogie	Galls Gap	Euroa	Telfords Bridge	Kialla West
Flood Class Level	Minor	1.50	2.20	2.50	1.20	4.50
	Moderate	2.20	3.00	4.00	1.80	5.00
	Major	3.00	4.00	4.60	2.40	6.60
Sep-2010	Peak (m)	3.37	4.84	5.36	2.58	6.65
	Warning	Major	Major	Major	Major	Major
	AEP (%)			~10%		20-10%
Oct-2010	Peak (m)	1.60	1.38	2.40	1.01	3.50
	Warning	Minor	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	2.11	2.01	3.27	1.74	4.23
	Warning	Minor	<Minor	Minor	Minor	<Minor
Dec-2010	Peak (m)	2.87	3.62	4.80	2.75	6.55
	Warning	Moderate	Moderate	Major	Major	Moderate
	AEP (%)					~20%
Jan-2011	Peak (m)	2.38	2.37	3.50	1.86	4.35
	Warning	Moderate	Minor	Minor	Moderate	<Minor
	AEP (%)					
Feb-2011	Peak (m)	1.83	1.47	2.21	0.72	4.49
	Warning	Minor	<Minor	<Minor	<Minor	<Minor
Historic Record	Peak (m)	-	-	6.05	-	-
	Date	-	-	Jun-1968	-	-
	Start Of Record	-	-	1963	-	-
	New Record Set	-	-	No	-	-
	New Record Date	-	-	-	-	-
	Peak (m)	-	-	-	-	-
	Increase (m)	-	-	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 5-9 Goulburn River (to Trawool) Bureau of Meteorology flood warning gauge summary

River Basin		Goulburn	Delatite	Acheron	Yea	Yea	Goulburn
Location		Doherty's	Tonga Bridge	Taggerty	Devlin's Bridge	Yea	Trawool
Flood Class Level	Minor	2.00	3.00	2.00	1.80	3.00	4.00
	Moderate	3.50	4.00	2.60	2.30	3.90	5.65
	Major	6.00	5.00	3.00	2.80	4.90	7.50
Sep-2010	Peak (m)	5.33	4.48	3.21	2.98	-	5.60
	Warning	Moderate	Moderate	Major	Major	-	Minor
	AEP (%)			<1%	~20%		~25%
Oct-2010	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	1.37	3.74	2.27	1.73	-	3.83
	Warning	<Minor	Minor	Minor	<Minor	-	<Minor
Dec-2010	Peak (m)	1.38	5.39	2.76	1.85	3.40	4.97
	Warning	<Minor	Major	Moderate	Minor	Minor	Minor
	AEP (%)			33-20%			
Jan-2011	Peak (m)	0.98	1.58	2.08	2.89	-	4.67
	Warning	<Minor	<Minor	Minor	Major	-	Minor
	AEP (%)				~20%		
Feb-2011	Peak (m)	1.00	2.83	1.89	1.12	-	2.32
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Historic Record	Peak (m)	4.66	5.71	3.13	4.32	-	9.08
	Date	Sep-1998	Sep-1975	Oct-1996	May-1974	-	Dec-1934
	Start Of Record	1954	1947	1945	1954	-	1925
	New Record Set	Yes	No	Yes	No	-	No
	New Record Date	Sep-2010	-	Sep-2010	-	-	-
	Peak (m)	5.33	-	3.21	-	-	-
	Increase (m)	0.67	-	0.08	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 5-10 Goulburn River (from Seymour) Bureau of Meteorology flood warning gauge summary

River Basin		Sunday	Goulburn	Hughes	Goulburn	Goulburn	Goulburn	Goulburn
Location		Tallarook	Seymour	Tarcombe Rd	Murchison	Arcadia Downs	Shepparton	McCoys Bridge
Flood Class Level	Minor	3.00	4.00	2.00	9.00	9.00	9.50	9.00
	Moderate	3.50	5.20	2.80	10.20	10.40	10.70	10.00
	Major	4.00	7.00	3.60	10.70	10.70	11.00	10.20
Sep-2010	Peak (m)	4.58	6.20	4.45	10.15	10.81	11.10	10.20
	Warning	Major	Moderate	Major	Minor	Major	Major	Moderate
	AEP (%)	~10%	20-10%	4-2%	~25%		~10%	~20%
Oct-2010	Peak (m)	-	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	4.68	5.90	2.34	9.43	9.76	9.63	8.76
	Warning	Major	Moderate	Minor	Minor	Minor	Minor	<Minor
	AEP (%)	10-4%	~20%					
Dec-2010	Peak (m)	4.34	5.33	3.12	9.82	10.58	10.81	10.12
	Warning	Major	Moderate	Moderate	Minor	Moderate	Moderate	Moderate
	AEP (%)	20-10%	33-25%	33-20%			~20%	>20%
Jan-2011	Peak (m)	3.78	6.08	2.74	9.91	10.19	9.83	8.58
	Warning	Moderate	Moderate	Minor	Minor	Minor	Minor	<Minor
	AEP (%)	50-20%	~20%					
Feb-2011	Peak (m)	4.31	4.00	1.79	7.28	9.09	9.20	7.85
	Warning	Major	<Minor	<Minor	<Minor	Minor	<Minor	<Minor
	AEP (%)	20-10%						
Historic Record	Peak (m)	5.25	7.64	4.44	12.22	10.70	12.25	11.71
	Date	May-1974	May-1974	Sep-1975	Sep-1916	Jul-1981	May-1974	Jun-1974
	Start Of Record	1945	1967	1958	1881	1977	1921	1965
	New Record Set	No	No	Yes	No	Yes	No	No
	New Record Date	-	-	Sep-2010	-	Sep-2010	-	-
	Peak (m)	-	-	4.45	-	10.81	-	-
	Increase (m)	-	-	0.01	-	0.11	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 5-11 Mitta Mitta River instantaneous flow and level gauge summary

River Basin		Victoria	Gibbo	Mitta Mitta	Mitta Mitta	Mitta Mitta	Mitta Mitta	Mitta Mitta
Gauge Number		401226	401217	401203	401202	401222	401223	401204
Gauge Location		Victoria Falls	Gibbo Park	Hinnomunjie	Mitta Mitta	Bowlers Lane	Eskdale Bridge	Tallandoon
September 2010	Date/Time of Peak	5/09/2010 7:30 AM	5/09/2010 11:00 AM	5/09/2010 5:00 AM	5/09/2010 8:49 AM	5/09/2010 10:30 AM	5/09/2010 2:05 PM	5/09/2010 4:00 PM
	Time Diff. (hrs)				4	2	4	2
	Peak Level (m)	2.34	3.07	541.91	264.93	248.67	236.00	4.11
	Peak Flow (m3/s)	11	111	347	115	0	0	170
December 2010	Date/Time of Peak	9/12/2010 1:30 PM	9/12/2010 4:45 AM	9/12/2010 12:30 AM	9/12/2010 1:38 AM	9/12/2010 3:00 AM	9/12/2010 4:45 AM	9/12/2010 7:45 AM
	Time Diff. (hrs)				1	1	2	3
	Peak Level (m)	1.96	1.53	541.27	263.76	247.69	235.18	2.78
	Peak Flow (m3/s)	8	21	217	13	0	0	79

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

Table 5-12 Kiewa River instantaneous flow and level gauge summary

River Basin		Kiewa West Branch	Kiewa	Kiewa	Kiewa	Kiewa
Gauge Number		402223	402203	402222	402220	402205
Gauge Location		U/S of Offtake	Mongans Bridge	Kiewa (main stream)	Kiewa (anabranch)	Bandiana
September 2010	Date/Time of Peak	4/09/2010 10:52 PM	5/09/2010 5:30 AM	5/09/2010 8:15 PM	5/09/2010 7:00 PM	6/09/2010 3:15 AM
	Time Diff. (hrs)		7	15		7
	Peak Level (m)	2.33	262.05	173.83	173.36	156.51
	Peak Flow (m3/s)	142	297	86	278	365
December 2010	Date/Time of Peak	8/12/2010 7:15 PM	9/12/2010 2:45 AM	9/12/2010 4:15 PM	9/12/2010 4:15 PM	10/12/2010 5:45 AM
	Time Diff. (hrs)		8	14		14
	Peak Level (m)	1.59	261.47	173.84	173.41	156.56
	Peak Flow (m3/s)	51	241	88	304	408
February 2011	Date/Time of Peak	19/02/2011 1:00 PM	11/02/2011 8:00 PM	12/02/2011 9:45 PM	13/02/2011 1:00 AM	5/02/2011 9:45 PM
	Time Diff. (hrs)		-185	26		-168
	Peak Level (m)	1.52	259.92	173.60	172.77	156.38
	Peak Flow (m3/s)	46	116	64	87	243

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to multiple storms in the month with the spatial and temporal distribution of rainfall influencing time of peak level.*

[5]*Murray River flow influences Bandiana gauge due to tail water effect.*

Table 5-13 King River instantaneous flow and level gauge summary

River Basin		King	King	King	King
Gauge Number		403228	403227	403240	403223
Gauge Location		Lake William Hovell	Cheshunt	Edi	Docker Road Bridge
September 2010	Date/Time of Peak	4/09/2010 11:00 PM	4/09/2010 11:44 PM	5/09/2010 1:44 AM	5/09/2010 4:30 AM
	Time Diff. (hrs)		1	2	3
	Peak Level (m)	374.00	295.12	191.49	159.31
	Peak Flow (m3/s)	310	253	235	587
December 2010	Date/Time of Peak	8/12/2010 10:15 PM	8/12/2010 9:45 PM	8/12/2010 11:00 PM	8/12/2010 11:15 PM
	Time Diff. (hrs)		-1	1	0
	Peak Level (m)	373.86	295.04	191.82	159.50
	Peak Flow (m3/s)	272	232	367	972

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to storages attenuating upstream flows, with downstream tributary flows contributing to earlier downstream peaks.*

Table 5-14 Buckland and Buffalo Rivers instantaneous flow and level gauge summary

River Basin		Buckland	Buckland	Rose	Dandongadale	Buffalo	Buffalo	Buffalo
Gauge Number		403253	403233	403217	403218	403222	403254	403220
Gauge Location		Twelve Mile	Harris Lane	Matong North	Matong North	Abbeyard	D/S Rose River Junction	Lake Buffalo
September 2010	Date/Time of Peak	5/09/2010 4:15 AM	5/09/2010 6:30 AM	5/09/2010 3:45 AM	4/09/2010 7:30 PM	4/09/2010 8:00 PM	5/09/2010 12:10 AM	5/09/2010 7:15 AM
	Time Diff. (hrs)		2				4	7
	Peak Level (m)	3.39	284.22	3.23	4.73	341.81	273.47	245.14
	Peak Flow (m3/s)	0	195	163	5	166	146	472
December 2010	Date/Time of Peak	9/12/2010 8:15 AM	9/12/2010 7:30 AM	8/12/2010 4:45 PM	8/12/2010 10:00 PM	9/12/2010 3:45 AM	9/12/2010 12:20 AM	9/12/2010 7:00 AM
	Time Diff. (hrs)		-1				-3	7
	Peak Level (m)	2.91	283.79	2.46	4.10	340.72	271.97	243.44
	Peak Flow (m3/s)	0	151	89	5	96	146	281

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to storages attenuating upstream flows, with downstream tributary flows contributing to earlier downstream peaks.*

Table 5-15 Ovens River instantaneous flow and level gauge summary

River Basin		Ovens	Ovens	Ovens	Ovens	Ovens	Ovens
Gauge Number		403205	403250	403210	403230	403200	403241
Gauge Location		Bright	Eurobin	Myrtleford	Rocky Point	Wangaratta	Peechelba
September 2010	Date/Time of Peak	4/09/2010 9:45 PM	5/09/2010 10:30 AM	5/09/2010 6:15 PM	5/09/2010 5:45 PM	6/09/2010 1:15 PM	7/09/2010 12:00 AM
	Time Diff. (hrs)		13	8	0	20	11
	Peak Level (m)	293.87	6.83	208.87	196.27	143.23	131.65
	Peak Flow (m3/s)	84	0	173	1149	543	1242
December 2010	Date/Time of Peak	9/12/2010 1:00 AM	9/12/2010 8:15 AM	9/12/2010 3:45 PM	9/12/2010 3:00 PM	10/12/2010 9:45 AM	10/12/2010 9:45 PM
	Time Diff. (hrs)		7	8	-1	19	12
	Peak Level (m)	293.46	5.73	208.34	195.33	143.19	131.53
	Peak Flow (m3/s)	64	0	163	642	498	1113

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Negative travel time between Myrtleford and Rocky Point due to impact of Buffalo River inflow on peak of hydrograph downstream of Myrtleford.*

Table 5-16 Broken River instantaneous flow and level gauge summary

River Basin		Broken	Broken	Broken	Broken	Broken	Broken	Broken
Gauge Number		404218	404243	404206	404226	404216	404224	404222
Gauge Location		Lake Nillahcootie (head gauge)	D/S Back Creek Junction	Moorngag	Lake Mokoan Diversion Weir	Goorambat	Gowangardie	Orrvale
September 2010	Date/Time of Peak	4/09/2010 10:45 PM	4/09/2010 9:45 PM	4/09/2010 11:30 PM	5/09/2010 4:30 AM	5/09/2010 6:45 PM	6/09/2010 3:30 PM	7/09/2010 9:15 PM
	Time Diff. (hrs)		-1	2	5	14	21	30
	Peak Level (m)	266.08	4.77	217.71	178.00	160.23	6.39	116.53
	Peak Flow (m3/s)	273	222	283	157	710	591	316
December 2010	Date/Time of Peak	8/12/2010 11:30 PM	8/12/2010 10:30 PM	9/12/2010 12:15 AM	9/12/2010 7:30 AM	9/12/2010 6:45 PM	11/12/2010 3:30 AM	11/12/2010 9:00 PM
	Time Diff. (hrs)		-1	2	7	11	33	17
	Peak Level (m)	265.85	4.25	216.96	177.79	159.64	5.64	116.22
	Peak Flow (m3/s)	215	228	202	159	453	330	245

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to storages attenuating upstream flows, with downstream tributary flows contributing to earlier downstream peaks.*

Table 5-17 Goulburn River instantaneous flow and level gauge summary

River Basin		Goulburn	Goulburn	Goulburn	Goulburn	Goulburn	Goulburn	Goulburn	Goulburn	Goulburn	Goulburn
Gauge Number		405263	405219	405203	405310	405201	405202	405200	405204	405276	405232
Gauge Location		U/S of Snake Creek Junction	Dohertys	Eildon	Ghin Ghin	Trawool	Seymour	Murchison	Shepparton	Loch Garry	McCoy Bridge
September 2010	Date/Time of Peak	5/09/2010 12:30 PM	5/09/2010 12:30 PM	4/09/2010 3:15 PM	6/09/2010 6:00 AM	6/09/2010 9:30 PM	5/09/2010 3:00 AM	7/09/2010 3:45 AM	8/09/2010 8:30 AM	9/09/2010 4:15 AM	10/09/2010 9:45 AM
	Time Diff. (hrs)		0			16	-43	49	29	20	29
	Peak Level (m)	4.92	303.55	206.54	6.89	144.53	136.45	118.82	111.21	107.04	101.67
	Peak Flow (m3/s)	199	247	6	0	470	680	581	1076	661	730
December 2010	Date/Time of Peak	10/12/2010 7:46 AM	9/12/2010 6:45 AM	31/12/2010 2:45 PM	10/12/2010 3:45 AM	10/12/2010 6:45 PM	9/12/2010 5:00 AM	10/12/2010 10:30 PM	12/12/2010 10:45 AM	13/12/2010 3:45 AM	14/12/2010 4:00 AM
	Time Diff. (hrs)		-25			15	-38	41	36	17	24
	Peak Level (m)	1.41	299.84	207.02	6.53	143.89	135.57	118.49	110.93	107.00	101.54
	Peak Flow (m3/s)	13	42	24	0	366	487	470	852	641	653
January 2011	Date/Time of Peak	14/01/2011 9:46 PM	15/01/2011 2:00 AM	31/01/2011 2:45 PM	15/01/2011 6:15 AM	15/01/2011 3:00 PM	14/01/2011 10:30 PM	16/01/2011 3:15 PM	19/01/2011 6:45 AM	21/01/2011 3:00 AM	22/01/2011 8:15 PM
	Time Diff. (hrs)		4			9	-17	41	64	44	41
	Peak Level (m)	1.07	299.41	207.80	5.68	143.60	136.32	118.60	109.95	105.95	100.05
	Peak Flow (m3/s)	5	19	74	0	329	644	530	376	325	275

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to spatial and temporal variability in rainfall impacting on tributary flows.*

Table 5-18 Goulburn River tributaries instantaneous flow and level gauge summary

River Basin		Delatite	Jamieson	Big	Big	Rubicon	Acheron	Murrindindi	Yea
Gauge Number		405214	405218	405264	405227	405241	405209	405205	405217
Gauge Location		Tonga Bridge	Gerrang Bridge	D/S of Frenchman Creek Junction	Jamieson	Rubicon	Taggerty	Murrundindi above Colwellls	Devlins Bridge
September 2010	Date/Time of Peak	4/09/2010 6:45 PM	5/09/2010 3:15 AM	5/09/2010 6:00 AM	5/09/2010 3:45 AM	4/09/2010 4:00 PM	5/09/2010 1:00 AM	5/09/2010 7:00 AM	4/09/2010 3:45 PM
	Time Diff. (hrs)				-2				
	Peak Level (m)	4.48	4.76	2.44	4.11	1.81	3.24	0.96	2.97
	Peak Flow (m3/s)	184	194	97	324	100	294	9	126
November 2010	Date/Time of Peak	28/11/2010 9:15 AM	28/11/2010 2:15 PM	28/11/2010 12:00 PM	28/11/2010 2:00 PM	28/11/2010 6:00 AM	1/11/2010 12:00 AM	1/11/2010 12:00 AM	28/11/2010 1:30 PM
	Time Diff. (hrs)				2				
	Peak Level (m)	3.75	2.56	1.23	1.44	1.12	2.31	0.80	1.72
	Peak Flow (m3/s)	125	51	21	37	22	57	7	60
December 2010	Date/Time of Peak	8/12/2010 8:00 PM	9/12/2010 12:15 AM	8/12/2010 11:00 PM	9/12/2010 4:00 AM	8/12/2010 7:00 PM	8/12/2010 5:00 PM	20/12/2010 5:30 PM	9/12/2010 5:45 AM
	Time Diff. (hrs)				5				
	Peak Level (m)	5.40	4.01	1.24	1.63	1.05	2.78	0.76	1.84
	Peak Flow (m3/s)	359	139	22	50	18	96	7	67
January 2011	Date/Time of Peak	13/01/2011 3:15 PM	15/01/2011 1:15 AM	14/01/2011 8:00 PM	15/01/2011 12:45 AM	14/01/2011 4:30 PM	14/01/2011 8:45 PM	15/01/2011 12:15 AM	14/01/2011 3:15 PM
	Time Diff. (hrs)				5				
	Peak Level (m)	1.59	1.92	1.53	2.07	1.32	2.08	0.91	2.91
	Peak Flow (m3/s)	25	16	37	81	35	46	9	122

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

5.5 Summary

Due to the geographical extent and topographical variation across the North East catchments the spatial distribution of rainfall and the site specific AEPs vary significantly between rainfall stations within the region. The September 2010 rainfall event recorded around 5% AEP at Benalla across the 24 to 72 hour durations and 20 to 10% AEP at Nariel Creek for the 48 to 72 hour durations, with other locations recording significantly higher AEPs. The October 2010 rainfall event recorded between 5 to 2% AEP at Nariel Creek for the 48 and 72 hour durations, with significantly higher AEPs elsewhere in the region. The December 2010 rainfall event recorded between 2 to 1% AEP at Benalla for the 48 and 72 hour durations, 20% AEP at Yarroweyah for the 48 hour duration and higher AEPs in other areas of the region.

During September 2010 the Upper Murray, Mitta Mitta and Kiewa rivers recorded between 10 to 2% AEP events, the King and Ovens around 10 to 4% AEP (2 to 1% AEP on the Buckland River), the Broken Creek between 10 to 4% AEP, and the Goulburn between 20 to 10% AEP. During October 2010 the Upper Murray and Tallangatta Rivers recorded between 10 to 2% AEP. The Broken River recorded between 10 to 4% AEP for December 2010.

6. SOUTH WEST REGION HYDROLOGICAL ANALYSIS

6.1 Overview of Flooding

August 2010 – Widespread rainfall, with the highest totals recorded around Cape Otway. Some recorded road closures and minor inundation around Port Fairy, Warrnambool and the Otway Coast. The Leigh and Barwon rivers recorded 'Moderate' flood levels.

September 2010 – Large rainfall totals were again recorded around Cape Otway and in the north east of the region. Flooding occurred at Invermay, Miners Rest, Beaufort and Skipton.

October 2010 – Large rainfall totals were recorded along the south coast from Cape Otway to Geelong and in the north east of the region.

November 2010 – No known flooding issues were recorded in the region.

December 2010 – Widespread rainfall with significant daily totals across the region. Flooding recorded around Chetwynd and Harrow.

January 2011 – Widespread heavy rainfall across the region. Flooding of many communities in most catchments.

February 2011 – No known flooding issues were recorded in the region.

6.2 Regional Description

The South West region includes the Glenelg, Hopkins, Barwon, Corangamite, Portland and Otway Coast catchments. Figure 6-1 below shows the major waterways in the region.

The Glenelg River flows from Rocklands Reservoir in the Grampians in a generally southerly direction through Balmoral, Harrow, Dergholm and Casterton, before meeting with its major tributary, the Wannon River, near Henty. The river then flows on to Dartmoor and Nelson where it flows into the ocean.

The Hopkins River flows south from the Great Dividing Range near Ararat through Wickliffe, Chatsworth, Hexam, Ellerslie and Framlingham before meeting with its major tributary, Mount Emu Creek, which rises to the west of Ballarat. The river continues in a generally southerly direction through Allansford to flow into the Southern Ocean to the east of Warrnambool. The Merri River also flows through Warrnambool, entering the ocean only 3 to 4 km to the west of the Hopkins River mouth.

The Barwon River flows in a north easterly direction from the Otway Ranges near Forest past Birregurra, Winchelsea and Inverleigh where it meets with its major tributary, the Leigh River. It is joined by its second major tributary, the Moorabool River downstream of Pollocksford at Fyansford on the western edge of Geelong. The river then flows through the City of Geelong and into Hospital Swamp and Lake Connewarre before flowing into the ocean at Ocean Grove/Barwon Heads.

The upper Moorabool River has two arms, the Moorabool River West Branch and Moorabool River East Branch. The Moorabool River West Branch begins at the small Moorabool Reservoir. This branch flows south through the Lal Lal Reservoir before joining the East Branch north of Meredith. The East Branch flows south from State Forest east of Mount Egerton. The Moorabool River continues to flow south through the rural towns of She Oaks, Maude, Russells Bridge, and Batesford before flowing into the Barwon River at Fyansford on the western edge of Geelong.

Hovells Creek begins north of Anakie near the Brisbane Ranges National Park. From here Hovells Creek flows south through the You Yang's Regional Park and on to Lara where it runs through Lara and then Limeburners Lagoon and into Corio Bay.

The Corangamite catchment drains from north to south via Woady Yaloak Creek and a number of other small creeks. The Woady Yaloak Creek flows into the Cundare Pool and subsequently into Lake Corangamite. A flood diversion system, designed to take flood waters from Woady Yaloak Creek to the Barwon River upstream of Inverleigh via Warrambine Creek operates when Lake Corangamite levels rise above predetermined levels. The flood diversion system is further described on the Corangamite CMA website (http://www.ccma.vic.gov.au/What-we-do/Water/Drainage-Schemes.aspx).

The Portland and Otway Coast catchments drain numerous rivers and creeks into the ocean. Many of the waterways pass through coastal communities such as Narrawong, Codrington, Port Fairy, Peterborough, Princetown, Apollo Bay, Lorne and Anglesea.

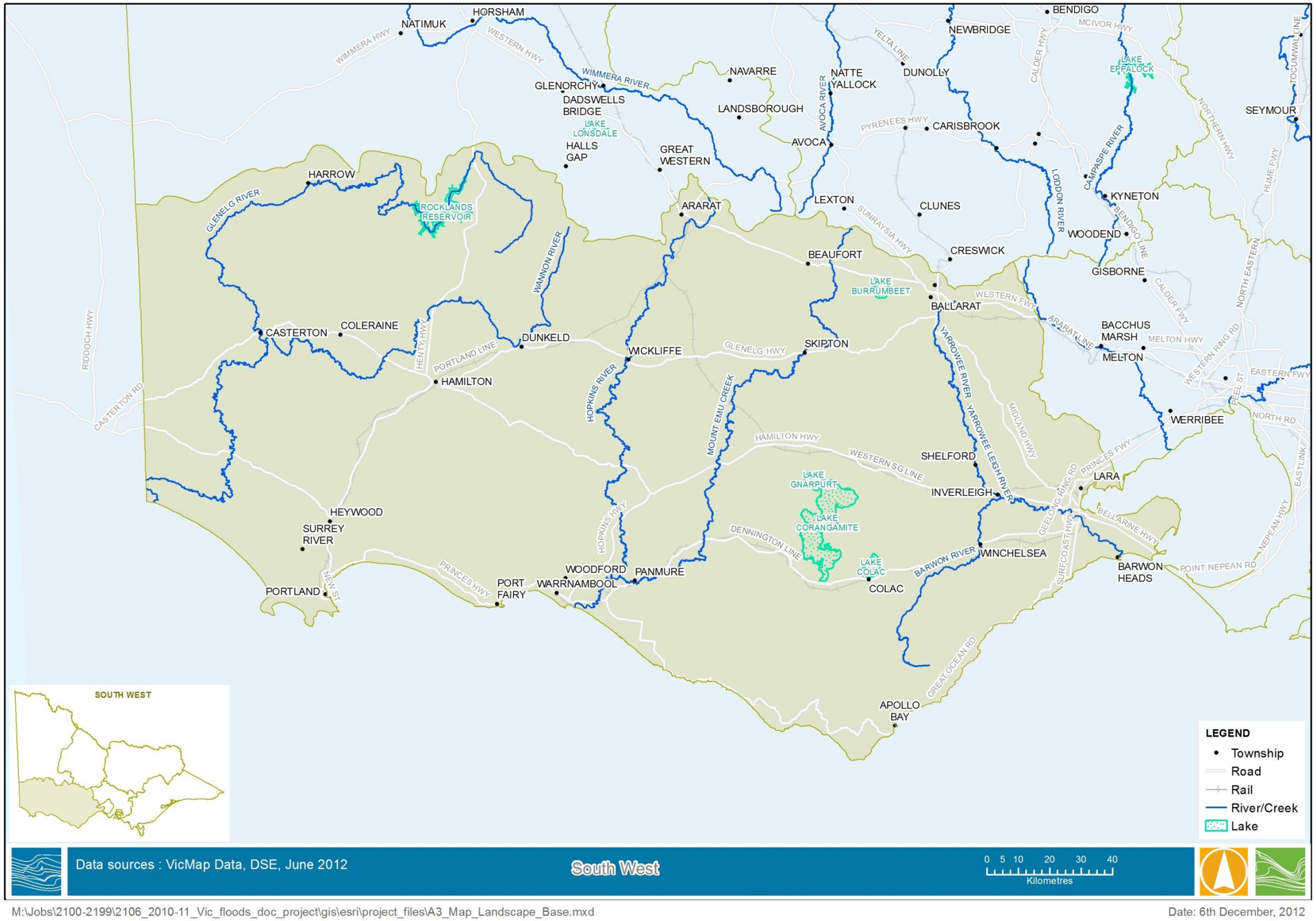


Figure 6-1 South West region

6.3 Rainfall

Section 2.1 provides a broad overview of the synoptic conditions that produced the rainfall events over the spring-summer 2010-11 period. This Section includes more detail about specific rainfall gauges within the South West region. It should be noted that daily rainfall gauges typically record rainfall totals over a 24 hour period to 9 am on the date recorded.

Table 6-1 below summarises the maximum daily rainfall and monthly totals for numerous rainfall gauges across the region and compares it against the historical monthly average over the spring-summer period as well as against the historical monthly and daily maximum rainfall totals. A high proportion of the gauges selected for analysis broke daily and monthly maximum rainfall records during the spring-summer 2010-11 period.

For a selected number of gauges an Intensity-Frequency-Duration (IFD) analysis was undertaken on the daily rainfall totals at 24, 48 and 72 hour durations. Using the geographical coordinates for the rainfall gauges analysed, the raw polynomial coefficients were taken from the Bureau of Meteorology's online IFD Data System[13], and used as input to an IFD spreadsheet tool developed by Water Technology, plotting the IFD curves for the rainfall gauge site. This was overlayed with the maximum 24, 48 and 72 hour rainfall totals for each month.

The gauges selected were chosen to provide a spread across the region with preference for gauges in proximity to areas of significant flooding. Note that the frequency attributed to the rainfall event does not necessarily correspond to the frequency of the flood event due to antecedent catchment conditions, timing of tributary flows etc. It must also be noted that the frequency of the event may differ when durations shorter than 24 hours are considered, however with daily rainfall gauges these shorter durations can not be assessed. Figure 6-3 to Figure 6-9 below show the IFD analysis undertaken.

Figure 6-2 below shows the location of the rainfall gauges analysed for both daily and monthly totals and also those gauges where IFD analysis was completed.

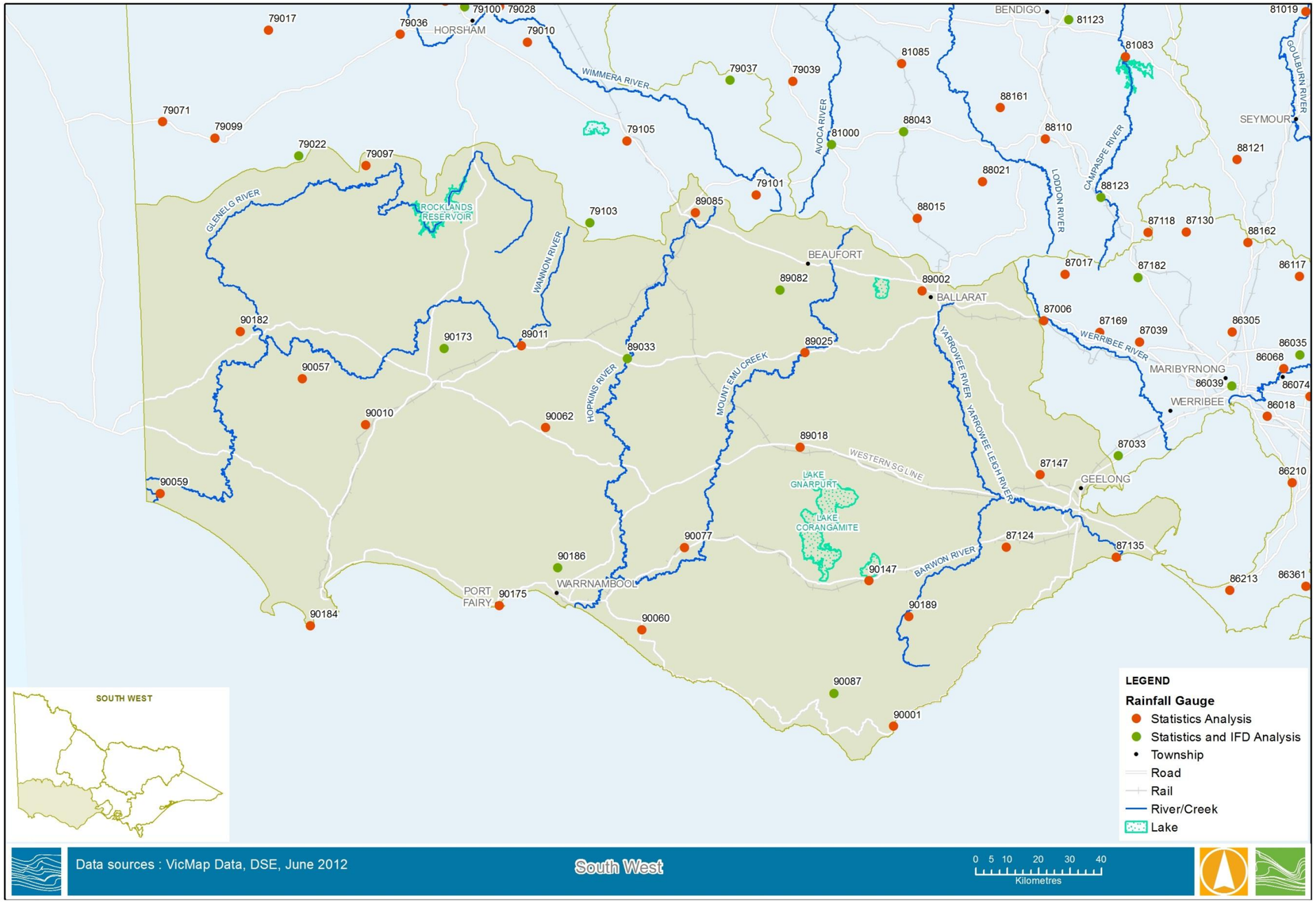
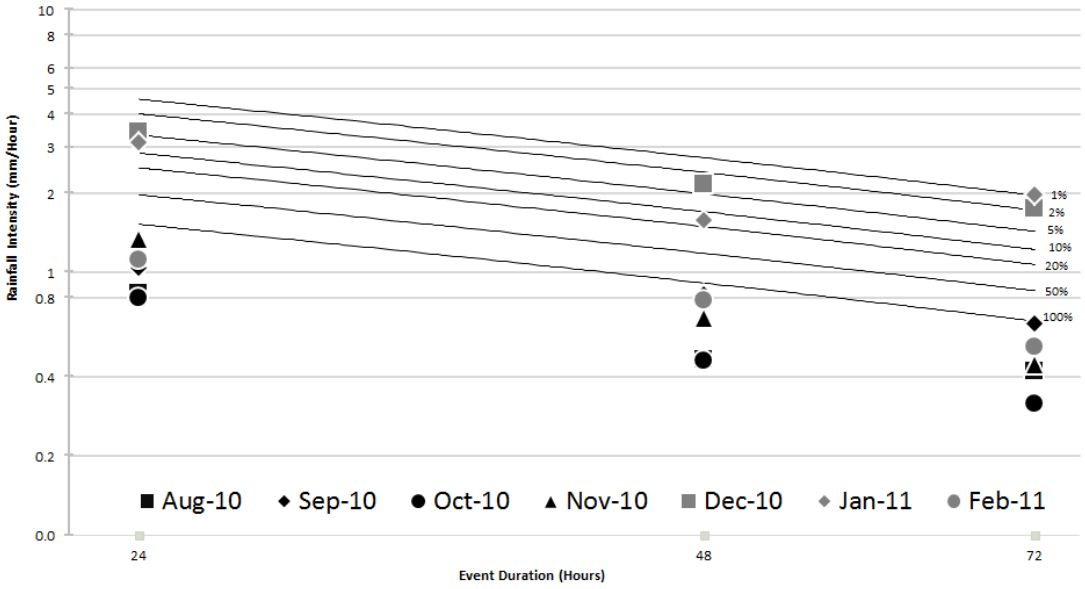


Figure 6-2 South West region rainfall gauges analysed

Table 6-1 South West region observed rainfall summary

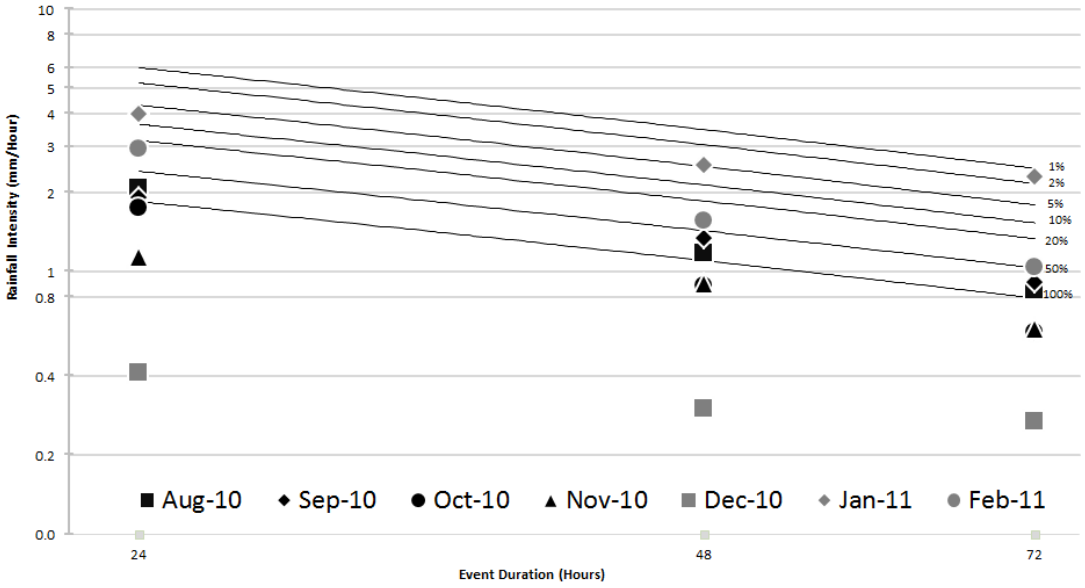
Location	Station Number	August 2010		September 2010		October 2010		November 2010		December 2010		January 2011		February 2011		Record Statistics			
		Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Avg.	Monthly Max.	Daily Max.	Start of record
Apollo Bay	90001	292.4	59.8 (11th)	113.6	15.0 (5th)	153.8	49.8 (31st)	79	23.0 (25th)	94.4	19.2 (12th)	159.8	58.0 (12th)	58.7	26.8 (19th)	50.5-126.2	378.4 (Mar 1932)	167.4 (30/11/1933)	1898
Ararat Prison	89085	152	32.0 (11th)	62.6	29.0 (4th)	91.2	34.2 (15th)	88.3	29.6 (25th)	105.5	38.5 (8th)	178	78.6 (14th)	75.2	30.2 (19th)	31.5-69.1	225.7 (Feb 1973)	98.6 (06/02/1973)	1969
Ballarat Aerodrome	89002	161	49.6 (12th)	107.8	46.0 (4th)	92.8	41.8 (31st)	100.6	27.2 (28th)	58.4	9.8 (8th)	206	95.0 (14th)	96.8	70.4 (5th)	39.6-75.1	240.3 (Feb 1973)	121.9 (06/02/1973)	1908
Bannockburn (Hillside)	87147	72.8	13.6 (12th)	59	25.2 (4th)	116.8	40.4 (31st)	103	29.8 (14th)	33	5.8 (9th)	121.2	40.2 (11th)	58	25.4 (5th)	33.7-64.5	225.8 (Feb 1973)	126.5 (06/02/1973)	1972
Barwon Downs (Gerangamete)	90189	156.6	30.6 (12th)	75.2	22.2 (5th)	72.6	22.0 (31st)	71	40.6 (25th)	38.2	8.4 (20th)	114	43.8 (14th)	43.2	30.0 (19th)	25.9-70.0	156.6 (Aug 2010)	67.4 (03/02/2005)	2001
Barwon Heads Golf Club	87135	97	20.8 (12th)	73.2	30.0 (4th)	116.4	22.0 (31st)	95.2	27.2 (25th)	54	16.6 (20th)	101.6	33.0 (14th)	82	42.0 (5th)	26.6-62.9	135.0 (Feb 2005)	93.2 (03/02/2005)	2001
Beaufort (Sheepwash	89082	142.2	33.2 (12th)	70.2	29.2 (4th)	104.2	39.8 (31st)	81.6	26.6 (25th)	114.8	38.0 (3rd)	164.8	78.6 (14th)	92.2	28.4 (11th)	32.4-67.6	218.1 (Feb 1973)	158.2 (06/02/1973)	1968
Branxholme (Bassett)	90010	138.8	43.4 (11th)	85.4	26.0 (4th)	61.4	17.8 (30th)	46.4	18.4 (26th)	81.8	28.6 (7th)	114.8	62.6 (12th)	44.2	31.0 (19th)	27.7-78.9	362.0 (Mar 1946)	173.5 (17/03/1946)	1883
Buckley (Balliwindi)	87124	107	22.2 (12th)	54.6	21.0 (4th)	118.8	33.0 (31st)	79.2	25.4 (25th)	22.8	4.0 (20th)	123.4	39.2 (14th)	50	25.2 (4th)	34.3-65.2	175.8 (Feb 1973)	101.1 (06/02/1973)	1968
Cape Nelson Lighthouse	90184	121	16.6 (25th)	75	17.4 (4th)	45.8	19.0 (30th)	34.4	9.2 (28th)	95.2	27.8 (19th)	145.2	73.8 (14th)	55.8	36.8 (19th)	24.9-101.0	210.6 (Aug 2001)	73.8 (14/01/2011)	1995
Casterton	90182	132.8	19.0 (11th)	65.6	16.0 (4th)	55.4	18.6 (30th)	49.8	13.8 (25th)	128.2	40.2 (6th)	141.6	78.6 (14th)	147	91.6 (9th)	37.9-82.6	147.0 (Feb 2011)	96.4 (20/01/2007)	2005
Colac (Shire Office)	90147	159	39.0 (12th)	67.2	13.0 (4th)[1]	90.8	19.2 (31st)[1]	77.4	41.2 (25th)	37.2	8.0 (8th)	152.8	57.1 (14th)[1]	47.4	31.7 (12th)[1]	34.9-87.8	204.8 (Oct 1975)	102.9 (06/02/1973)	1898
Dunkeld	89011	134.2	25.8 (11th)	57	13.6 (5th)	90.8	33.4 (15th)	65.8	21.8 (25th)	133	78.4 (8th)	171.8	89.4 (14th)	44.8	22.6 (19th)	36.6-79.0	251.4 (Mar 1946)	109.0 (07/02/1957)	1897
Hamilton Airport	90173	128.8	24.2 (11th)	59.6	15.2 (4th)	73.6	27.4 (15th)	49.6	19.6 (25th)	126	84.8 (8th)	124.6	60.8 (12th)	41.2	25.8 (19th)	24.8-78.7	147.8 (Dec 1985)	84.8 (08/12/2010)	1983
Harrow (Pine Hills)	79022	121.7	17.0 (1st)	69.1	24.8 (4th)	41.2	19.0 (15th)	60	32.0 (25th)	147.7	82.0 (8th)	156	75.0 (14th)	79.4	26.8 (19th)	24.7-70.5	183.8 (Jul 1964)	88.9 (25/01/1952)	1883
Lismore (Post Office)	89018	150.6	31.4 (11th)	54	10.8 (4th)	105.2	33.2 (31st)	84	41.2 (25th)	72.8	20.2 (7th)	145.8	58.6 (14th)	57.8	22.4 (19th)	35.3-68.3	175.2 (Dec 1966)	122.6 (08/02/2002)	1919
Merino	90057	159.2	38.0 (11th)	105.6	29.0 (4th)	59.4	16.0 (30th)	53.2	21.8 (25th)	176	67.0 (6th)	121.2	55.6 (12th)	59.2	33.8 (19th)	29.8-91.4	271.2 (Mar 1946)	124.2 (07/03/1910)	1886
Nelson	90059	168.6	25.8 (11th)	83	16.6 (5th)	65.6	22.0 (30th)	42.2	12.0 (27th)	97.8	27.8 (6th)	196.4	113.2 (14th)	74.8	45.2 (19th)	29.2-106.2	234.8 (Jun 1955)	113.2 (14/01/2011)	1884
Nullawarre	90060	207.6	45.4 (11th)	108.6	18.2 (10th)	91.2	30.2 (31st)	63.6	19.6 (25th)	147.4	70.2 (8th)	100.6	45.6 (12th)	47.8	27.0 (19th)	39.6-106.0	276.5 (Mar 1946)	117.9 (17/03/1946)	1899
Penshurst (The Gums)	90062	179.8	29.0 (11th)	69.8	14.0 (5th)	91	31.0 (31st)	69.4	27.8 (25th)	133.6	86.4 (8th)	105.8	46.4 (14th)	41.4	27.8 (19th)	33.2-78.2	275.4 (Mar 1946)	124.2 (17/03/1946)	1906
Port Fairy AWS	90175	163.6	55.8 (11th)	87.4	20.4 (4th)	66.6	20.4 (15th)	38.2	10.6 (28th)	105.2	43.0 (8th)	108.4	59.4 (12th)	40.2	28.0 (19th)	30.9-90.0	163.6 (Aug 2010)	70.8 (13/12/2008)	1990
Skipton Post Office	89025	133.4	32.4 (12th)	71.3	13.0 (10th)	111.2	39.8 (31st)	81.2	27.0 (25th)	70.8	17.8 (8th)	153	64.4 (14th)	71	23.0 (11th)	36.6-64.4	208.4 (Oct 1975)	109.2 (08/02/2002)	1897
Terang	90077	196.6	40.2 (12th)	116	15.0 (5th)	86.2	20.0 (31st)	66.2	24.0 (25th)	101	52.0 (8th)	122.8	52.0 (12th)	81	42.0 (17th)	37.9-92.7	310.1 (Mar 1946)	98.0 (18/03/1946)	1896
Warrnambool Airport Ndb	90186	178	35.6 (11th)	109.2	15.8 (10th)	80.8	21.0 (31st)	59.2	20.8 (25th)	113.4	61.4 (8th)	107.8	56.4 (12th)	51	33.6 (19th)	33.4-95.1	204.4 (Aug 2001)	74.6 (11/04/2011)	1998
Wickliffe	89033	155.2	31.6 (11th)	67.8	19.5 (10th)[1]	76.6	23.0 (15th)	93	18.0 (14th)	98.4	61.8 (8th)	119.4	53.4 (14th)[1]	50.4	31.8 (19th)	30.7-60.8	189.2 (Mar 1946)	109.5 (07/03/1910)	1879
Wyelangta	90087	544.6	104.0 (12th)	213.2	33.8 (5th)	206.6	76.0 (31st)	142.6	30.2 (25th)	174.6	51.2 (8th)	164.8	65.6 (14th)	105	26.8 (19th)	87.7-231.4	680.7 (Aug 1939)	202.2 (02/02/1990)	1936

[1] *Note: Gauge recordings were aggregated over a number of days. Daily totals were disaggregated using the daily rainfall pattern from the nearest gauge of complete record.*
[2] *Note: Records of data were incomplete for the month. The total and highest daily rainfall cannot be determined using incomplete data.*
[3] *Note: Gauge broke daily or monthly statistical records over the period.*
[4] *Note: Analysis carried out early May 2012, any events after that not captured in historical records columns.*



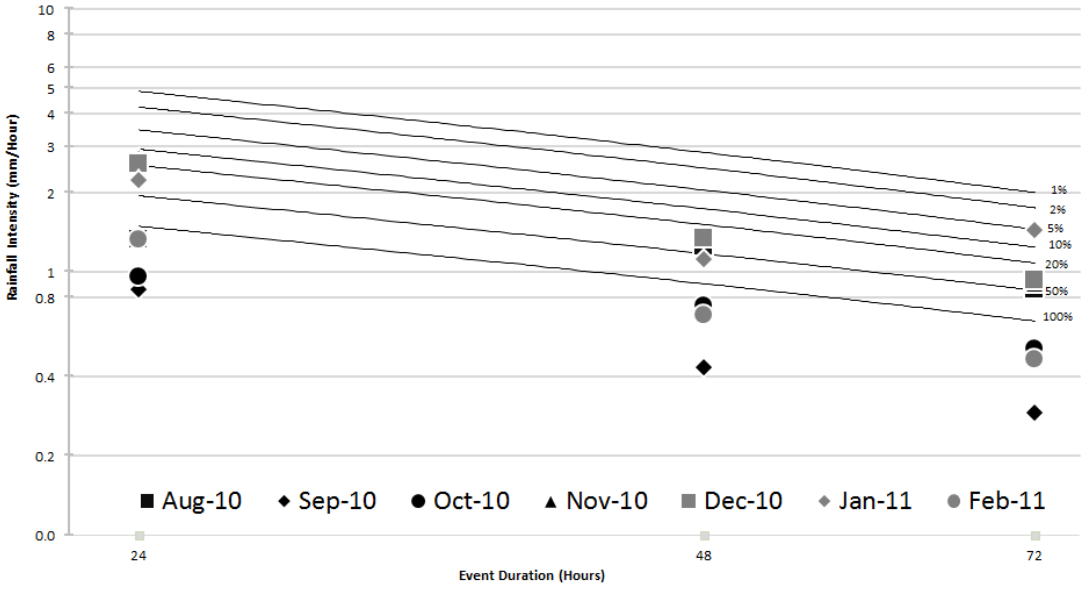
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	19.8	0.8	27/08/2010	>100%	22.2	0.5	2/08/2010	>100%	30.2	0.4	27/08/2010	>100%
Sep 10	24.8	1.0	4/09/2010	>100%	39.2	0.8	5/09/2010	>100%	45.6	0.6	6/09/2010	>100%
Oct 10	19.0	0.8	15/10/2010	>100%	22.0	0.5	16/10/2010	>100%	22.6	0.3	17/10/2010	>100%
Nov 10	32.0	1.3	25/11/2010	>100%	32.0	0.7	25/11/2010	>100%	32.0	0.4	25/11/2010	>100%
Dec 10	82.0	3.4	8/12/2010	5%-2%	103.4	2.2	8/12/2010	5%-2%	125.2	1.7	8/12/2010	2%-1%
Jan 11	75.0	3.1	14/01/2011	10%-5%	75.4	1.6	12/01/2011	10%-20%	142.2	2.0	14/01/2011	<1%
Feb 11	26.8	1.1	19/02/2011	>100%	37.2	0.8	19/02/2011	>100%	37.2	0.5	19/02/2011	>100%

Figure 6-3 079022 Harrow (Pine Hills) Rainfall Intensity-Frequency-Duration Analysis



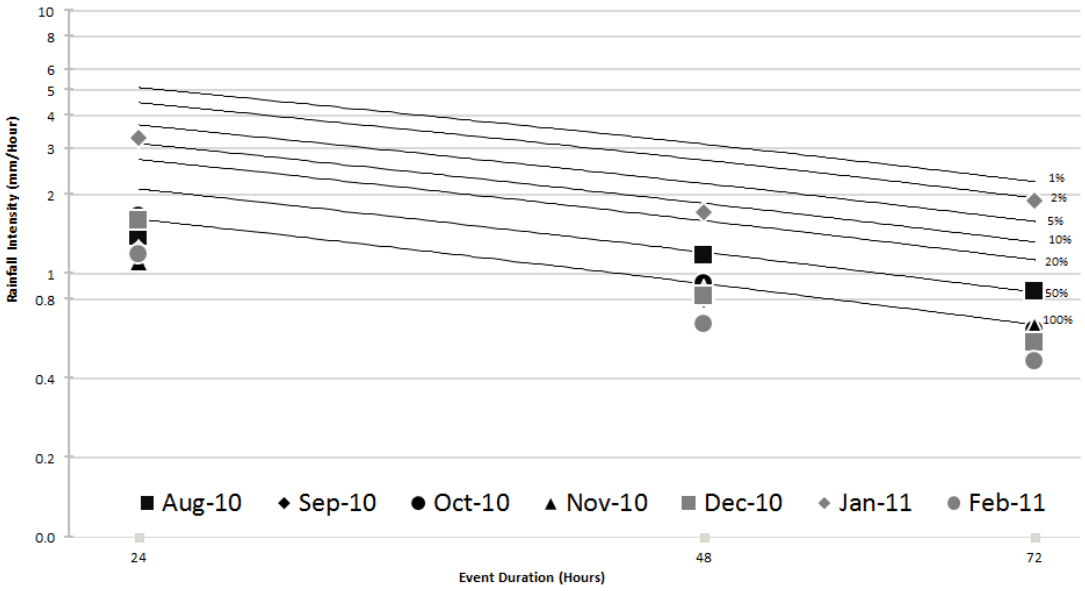
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	49.6	2.1	12/08/2010	100%-50%	56.0	1.2	12/08/2010	100%-50%	60.6	0.8	12/08/2010	100%-50%
Sep 10	46.0	1.9	4/09/2010	100%-50%	64.4	1.3	5/09/2010	100%-50%	65.4	0.9	6/09/2010	100%-50%
Oct 10	41.8	1.7	31/10/2010	>100%	42.2	0.9	31/10/2010	>100%	42.2	0.6	31/10/2010	>100%
Nov 10	27.2	1.1	28/11/2010	>100%	43.0	0.9	1/11/2010	>100%	43.6	0.6	2/11/2010	>100%
Dec 10	9.8	0.4	8/12/2010	>100%	14.4	0.3	21/12/2010	>100%	19.2	0.3	20/12/2010	>100%
Jan 11	95.0	4.0	14/01/2011	10%-5%	122.2	2.5	14/01/2011	5%-2%	164.8	2.3	14/01/2011	2%-1%
Feb 11	70.4	2.9	5/02/2011	50%-20%	74.8	1.6	5/02/2011	50%-20%	74.8	1.0	5/02/2011	50%-20%

Figure 6-4 089002 Ballarat Aerodrome Rainfall Intensity-Frequency-Duration Analysis



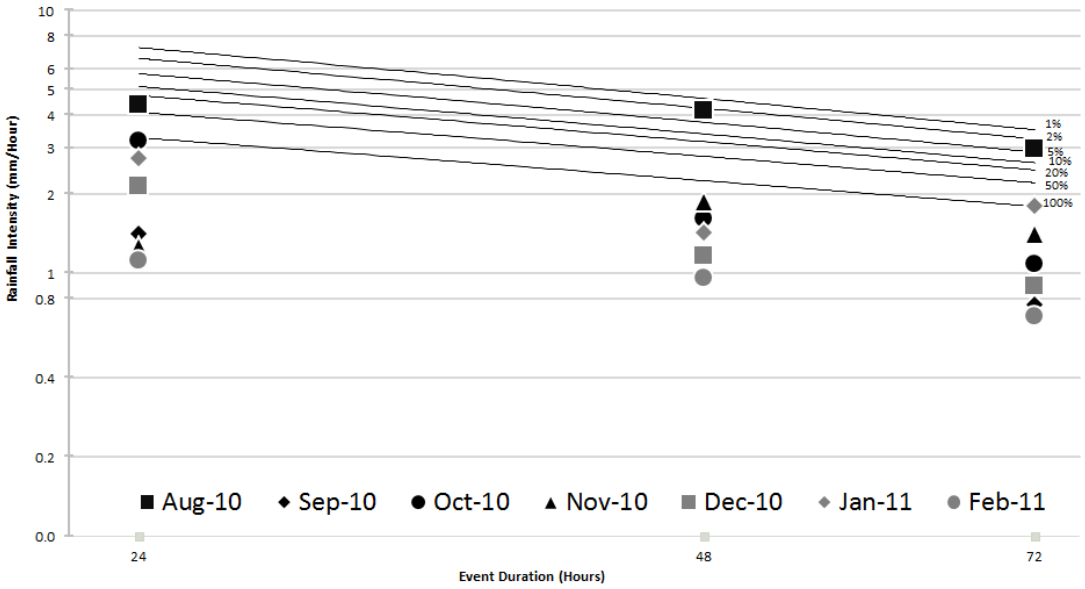
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	31.6	1.3	11/08/2010	>100%	59.6	1.2	12/08/2010	50%-20%	61.6	0.9	13/08/2010	50%-20%
Sep 10	20.4	0.9	10/09/2010	>100%	20.8	0.4	11/09/2010	>100%	20.8	0.3	10/09/2010	>100%
Oct 10	23.0	1.0	15/10/2010	>100%	35.4	0.7	16/10/2010	>100%	36.6	0.5	17/10/2010	>100%
Nov 10	65.0	2.7	29/11/2010	10%-20%	65.0	1.4	29/11/2010	50%-20%	65.0	0.9	29/11/2010	50%-20%
Dec 10	61.8	2.6	8/12/2010	10%-20%	64.2	1.3	8/12/2010	50%-20%	66.4	0.9	10/12/2010	50%-20%
Jan 11	53.4	2.2	14/01/2011	50%-20%	53.6	1.1	12/01/2011	100%-50%	103.4	1.4	14/01/2011	10%-5%
Feb 11	31.8	1.3	19/02/2011	>100%	32.6	0.7	19/02/2011	>100%	33.4	0.5	19/02/2011	>100%

Figure 6-5 089033 Wickliffe Rainfall Intensity-Frequency-Duration Analysis



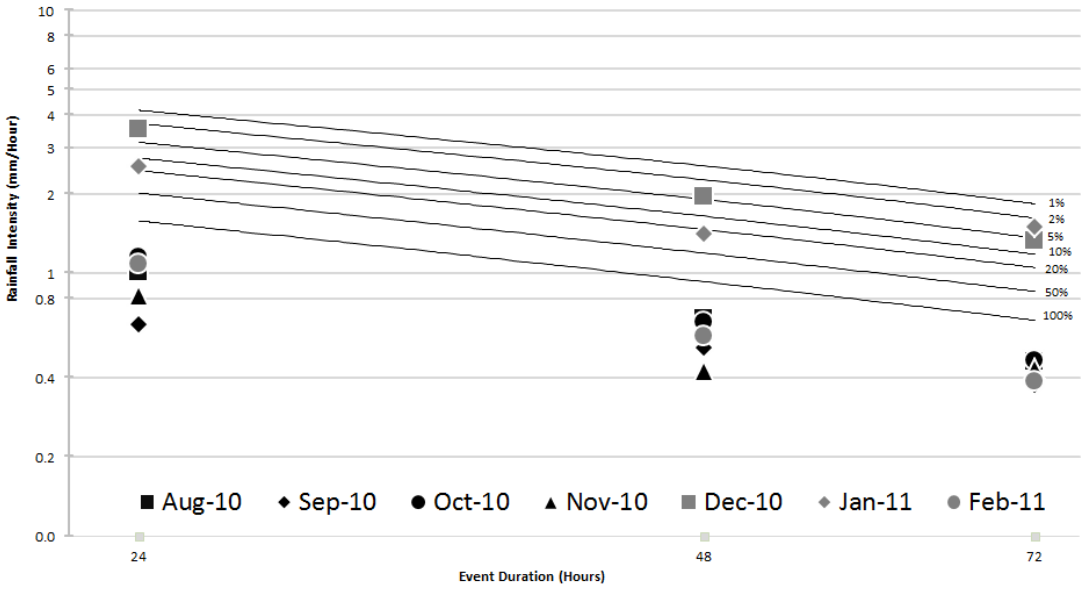
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	33.2	1.4	12/08/2010	>100%	56.2	1.2	12/08/2010	100%-50%	61.2	0.9	13/08/2010	100%-50%
Sep 10	29.2	1.2	4/09/2010	>100%	38.0	0.8	5/09/2010	>100%	38.0	0.5	5/09/2010	>100%
Oct 10	39.8	1.7	31/10/2010	100%-50%	44.0	0.9	31/10/2010	>100%	44.0	0.6	31/10/2010	>100%
Nov 10	26.6	1.1	25/11/2010	>100%	41.2	0.9	1/11/2010	>100%	45.4	0.6	1/11/2010	>100%
Dec 10	38.0	1.6	3/12/2010	>100%	39.2	0.8	4/12/2010	>100%	39.2	0.5	4/12/2010	>100%
Jan 11	78.6	3.3	14/01/2011	10%-5%	81.6	1.7	14/01/2011	10%-20%	136.2	1.9	14/01/2011	5%-2%
Feb 11	28.4	1.2	11/02/2011	>100%	30.8	0.6	5/02/2011	>100%	33.2	0.5	6/02/2011	>100%

Figure 6-6 089082 Beaufort (Sheepwash) Rainfall Intensity-Frequency-Duration Analysis



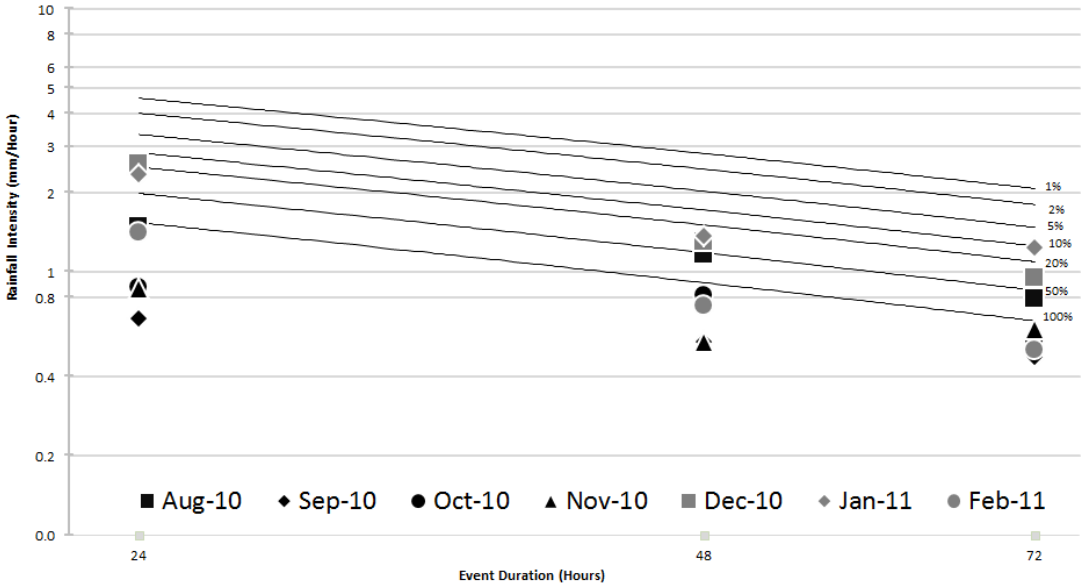
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	104.0	4.3	12/08/2010	50%-20%	198.2	4.1	12/08/2010	5%-2%	214.0	3.0	13/08/2010	5%-2%
Sep 10	33.8	1.4	5/09/2010	>100%	45.4	0.9	5/09/2010	>100%	54.2	0.8	6/09/2010	>100%
Oct 10	76.0	3.2	31/10/2010	>100%	77.4	1.6	31/10/2010	>100%	77.4	1.1	31/10/2010	>100%
Nov 10	30.2	1.3	25/11/2010	>100%	89.4	1.9	1/11/2010	>100%	101.2	1.4	2/11/2010	>100%
Dec 10	51.2	2.1	8/12/2010	>100%	55.8	1.2	9/12/2010	>100%	63.8	0.9	10/12/2010	>100%
Jan 11	65.6	2.7	14/01/2011	>100%	68.2	1.4	14/01/2011	>100%	129.2	1.8	14/01/2011	>100%
Feb 11	26.8	1.1	19/02/2011	>100%	45.8	1.0	20/02/2011	>100%	49.2	0.7	21/02/2011	>100%

Figure 6-7 090087 Wyelangta Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	24.2	1.0	11/08/2010	>100%	32.0	0.7	12/08/2010	>100%	33.0	0.5	13/08/2010	>100%
Sep 10	15.2	0.6	4/09/2010	>100%	24.8	0.5	5/09/2010	>100%	26.8	0.4	6/09/2010	>100%
Oct 10	27.4	1.1	15/10/2010	>100%	31.0	0.6	16/10/2010	>100%	33.4	0.5	17/10/2010	>100%
Nov 10	19.6	0.8	25/11/2010	>100%	20.2	0.4	26/11/2010	>100%	31.0	0.4	1/11/2010	>100%
Dec 10	84.8	3.5	8/12/2010	5%-2%	93.4	1.9	8/12/2010	5%-2%	95.2	1.3	8/12/2010	10%-5%
Jan 11	60.8	2.5	12/01/2011	10%-20%	67.4	1.4	12/01/2011	50%-20%	107.6	1.5	14/01/2011	5%-2%
Feb 11	25.8	1.1	19/02/2011	>100%	27.4	0.6	19/02/2011	>100%	27.8	0.4	19/02/2011	>100%

Figure 6-8 090173 Hamilton Airport Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	35.6	1.5	11/08/2010	>100%	55.4	1.2	12/08/2010	100%-50%	56.6	0.8	13/08/2010	100%-50%
Sep 10	15.8	0.7	10/09/2010	>100%	25.8	0.5	7/09/2010	>100%	34.2	0.5	6/09/2010	>100%
Oct 10	21.0	0.9	31/10/2010	>100%	38.8	0.8	31/10/2010	>100%	39.0	0.5	31/10/2010	>100%
Nov 10	20.8	0.9	25/11/2010	>100%	25.8	0.5	1/11/2010	>100%	43.6	0.6	1/11/2010	>100%
Dec 10	61.4	2.6	8/12/2010	10%-20%	62.0	1.3	9/12/2010	50%-20%	68.0	0.9	10/12/2010	50%-20%
Jan 11	56.4	2.4	12/01/2011	50%-20%	65.2	1.4	12/01/2011	50%-20%	88.8	1.2	14/01/2011	10%-20%
Feb 11	33.6	1.4	19/02/2011	>100%	35.4	0.7	20/02/2011	>100%	36.2	0.5	21/02/2011	>100%

Figure 6-9 090186 Warrnambool Airport Ndb Rainfall Intensity-Frequency-Duration Analysis

6.4 Streamflow

Two separate streamflow analyses were undertaken. The first was based on information provided by the Bureau of Meteorology for flood warning gauges over the spring-summer 2010-11 period (excluding August 2010), the second based on instantaneous flow and level data obtained from DSE on 268 streamflow gauges. These analyses are summarised below in Table 6-2 to Table 6-11.

The streamflow gauge analysis for flood warning gauges included a summary of flood class levels, peak level and flood class and where available frequency of flooding. This analysis was based on information provided by the Bureau of Meteorology, with no attempt to infill missing data. The frequency of flooding was provided for gauges where a flood frequency analysis had been undertaken in the past and as documented in the Victorian Strategic Flood Intelligence Report[14]. The flood frequency analysis included in the above mentioned VICSES document includes flood frequency analysis from two distinct sources. The first source included flood frequency analysis undertaken by Thiess for the Victorian Flood Warning Station Information Manual[15], covering the majority of flood warning gauges. The second source of flood frequency analysis was for gauges analysed as part of recent flood studies. The accuracy of the flood frequencies may differ given the source and the length of data record available.

The DSE instantaneous streamflow gauge analysis concentrated on peak levels and flows and timing of peaks. Travel times were calculated between peaks. These travel times were found to be inconsistent in some cases (i.e. downstream gauges sometimes peaking earlier). Each case was assessed and it is likely that this was due to the spatial and temporal distribution of rainfall, the effect of storages attenuating or totally storing upstream flows, the timing of tributary flows or the occurrence of multiple peaks within a month obscuring the analysis. This analysis was only conducted on months where a significant flow event occurred (generally above Minor flood levels).

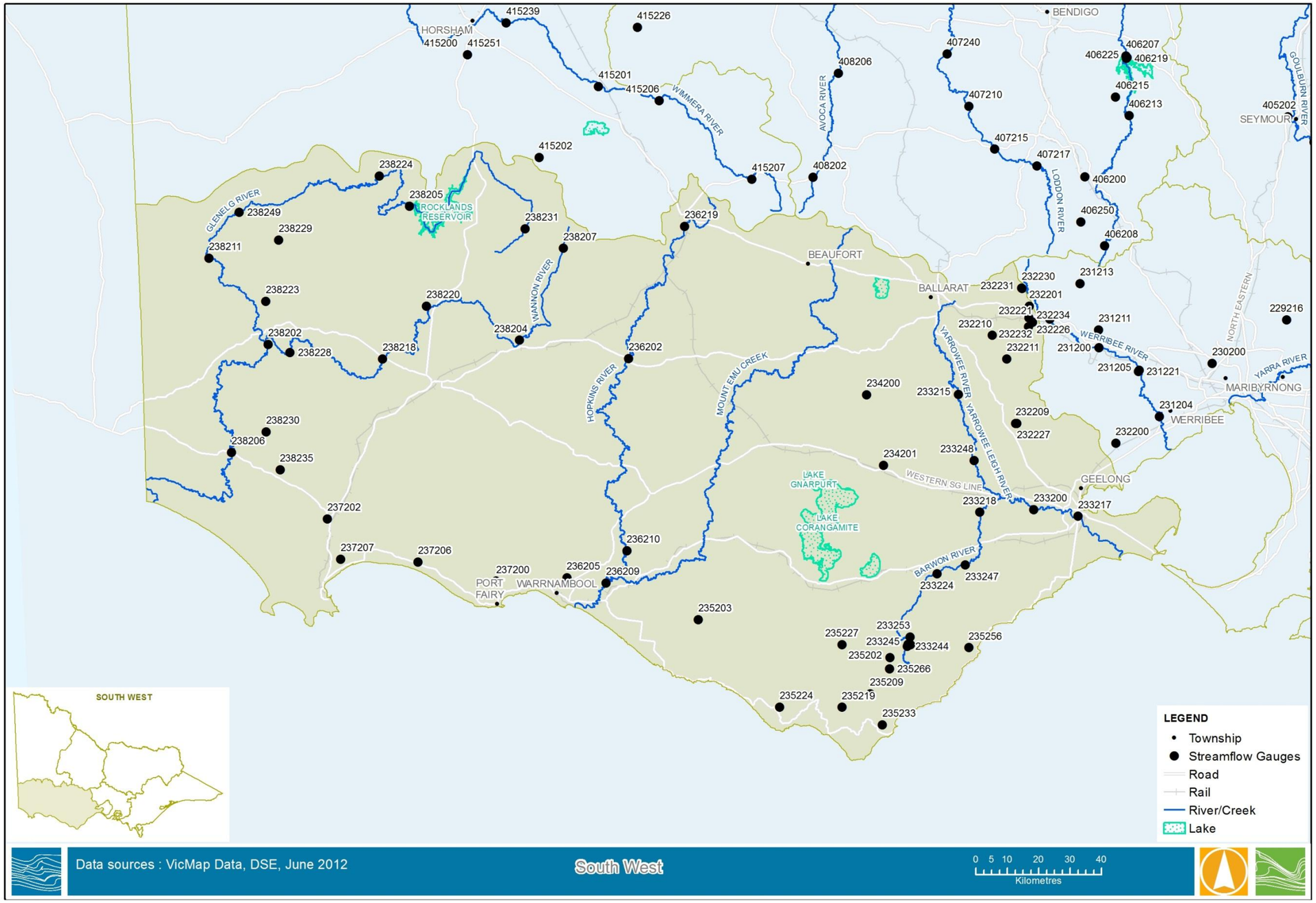


Figure 6-10 South West region streamflow gauges analysed

Table 6-2 Barwon River Bureau of Meteorology flood warning gauge summary

River Basin		Barwon	Leigh	Leigh	Barwon	Moorabool	Barwon
Location		Ricketts Marsh	Mt Mercer	Shelford	Pollocksford	Batesford	Geelong
Flood Class Level	Minor	3.00	2.00	5.00	3.50	2.70	2.50
	Moderate	4.80	2.60	7.00	4.50	4.00	3.10
	Major	6.50	3.50	9.00	6.50	4.90	4.30
Sep-2010	Peak (m)	3.85	2.58	6.18	3.49	1.55	2.61
	Warning	Minor	Minor	Minor	<Minor	<Minor	Minor
Oct-2010	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Dec-2010	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Jan-2011	Peak (m)	3.66	4.20	7.36	5.95	3.22	3.68
	Warning	Minor	Major	Moderate	Moderate	Minor	Moderate
			~2%		~20%		
Feb-2011	Peak (m)	-	0.97	2.27	1.93	3.86	2.48
	Warning	<Minor	<Minor	<Minor	<Minor	Minor	<Minor
Historic Record	Peak (m)	6.99	5.73	6.66	9.55	6.10	5.82
	Date	Oct-1976	Feb-1973	Nov-1995	Aug-1990	Jun-1952	Jun-1952
	Start Of Record	1971	1956	1994	1969	-	-
	New Record Set	No	No	Yes	No	No	No
	New Record Date	-	-	Jan-2011	-	-	-
	Peak (m)	-	-	7.36	-	-	-
	Increase (m)	-	-	0.70	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 6-3 Glenelg River Bureau of Meteorology flood warning gauge summary

River Basin		Glenelg	Glenelg
Location		Dergholm	Casterton
Flood Class Level	Minor	3.70	3.80
	Moderate	4.50	5.20
	Major	5.00	6.00
Sep-2010	Peak (m)	3.98	3.86
	Warning	Minor	Minor
Oct-2010	Peak (m)	-	-
	Warning	<Minor	<Minor
Nov-2010	Peak (m)	-	-
	Warning	<Minor	<Minor
Dec-2010	Peak (m)	4.60	4.15
	Warning	Moderate	Minor
Jan-2011	Peak (m)	4.96	4.87
	Warning	Moderate	Minor
Feb-2011	Peak (m)	-	-
	Warning	<Minor	<Minor
Historic Record	Peak (m)	-	6.16
	Date	-	Sep-1983
	Start Of Record	-	1956
	New Record Set	-	No
	New Record Date	-	-
	Peak (m)	-	-
	Increase (m)	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 6-4 Barwon and Leigh Rivers instantaneous flow and level gauge summary

River Basin		West Barwon	East Barwon	East Barwon	Barwon	Barwon	Barwon	Leigh	Leigh	Barwon	Barwon
Gauge Number		233245	233214	233253	233224	233247	233218	233215	233248	233200	233217
Gauge Location		Compensation Weir Spill	Forrest	Offtake	Rickets Marsh	Kildean Lane	Inverleigh	Mount Mercer	Shelford (Golf Hill)	Pollocksford	Geelong
August 2010	Date/Time of Peak	11/08/2010 4:40 PM	11/08/2010 3:45 PM	11/08/2010 12:30 PM	12/08/2010 5:15 PM	13/08/2010 12:15 PM	14/08/2010 11:45 AM	12/08/2010 1:30 PM	12/08/2010 8:45 PM	13/08/2010 6:00 PM	14/08/2010 4:45 AM
	Time Diff. (hrs)					19	24		7	21	11
	Peak Level (m)	0.15	2.44	0.88	6.08	5.27	2.08	2.59	6.01	2.49	2.18
	Peak Flow (m3/s)	0	32	6	82	74	55	125	124	80	95
September 2010	Date/Time of Peak	1/09/2010 10:40 AM	5/09/2010 12:00 PM	10/09/2010 6:50 PM	5/09/2010 6:45 AM	6/09/2010 11:15 AM	7/09/2010 12:15 PM	4/09/2010 9:45 PM	5/09/2010 3:00 AM	5/09/2010 10:30 PM	6/09/2010 12:15 PM
	Time Diff. (hrs)					29	25		5	20	14
	Peak Level (m)	0.08	0.75	0.42	3.90	4.39	1.87	2.62	6.23	3.56	2.58
	Peak Flow (m3/s)	0	3	1	37	51	42	127	132	128	137
January 2011	Date/Time of Peak	14/01/2011 7:30 PM	14/01/2011 12:30 PM	14/01/2011 5:20 PM	14/01/2011 11:00 PM	15/01/2011 5:00 AM	16/01/2011 11:15 AM	14/01/2011 6:45 PM	14/01/2011 10:45 PM	15/01/2011 2:30 PM	15/01/2011 11:00 PM
	Time Diff. (hrs)					6	30		4	16	9
	Peak Level (m)	0.09	0.98	1.29	3.67	4.21	1.80	4.21	7.94	6.09	3.66
	Peak Flow (m3/s)	0	6	6	34	46	38	225	198	341	420
February 2011	Date/Time of Peak	16/02/2011 4:00 PM	19/02/2011 6:30 PM	20/02/2011 3:00 AM	19/02/2011 9:15 PM	22/02/2011 5:30 PM	23/02/2011 2:15 PM	4/02/2011 9:00 PM	5/02/2011 6:00 AM	6/02/2011 9:30 AM	6/02/2011 12:00 PM
	Time Diff. (hrs)					68	21		9	28	2
	Peak Level (m)	0.08	0.35	0.32	0.52	1.06	0.37	1.99	5.35	1.95	2.45
	Peak Flow (m3/s)	0	0	1	1	1	1	72	101	56	122

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: For these events, the Barwon River (downstream from the Leigh River) was dominated by Leigh River flows, thus the travel time for Barwon River at Pollocksford was calculated from Leigh River at Shelford.*

Table 6-5 Moorabool River instantaneous flow and level gauge summary

River Basin		Little	Moorabool East	Moorabool East	Moorabool East	Moorabool East	Moorabool West	Moorabool West	Moorabool
Gauge Number		232200	232230	232234	232221	232226	232210	232211	232227
Gauge Location		Little River	Korweinguboora Reservoir (HG)	U/S Bostock Reservoir	Bostock Reservoir	D/S Bostock Reservoir	Lal Lal	Mount Doran	Sheoaks Diversion Weir
January 2011	Date/Time of Peak	14/01/2011 5:15 AM	14/01/2011 11:40 AM	14/01/2011 5:40 PM	14/01/2011 5:00 PM	15/01/2011 7:13 AM	14/01/2011 3:30 PM	14/01/2011 2:00 PM	14/01/2011 11:00 PM
	Time Diff. (hrs)			6	-1	14		-2	
	Peak Level (m)	3.03	584.17	1.62	494.51	1.31	1.45	1.30	1.55
	Peak Flow (m3/s)	66	3	60	139	1	11	7	70
February 2011	Date/Time of Peak	5/02/2011 3:30 AM	5/02/2011 5:40 AM	5/02/2011 11:30 AM	5/02/2011 1:20 PM	5/02/2011 12:33 PM	5/02/2011 4:15 AM		4/02/2011 11:45 PM
	Time Diff. (hrs)			6	2	-1			
	Peak Level (m)	5.41	584.07	1.27	494.39	2.39	1.42		1.75
	Peak Flow (m3/s)	232	1	33	95	0	10		69

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to storages attenuating upstream flows, with downstream tributary flows contributing to earlier downstream peaks.*

Table 6-6 Otway Coast instantaneous flow and level gauge summary

River Basin		St George	Curdies	Barham East	Aire	Aire	Gellibrand	Gellibrand	Gellibrand	Gellibrand
Gauge Number		235256	235203	235233	235209	235219	235266	235202	235227	235224
Gauge Location		Allenvale Reservoir (head gauge)	Curdies	Apollo Bay Paradise	Beech Forest	Wyelangta	D/S West Gellibrand Dam	Upper Gellibrand	Bunkers Hill	Burrupa
August 2010	Date/Time of Peak	11/08/2010 3:00 PM	11/08/2010 10:00 PM	11/08/2010 10:30 AM	11/08/2010 5:46 PM	11/08/2010 7:15 PM	11/08/2010 5:00 PM	11/08/2010 5:30 PM	12/08/2010 5:00 AM	13/08/2010 1:00 AM
	Time Diff. (hrs)					1		0	12	20
	Peak Level (m)	120.53	7.19	1.54	2.80	2.97	2.32	4.94	5.50	6.98
	Peak Flow (m3/s)	10	806	42	125	119	5	62	207	372

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

Table 6-7 Glenelg River instantaneous flow and level gauge summary

River Basin		Glenelg	Glenelg	Glenelg	Glenelg	Glenelg	Glenelg
Gauge Number		238231	238205	238224	238249	238202	238206
Gauge Location		Bid Cord	Rocklands Reservoir	Fulham Bridge	D/S Burkes Bridge	Sandford	Dartmoor
September 2010	Date/Time of Peak	5/09/2010 7:00 PM	4/09/2010 11:45 PM	5/09/2010 11:45 PM	5/09/2010 2:45 AM	5/09/2010 3:00 AM	7/09/2010 3:30 AM
	Time Diff. (hrs)			24	-21	0	49
	Peak Level (m)	1.00	179.00	2.29	2.82	5.57	8.52
	Peak Flow (m3/s)	1	1	67	26	175	196
December 2010	Date/Time of Peak	8/12/2010 1:45 PM	8/12/2010 3:15 AM	9/12/2010 12:45 AM	10/12/2010 3:00 AM	13/12/2010 4:30 AM	14/12/2010 9:00 PM
	Time Diff. (hrs)			22	26	74	41
	Peak Level (m)	1.49	179.40	2.74	3.28	4.89	6.78
	Peak Flow (m3/s)	7	4	132	26	143	131
January 2011	Date/Time of Peak	14/01/2011 4:21 AM	14/01/2011 3:45 AM	15/01/2011 4:30 AM	14/01/2011 9:00 AM	14/01/2011 12:30 PM	17/01/2011 3:00 AM
	Time Diff. (hrs)			25	-20	4	62
	Peak Level (m)	1.82	179.23	2.38	2.71	5.36	7.53
	Peak Flow (m3/s)	10	2	78	26	165	158

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to spatial and temporal variability in rainfall impacting on tributary flows.*

Table 6-8 Glenelg River tributaries instantaneous flow and level gauge summary

River Basin		Chetwynd	Wando	Dundas	Wannon	Wannon	Wannon	Wannon	Stokes	Crawford
Gauge Number		238229	238223	238220	238207	238204	238218	238228	238230	238235
Gauge Location		Chetwynd	Wando Vale	Cavendish	Jimmy Creek	Dunkeld	Wannon Falls	Henty	Teakettle	Lower Crawford
September 2010	Date/Time of Peak	4/09/2010 9:24 AM	4/09/2010 9:15 AM	5/09/2010 2:15 AM	4/09/2010 8:00 PM	12/09/2010 7:30 PM	6/09/2010 2:45 PM	7/09/2010 9:30 PM	5/09/2010 12:45 AM	5/09/2010 8:00 PM
	Time Diff. (hrs)					191	-149	31		
	Peak Level (m)	1.83	1.85	3.98	1.44	2.47	1.52	4.57	3.59	2.84
	Peak Flow (m3/s)	27	28	54	5	4	70	91	24	36
December 2010	Date/Time of Peak	8/12/2010 1:42 AM	8/12/2010 11:00 AM	8/12/2010 7:30 AM	8/12/2010 4:00 AM	15/12/2010 10:15 AM	9/12/2010 3:45 AM	13/12/2010 11:00 AM	8/12/2010 12:30 AM	9/12/2010 9:45 PM
	Time Diff. (hrs)					174	-151	103		
	Peak Level (m)	1.16	1.27	4.17	2.86	2.81	1.64	3.35	3.77	1.87
	Peak Flow (m3/s)	4	10	69	14	6	89	48	31	6
January 2011	Date/Time of Peak	13/01/2011 11:45 PM	14/01/2011 12:00 AM	14/01/2011 9:15 AM	14/01/2011 12:00 AM	17/01/2011 12:00 PM	18/01/2011 7:30 PM	14/01/2011 1:00 PM	14/01/2011 6:00 AM	15/01/2011 1:00 PM
	Time Diff. (hrs)					84	32	-103		
	Peak Level (m)	1.54	1.70	3.75	3.22	3.79	1.52	3.98	4.21	2.13
	Peak Flow (m3/s)	16	22	37	15	39	70	67	53	10

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to spatial and temporal variability in rainfall impacting on tributary flows.*

Table 6-9 Corangamite instantaneous flow and level gauge summary

River Basin		Woady Yaloak	Woady Yaloak
Gauge Number		234200	234201
Gauge Location		Pitfield	Cressy (Yarima)
August 2010	Date/Time of Peak	12/08/2010 11:30 AM	12/08/2010 9:15 PM
	Time Diff. (hrs)		10
	Peak Level (m)	3.17	4.25
	Peak Flow (m3/s)	80	112
January 2011	Date/Time of Peak	14/01/2011 1:00 PM	14/01/2011 6:30 PM
	Time Diff. (hrs)		6
	Peak Level (m)	5.38	6.66
	Peak Flow (m3/s)	229	686

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

Table 6-10 Hopkins River instantaneous flow and level gauge summary

River Basin		Hopkins	Hopkins	Hopkins	Hopkins	Merri
Gauge Number		236219	236202	236210	236209	236205
Gauge Location		Ararat	Wickliffe	Framlingham	Hopkins Falls	Woodford
August 2010	Date/Time of Peak	11/08/2010 4:34 PM	13/08/2010 10:15 PM	13/08/2010 1:00 PM	13/08/2010 10:15 PM	12/08/2010 8:15 AM
	Time Diff. (hrs)		54	-9	9	
	Peak Level (m)	2.49	3.86	5.72	3.03	7.79
	Peak Flow (m3/s)	27	45	255	352	250
September 2010	Date/Time of Peak	4/09/2010 9:09 PM	6/09/2010 1:45 PM	9/09/2010 5:30 AM	8/09/2010 3:15 PM	6/09/2010 2:00 AM
	Time Diff. (hrs)		41	64	-14	
	Peak Level (m)	2.82	4.13	3.41	2.51	4.91
	Peak Flow (m3/s)	37	72	101	217	73
January 2011	Date/Time of Peak	14/01/2011 10:43 AM	15/01/2011 10:30 AM	17/01/2011 2:45 PM	17/01/2011 11:15 AM	15/01/2011 12:30 AM
	Time Diff. (hrs)		24	52	-4	
	Peak Level (m)	3.56	5.89	5.89	4.02	2.16
	Peak Flow (m3/s)	96	697	267	817	18

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to spatial and temporal variability in rainfall impacting on tributary flows.*

Table 6-11 Portland and Millicent Coasts instantaneous flow and level gauge summary

River Basin		Moyne	Fitzroy	Eumeralla	Surry	Big
Gauge Number		237200	237202	237206	237207	401216
Gauge Location		Toolong	Heywood	Codrington	Heathmere	Jokers Creek
August 2010	Date/Time of Peak	11/08/2010 8:15 PM				
	Time Diff. (hrs)					
	Peak Level (m)	4.34				
	Peak Flow (m3/s)	99				
September 2010	Date/Time of Peak	5/09/2010 7:30 PM	5/09/2010 1:30 AM	7/09/2010 10:00 PM	6/09/2010 8:45 AM	4/09/2010 7:15 PM
	Time Diff. (hrs)					
	Peak Level (m)	3.46	2.30	2.61	1.61	3.71
	Peak Flow (m3/s)	50	18	13	19	184
December 2010	Date/Time of Peak					8/12/2010 10:15 PM
	Time Diff. (hrs)					
	Peak Level (m)					3.19
	Peak Flow (m3/s)					126

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

6.5 Summary

During the August 2010 rainfall event Wyelangta recorded between 5 and 2% AEP at durations of 48 and 72 hours, with other locations recording around 50% AEP or higher for the same durations. The December rainfall event was estimated at between 5% and 2% AEP at Hamilton and Harrow for the 24, 48 and 72 hour durations, with significantly higher AEPs in other locations. With the exception of a few gauges in the very south of the region, the January 2011 rainfall event generally recorded between 5 and 1% AEP for the 72 hour duration.

Using the available flood frequency information, the peak flow in the Leigh River at Mount Mercer in January 2011 was estimated at 2% AEP, while the peak flow in the Barwon River at Pollocksford was estimated at about 20% AEP. Data and analyses for other waterways within the south west region are sparse. The 2010-11 Comrie Review Submission[16] from the Glenelg Hopkins CMA was consulted for further estimates of the historic flows. A number of submission estimates place flows in the Hopkins River for the January 2011 flood in the vicinity of a 1% AEP event. With the exception of one or two gauge locations, the September and November 2010 floods were estimated at between 50 and 20% AEP. The August 2010 flood was estimated at between 50 and 5% AEP for many of the gauges in the southern half of the region.

[16] Water Technology (May 2011), *Glenelg Hopkins CMA Submission to the Review of 2010-11 Flood Warnings and Response*, Glenelg Hopkins CMA. (In association with Michael Cawood and Associates).

7. PORT PHILLIP AND WESTERN PORT REGION HYDROLOGICAL ANALYSIS

7.1 Overview of Flooding

August 2010 – Higher rainfall to the east of the region but no known flooding issues.

September 2010 – Higher rainfall in the north east corner of the region, with some flooding on the Maribyrnong River.

October 2010 – Widespread rainfall across the region with some high daily totals recorded, and flooding observed around Yarra Glen and Healesville.

November 2010 – Widespread heavy rainfall was recorded across the region with flash flooding in the western suburbs of Melbourne.

December 2010 – Severe thunderstorms over Melbourne resulted in flash flooding. Damage from the storm event was significant.

January 2011 – Rainfall was heaviest across the north and west of the region, with some flooding.

February 2011 – Significant flash flooding occurred across the region with very high daily rainfall totals recorded, particularly over the eastern suburbs.

7.2 Regional Description

The Port Phillip and Western Port region includes the Werribee, Maribyrnong, Yarra, Patterson and Bunyip catchments, Figure 7-1 below shows the major waterways in the region.

The Werribee River flows south east from north of Ballan across the Western Plains to downstream of Bacchus Marsh where it enters Melton Reservoir. From Melton Reservoir the river continues to flow south through Werribee and Werribee South where it discharges into Port Phillip Bay.

The Maribyrnong River has two major tributaries, Jacksons Creek and Deep Creek. Both creeks flow south from north of Sunbury before joining at Keilor North to form the Maribyrnong River. From here the Maribyrnong River flows south through Melbourne's north western suburbs (e.g. Avondale Heights, Essendon West, Ascot Vale, Seddon, Maribyrnong and Kensington) before flowing into the Yarra River north of the West Gate Bridge.

The Yarra River runs west from near Mt Baw Baw to the Upper Yarra Reservoir. From here it continues in a westerly direction through the regional towns of Warburton and Yarra Glen. The Yarra then turns to the south west and passes through the suburbs of Warrandyte, Ivanhoe, Abbotsford and Richmond before flowing through Melbourne's CBD and discharging into Port Phillip Bay.

The Bunyip River rises near Mount Beenak in the Bunyip State Park. It then flows south to Longwarry North where it merges with the Tarago River. The river continues south past Bunyip where it has been channelised. This channel flows through the regional towns of Iona, Cora Lynn, and Koo Wee Rup, across what was the Koo Wee Rup swamp and into Western Port Bay.

Patterson Lakes in Melbourne's south east is formed around the Patterson River where it discharges into Port Phillip Bay. Two major tributaries meet to form Patterson River near Bangholme. The first of the two major tributaries is Dandenong Creek, which flows south from the Dandenong Ranges through the suburbs of Ferntree Gully, Bayswater and Dandenong. The second of the two major tributaries is Eumemmerring Creek, which flows west through the suburbs of Berwick and Narre Warren.

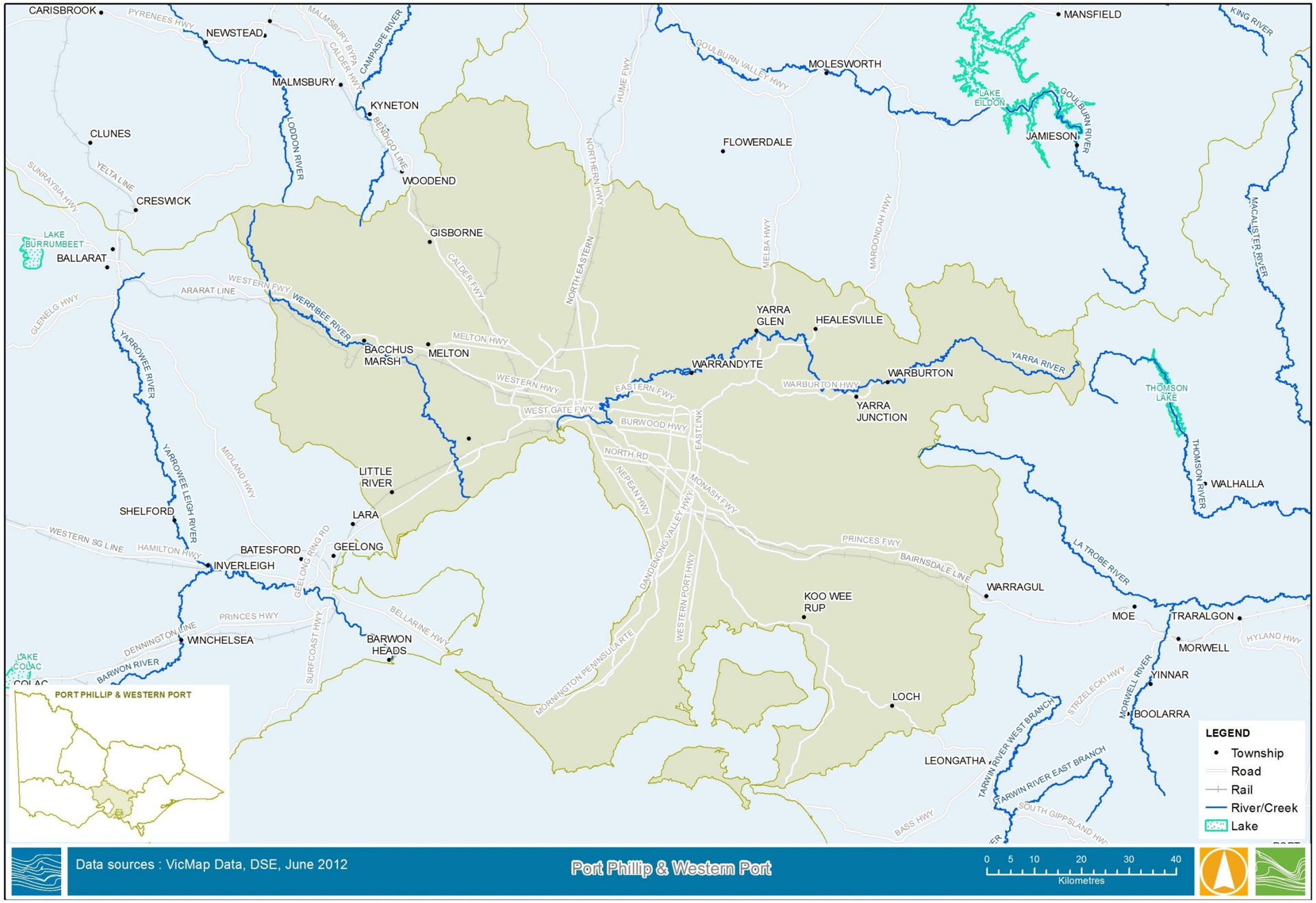


Figure 7-1 Port Phillip and Western Port region

7.3 Rainfall

Section 2.1 provides a broad overview of the synoptic conditions that produced the rainfall events over the spring-summer 2010-11 period. This Section includes more detail about specific rainfall gauges within the Port Phillip and Western Port region. It should be noted that daily rainfall gauges typically record rainfall totals over a 24 hour period to 9 am on the date recorded.

Table 7-1 below summarises the maximum daily rainfall and monthly totals for numerous rainfall gauges across the region and compares it against the historical monthly average over the spring-summer period as well as against the historical monthly and daily maximum rainfall totals. A high proportion of the gauges selected for analysis broke daily and monthly maximum rainfall records during the spring-summer 2010-11 period.

For a selected number of gauges an Intensity-Frequency-Duration (IFD) analysis was undertaken on the daily rainfall totals at 24, 48 and 72 hour durations. Using the geographical coordinates for the rainfall gauges analysed, the raw polynomial coefficients were taken from the Bureau of Meteorology's online IFD Data System[13], and used as input to an IFD spreadsheet tool developed by Water Technology, plotting the IFD curves for the rainfall gauge site. This was overlayed with the maximum 24, 48 and 72 hour rainfall totals for each month.

The gauges selected were chosen to provide a spread across the region with preference for gauges in proximity to areas of significant flooding. Note that the frequency attributed to the rainfall event does not necessarily correspond to the frequency of the flood event due to antecedent catchment conditions, timing of tributary flows etc. It must also be noted that the frequency of the event may differ when durations shorter than 24 hours are considered, however with daily rainfall gauges these shorter durations can not be assessed. Figure 7-3 to Figure 7-8 below show the IFD analysis undertaken.

Figure 7-2 below shows the location of the rainfall gauges analysed for both daily and monthly totals and also those gauges where IFD analysis was completed.

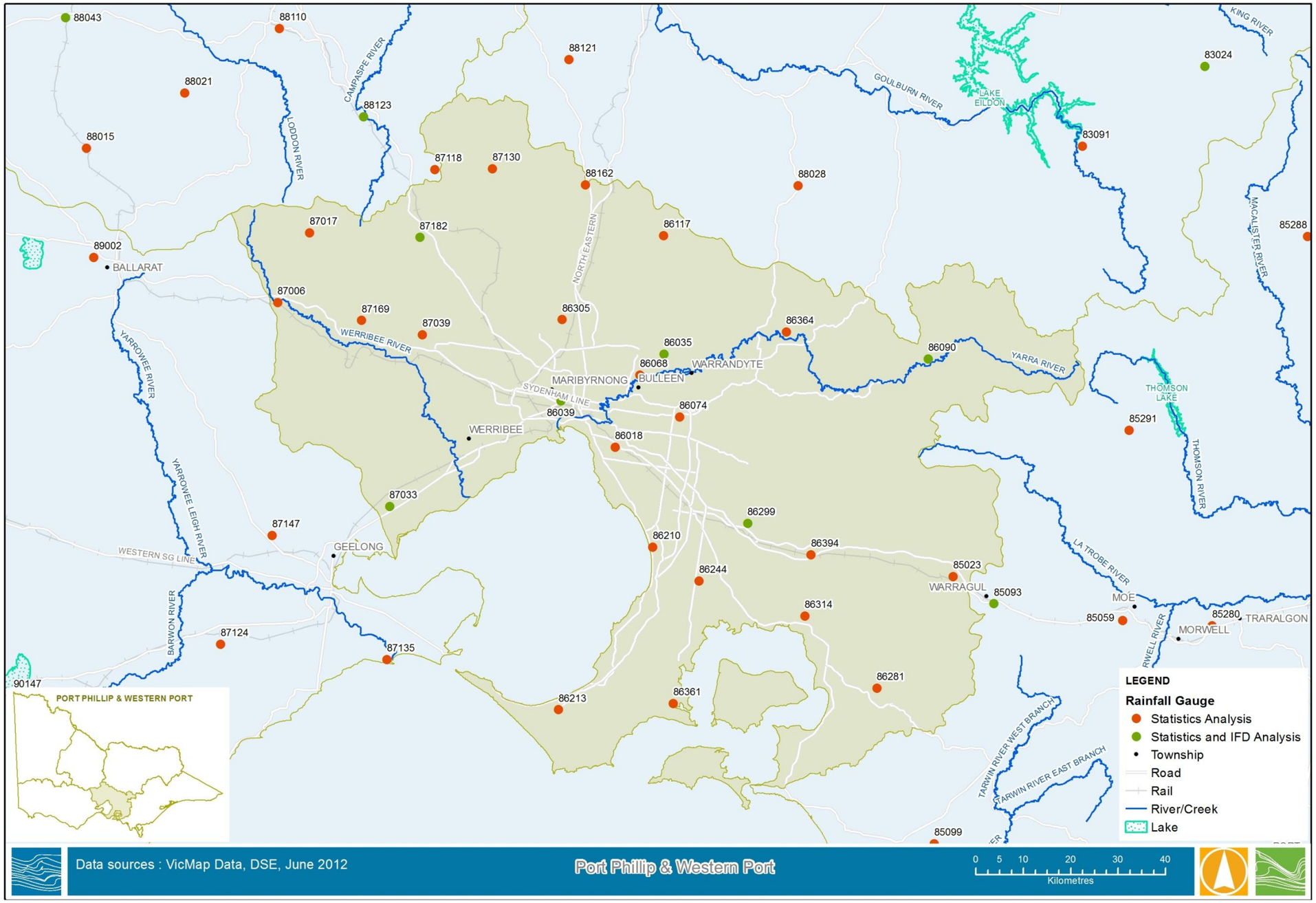
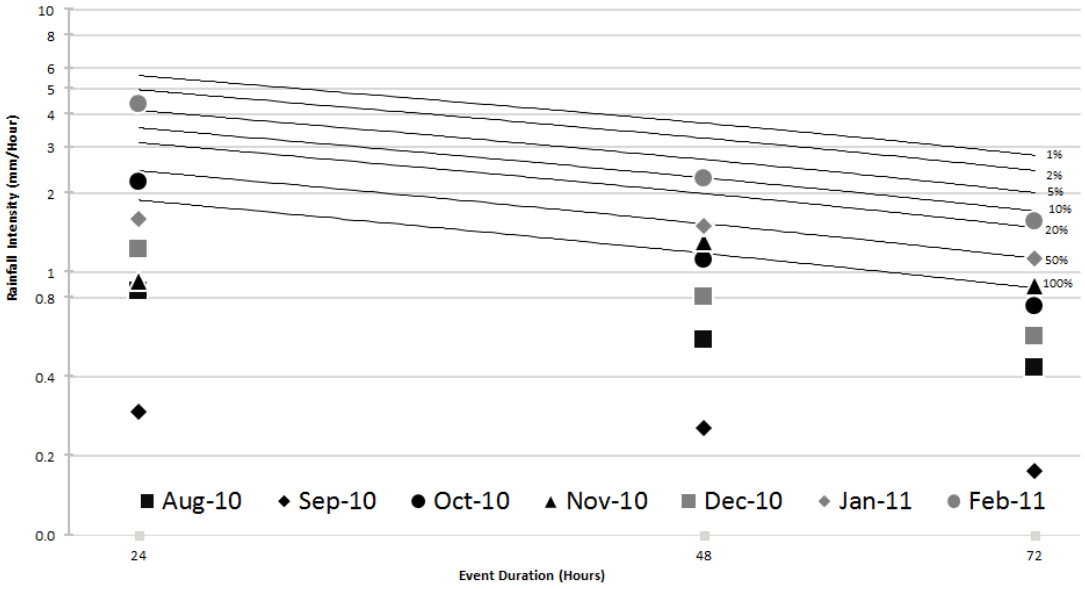


Figure 7-2 Port Phillip and Western Port region rainfall gauges analysed

Table 7-1 Port Phillip and Western Port region observed rainfall summary

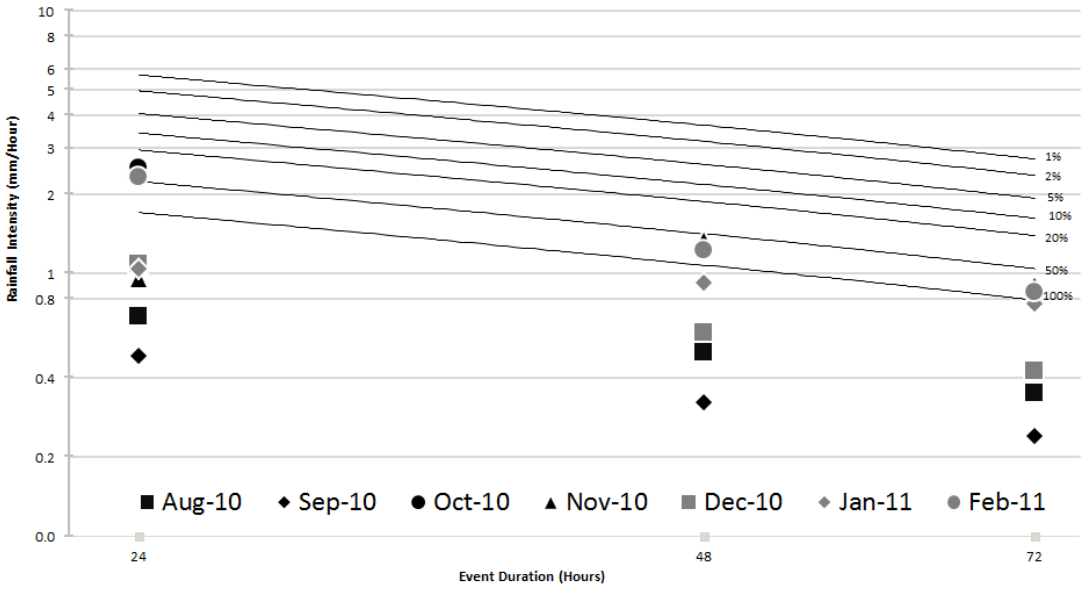
Location	Station Number	August 2010		September 2010		October 2010		November 2010		December 2010		January 2011		February 2011		Record Statistics			
		Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Avg.	Monthly Max.	Daily Max.	Start of record
Bacchus Marsh (Golf Club)	87169	66.8	13.0 (12th)[1]	32.2	12.6 (4th)	115.4	58.0 (31st)	159.7	44.0 (28th)	46	19.6 (2nd)	146.4	37.2 (14th)	102.8	69.8 (5th)	25.0-71.2	191.0 (Feb 2005)	80.0 (03/02/2005)	1990
Ballan	87006	119.2	22.6 (12th)	62.6	24.2 (4th)	109	39.0 (31st)	156.4	50.2 (28th)	50.8	9.9 (9th)[1]	151.6	54.4 (14th)	161.4	119.4 (5th)	43.4-75.5	359.7 (Sep 1916)	119.4 (05/02/2011)	1875
Berwick (Buchanan Road)	86299	120.4	22.4 (2nd)	67.2	11.2 (5th)	161.6	61.4 (31st)	147.8	38.4 (28th)	105	23.0 (3rd)	88.4	32.2 (15th)	235.6	150.0 (5th)	54.6-93.6	235.6 (Feb 2011)	150.0 (05/02/2011)	1979
Blackwood	87017	172.2	22.6 (19th)	113	35.4 (4th)	153.2	47.8 (31st)	184.6	66.1 (28th)1	62.8	16.8 (2nd)	211.4	90.6 (14th)	118.8	61.0 (5th)	50.4-110.6	407.4 (Sep 1916)	123.8 (24/10/1985)	1878
Bonbeach (Carrum)	86210	102	18.3 (12th)	72.5	14.0 (10th)	136.6	69.0 (31st)	144.1	45.0 (13th)	104	29.0 (9th)	89	32.2 (15th)	161.6	112.0 (5th)	42.2-70.1	212.8 (Feb 1973)	112.0 (05/02/2011)	1955
Caulfield (Racecourse)	86018	82	16.0 (12th)	51.2	11.8 (4th)	146.4	63.0 (31st)	103.6	28.0 (13th)	115.4	31.6 (9th)	89.4	31.8 (14th)	181.8	100.0 (5th)	49.3-72.4	276.3 (Mar 1911)	133.9 (29/01/1963)	1887
Cerberus	86361	119.6	22.2 (2nd)	63	17.4 (4th)	111.2	61.0 (31st)	81.4	25.4 (14th)	78.8	22.0 (9th)	93.8	33.6 (12th)	115.4	47.8 (19th)	39.1-76.4	192.8 (Apr 2001)	104.0 (23/04/2001)	1986
Cranbourne South	86244	137.8	26.6 (2nd)	81	11.4 (5th)	116.6	46.0 (31st)	101.3	25.6 (13th)	119.5	38.6 (9th)	97.6	28.3 (15th)	119.9	59.0 (5th)	46.6-78.9	213.6 (Feb 1973)	110.9 (03/02/2005)	1967
Drouin Bowling Club	85023	135.2	25.5 (2nd)	93.6	25.8 (5th)	134.5	37.2 (31st)	104.3	31.7 (28th)	145	36.2 (9th)	73.2	19.4 (11th)	226.2	110.0 (5th)	56.1-106.1	302.9 (Aug 1900)	180.1 (01/12/1934)	1899
Eltham	86035	83	20.2 (12th)	48.2	7.0 (1st)	143	52.8 (31st)	112.6	22.2 (28th)	104.4	29.4 (9th)	108	38.0 (14th)	161.2	104.2 (5th)	48.2-72.5	229.8 (Jan 1963)	130.0 (29/01/1963)	1906
Flemington Racecourse	86039	66.2	16.4 (12th)	43.8	11.6 (4th)	139.6	60.0 (31st)	125.6	22.8 (14th)	60.6	25.8 (9th)	90.6	24.8 (14th)	128.6	55.6 (5th)	42.7-59.8	201.4 (Feb 2005)	141.7 (29/01/1963)	1904
Gisborne (Rosslynne Reservoir)	87182	127.2	20.6 (12th)[1]	84.8	26.2 (4th)	153.6	60.8 (31st)	215.7	57.4 (28th)	75	25.2 (9th)	175.8	58.4 (14th)	90.8	40.8 (5th)	40.5-131.4	215.7 (Nov 2010)	60.8 (31/10/2010)	2008
Greenvale Reservoir	86305	79.2	21.0 (12th)	51.6	8.2 (5th)	113	38.0 (31st)	146.8	34.8 (27th)	64.2	20.0 (9th)	97.4	23.4 (14th)	75.4	35.2 (5th)	43.1-65.5	179.6 (Feb 2005)	125.8 (03/02/2005)	1972
Koo Wee Rup (SRW)	86314	128	20.0 (2nd)	82.2	11.0 (5th)	109.1	39.6 (31st)	128.9	43.0 (28th)	84	18.2 (9th)	77.5	20.4 (15th)	130.9	57.4 (5th)	45.9-81.8	193.9 (Mar 1970)	78.1 (03/02/2005)	1957
Little River	87033	64.2	15.5 (12th)	56.2	24.0 (4th)	94	41.4 (31st)	128	35.4 (25th)	43.4	11.4 (18th)	111.8	33.6 (14th)	121.6	76.4 (5th)	31.8-50.2	252.3 (Feb 1973)	121.8 (10/12/1988)	1906
Melton	87039	65.4	15.4 (12th)	30.4	13.8 (4th)	110	52.0 (31st)	162.8	38.4 (28th)	66.4	22.0 (2nd)	128.2	36.4 (14th)	105.2	68.0 (5th)	33.8-49.7	268.8 (Sep 1916)	141.2 (06/03/1918)	1883
Mitcham	86074	105.2	20.8 (12th)	66.4	9.4 (5th)	139.6	66.0 (31st)	116.8	21.2 (28th)	155	47.2 (20th)	100.2	43.0 (14th)	174.4	93.4 (5th)	54.9-84.2	226.9 (Feb 1939)	124.7 (29/01/1963)	1936
Nyora (Post Office)	86281	155.6	24.4 (2nd)	107.8	18.4 (5th)	138.6	52.6 (31st)	137	57.0 (28th)	96.2	25.5 (20th)	99.8	29.6 (12th)	133.4	53.0 (5th)	53.5-104.4	218.0 (Jun 1977)	79.0 (03/02/2005)	1970
Pakenham	86394	116.4	25.2 (2nd)	68.6	8.8 (6th)	141.2	52.8 (31st)	118.2	36.8 (28th)	106.6	27.0 (20th)	75.4	23.8 (15th)	199.4	133.8 (5th)	43.2-80.6	199.4 (Feb 2011)	133.8 (05/02/2011)	1998
Romsey	87130	120.4	19.0 (11th)	81.4	31.0 (4th)	137.1	55.8 (31st)	156	42.0 (28th)	76.2	20.2 (9th)	186.4	61.2 (14th)	114.4	63.0 (5th)	44.4-77.0	201.7 (Oct 1975)	122.9 (08/11/1971)	1970
Rosebud (Country Club)	86213	129.8	22.0 (2nd)	74.8	18.2 (4th)	105.8	39.0 (31st)	102.8	23.6 (14th)	63.6	10.2 (3rd)	93.4	27.2 (12th)	76.6	29.2 (5th)	41.3-83.4	238.0 (Feb 1973)	112.5 (05/02/1973)	1927
Tarrawarra Monastery	86364	97.4	19.2 (12th)	76.4	12.0 (5th)	146.2	64.0 (31st)	121.8	40.8 (28th)	108.4	38.4 (20th)	89.4	32.4 (15th)	200.8	69.0 (5th)	54.2-83.0	200.8 (Feb 2011)	73.0 (03/02/2005)	1986
Toorourrong Reservoir (Toorrourrong)	86117	117.2	24.4 (12th)	79.4	16.8 (5th)	153.4	70.0 (31st)	160.4	57.2 (28th)	109.4	33.8 (9th)	112.8	43.6 (14th)	127.8	52.5 (6th)	54.2-80.0	251.0 (Sep 1916)	129.6 (03/02/2005)	1892
Viewbank	86068	84	21.6 (12th)	52.4	8.8 (4th)	148.6	58.6 (31st)	110.6	24.0 (28th)	109.2	35.8 (20th)	108.8	41.2 (14th)	138	84.0 (5th)	43.5-85.6	163.0 (Nov 2011)	107.8 (03/12/2003)	1999
Wallan (Kilmore Gap)	88162	125.6	28.2 (12th)	95	27.8 (4th)	130.4	55.6 (31st)	165.8	51.0 (28th)	73.6	22.0 (9th)	120.4	41.0 (14th)	118.2	65.4 (5th)	45.8-74.9	174.8 (Feb 2005)	111.0 (03/02/2005)	1993
Warburton (O'Shannassy Reservoir (Quarters))	86090	242.8	32.4 (2nd)	174.4	64.6 (5th)	156	44.2 (31st)	135.4	52.8 (28th)	148	31.2 (9th)	126.6	48.4 (11th)	200.6	57.8 (6th)	64.8-172.0	408.5 (Aug 1939)	124.2 (06/02/1973)	1915

[1]*Note: Gauge recordings were aggregated over a number of days. Daily totals were disaggregated using the daily rainfall pattern from the nearest gauge of complete record.*
[2]*Note: Records of data were incomplete for the month. The total and highest daily rainfall cannot be determined using incomplete data.*
[3]*Note: Gauge broke daily or monthly statistical records over the period.*
[4]*Note: Analysis carried out early May 2012, any events after that not captured in historical records columns.*



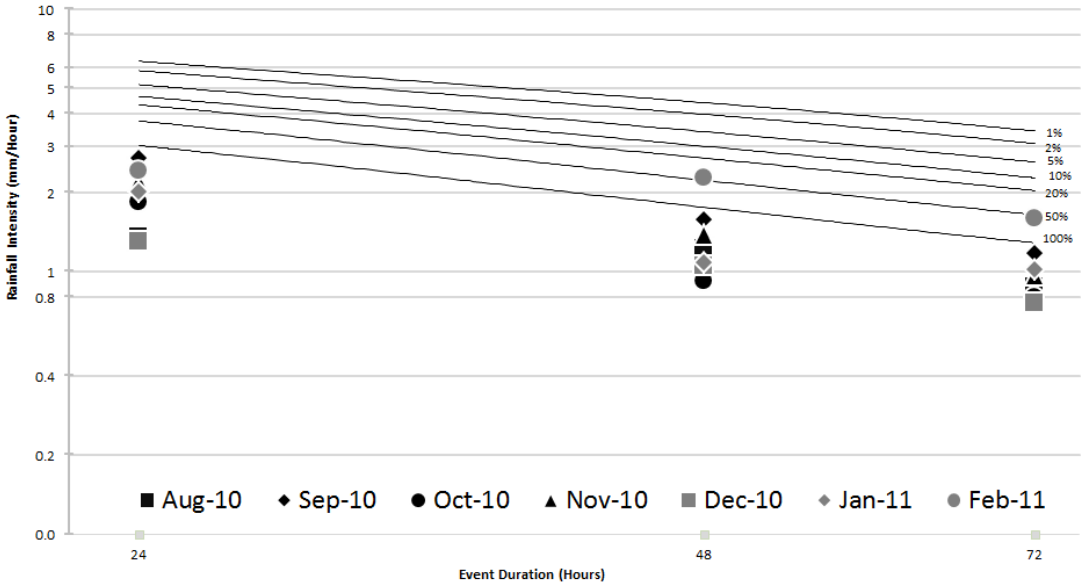
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	20.2	0.8	12/08/2010	>100%	26.4	0.6	12/08/2010	>100%	31.2	0.4	12/08/2010	>100%
Sep 10	7.0	0.3	1/09/2010	>100%	12.2	0.3	2/09/2010	>100%	12.6	0.2	6/09/2010	>100%
Oct 10	52.8	2.2	31/10/2010	100%-50%	53.4	1.1	31/10/2010	>100%	53.4	0.7	31/10/2010	>100%
Nov 10	22.2	0.9	28/11/2010	>100%	62.6	1.3	1/11/2010	100%-50%	63.8	0.9	2/11/2010	100%-50%
Dec 10	29.4	1.2	9/12/2010	>100%	38.6	0.8	9/12/2010	>100%	40.8	0.6	10/12/2010	>100%
Jan 11	38.0	1.6	14/01/2011	>100%	72.0	1.5	15/01/2011	100%-50%	81.0	1.1	15/01/2011	100%-50%
Feb 11	104.2	4.3	5/02/2011	5%-2%	108.6	2.3	5/02/2011	10%-20%	112.0	1.6	6/02/2011	10%-20%

Figure 7-3 086035 Eltham Rainfall Intensity-Frequency-Duration Analysis



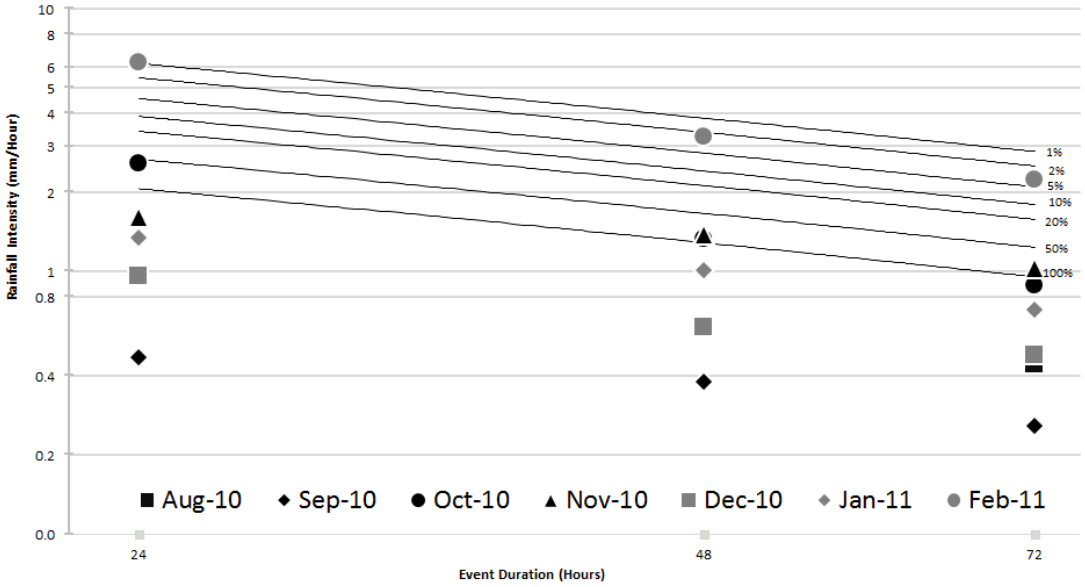
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	16.4	0.7	12/08/2010	>100%	24.0	0.5	12/08/2010	>100%	25.2	0.4	13/08/2010	>100%
Sep 10	11.6	0.5	4/09/2010	>100%	15.4	0.3	5/09/2010	>100%	17.2	0.2	6/09/2010	>100%
Oct 10	60.0	2.5	31/10/2010	50%-20%	60.0	1.3	31/10/2010	100%-50%	60.0	0.8	31/10/2010	100%-50%
Nov 10	22.8	1.0	14/11/2010	>100%	64.2	1.3	1/11/2010	100%-50%	64.8	0.9	2/11/2010	100%-50%
Dec 10	25.8	1.1	9/12/2010	>100%	28.4	0.6	10/12/2010	>100%	30.4	0.4	10/12/2010	>100%
Jan 11	24.8	1.0	14/01/2011	>100%	43.8	0.9	15/01/2011	>100%	54.8	0.8	15/01/2011	>100%
Feb 11	55.6	2.3	5/02/2011	50%-20%	58.6	1.2	5/02/2011	100%-50%	60.6	0.8	6/02/2011	100%-50%

Figure 7-4 086039 Flemington Racecourse Rainfall Intensity-Frequency-Duration Analysis



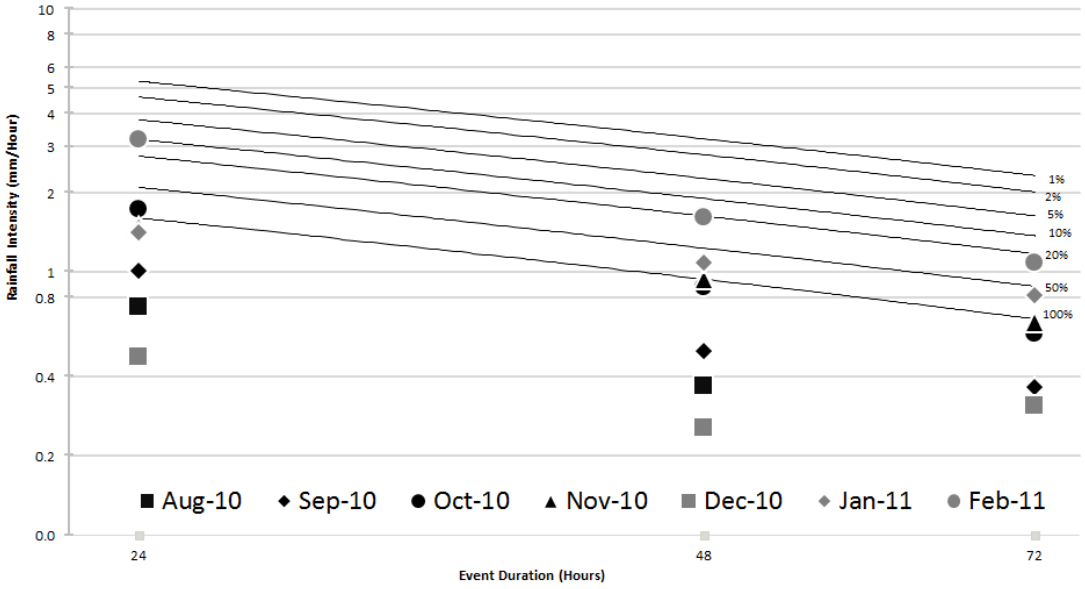
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	32.4	1.4	2/08/2010	>100%	58.6	1.2	2/08/2010	>100%	62.6	0.9	2/08/2010	>100%
Sep 10	64.6	2.7	5/09/2010	>100%	75.2	1.6	6/09/2010	>100%	84.2	1.2	7/09/2010	>100%
Oct 10	44.2	1.8	31/10/2010	>100%	44.2	0.9	31/10/2010	>100%	57.2	0.8	16/10/2010	>100%
Nov 10	52.8	2.2	28/11/2010	>100%	66.2	1.4	29/11/2010	>100%	69.6	1.0	28/11/2010	>100%
Dec 10	31.2	1.3	9/12/2010	>100%	50.2	1.0	9/12/2010	>100%	54.2	0.8	9/12/2010	>100%
Jan 11	48.4	2.0	11/01/2011	>100%	51.6	1.1	12/01/2011	>100%	73.2	1.0	13/01/2011	>100%
Feb 11	57.8	2.4	6/02/2011	>100%	109.0	2.3	6/02/2011	50%-20%	114.2	1.6	6/02/2011	100%-50%

Figure 7-5 086090 Warburton (O'Shannassy Reservoir) Rainfall Intensity-Frequency-Duration Analysis



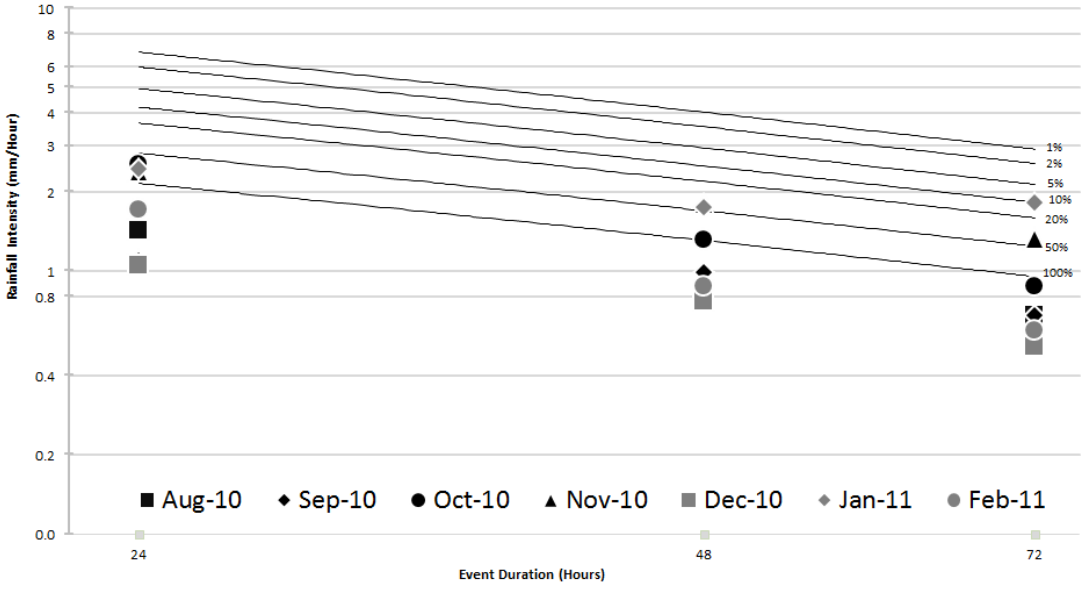
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	22.6	0.9	12/08/2010	>100%	29.4	0.6	2/08/2010	>100%	31.8	0.4	2/08/2010	>100%
Sep 10	11.2	0.5	5/09/2010	>100%	18.2	0.4	5/09/2010	>100%	18.4	0.3	7/09/2010	>100%
Oct 10	61.4	2.6	31/10/2010	100%-50%	63.4	1.3	31/10/2010	100%-50%	63.4	0.9	31/10/2010	>100%
Nov 10	38.4	1.6	28/11/2010	>100%	66.4	1.4	1/11/2010	100%-50%	73.8	1.0	28/11/2010	100%-50%
Dec 10	23.0	1.0	3/12/2010	>100%	29.4	0.6	3/12/2010	>100%	34.4	0.5	4/12/2010	>100%
Jan 11	32.2	1.3	15/01/2011	>100%	48.2	1.0	15/01/2011	>100%	51.2	0.7	15/01/2011	>100%
Feb 11	150.0	6.3	5/02/2011	<1%	156.2	3.3	6/02/2011	5%-2%	159.6	2.2	7/02/2011	5%-2%

Figure 7-6 086299 Berwick (Buchanan Road) Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	17.6	0.7	13/08/2010	>100%	17.6	0.4	13/08/2010	>100%	22.2	0.3	13/08/2010	>100%
Sep 10	24.0	1.0	4/09/2010	>100%	24.0	0.5	4/09/2010	>100%	26.0	0.4	4/09/2010	>100%
Oct 10	41.4	1.7	31/10/2010	100%-50%	41.8	0.9	31/10/2010	>100%	41.8	0.6	31/10/2010	>100%
Nov 10	35.4	1.5	25/11/2010	>100%	45.0	0.9	14/11/2010	>100%	46.4	0.6	15/11/2010	>100%
Dec 10	11.4	0.5	18/12/2010	>100%	12.2	0.3	19/12/2010	>100%	22.2	0.3	20/12/2010	>100%
Jan 11	33.6	1.4	14/01/2011	>100%	51.8	1.1	12/01/2011	100%-50%	58.4	0.8	14/01/2011	100%-50%
Feb 11	76.4	3.2	5/02/2011	10%-20%	77.4	1.6	5/02/2011	50%-20%	78.0	1.1	5/02/2011	50%-20%

Figure 7-7 087033 Little River Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	34.2	1.4	12/08/2010	>100%	40.0	0.8	13/08/2010	>100%	48.6	0.7	12/08/2010	>100%
Sep 10	26.2	1.1	4/09/2010	>100%	47.4	1.0	5/09/2010	>100%	48.6	0.7	5/09/2010	>100%
Oct 10	60.8	2.5	31/10/2010	100%-50%	62.6	1.3	31/10/2010	>100%	62.6	0.9	31/10/2010	>100%
Nov 10	57.4	2.4	28/11/2010	100%-50%	85.8	1.8	28/11/2010	50%-20%	95.6	1.3	28/11/2010	50%-20%
Dec 10	25.2	1.1	9/12/2010	>100%	36.6	0.8	9/12/2010	>100%	37.0	0.5	10/12/2010	>100%
Jan 11	58.4	2.4	14/01/2011	100%-50%	83.8	1.7	14/01/2011	50%-20%	130.2	1.8	14/01/2011	10%-20%
Feb 11	40.8	1.7	5/02/2011	>100%	41.8	0.9	5/02/2011	>100%	42.4	0.6	6/02/2011	>100%

Figure 7-8 087182 Gisborne (Rosslynne Res.) Rainfall Intensity-Frequency-Duration Analysis

7.4 Streamflow

Two separate streamflow analyses were undertaken. The first was based on information provided by the Bureau of Meteorology for flood warning gauges over the spring-summer 2010-11 period (excluding August 2010), the second based on instantaneous flow and level data obtained from DSE on 268 streamflow gauges. These analyses are summarised below in Table 7-2 to Table 7-4.

The streamflow gauge analysis for flood warning gauges included a summary of flood class levels, peak level and flood class and where available frequency of flooding. This analysis was based on information provided by the Bureau of Meteorology, with no attempt to infill missing data. The frequency of flooding was provided for gauges where a flood frequency analysis had been undertaken in the past and as documented in the Victorian Strategic Flood Intelligence Report[14]. The flood frequency analysis included in the above mentioned VICSES document includes flood frequency analysis from two distinct sources. The first source included flood frequency analysis undertaken by Thiess for the Victorian Flood Warning Station Information Manual[15], covering the majority of flood warning gauges. The second source of flood frequency analysis was for gauges analysed as part of recent flood studies. The accuracy of the flood frequencies may differ given the source and the length of data record available.

Melbourne Water provides flood forecasting and warning services for their jurisdictional area. No additional information was sought from them regarding flood warnings. This decision was made as DSE felt that many government agencies were already overburdened with requests for information, with a number of high level reviews running concurrently. It was decided that this study would utilise available gauge information only.

The DSE instantaneous streamflow gauge analysis concentrated on peak levels and flows and timing of peaks. Travel times were calculated between peaks. These travel times were found to be inconsistent in some cases (i.e. downstream gauges sometimes peaking earlier). Each case was assessed and it is likely that this was due to the spatial and temporal distribution of rainfall, the effect of storages attenuating or totally storing upstream flows, the timing of tributary flows or the occurrence of multiple peaks within a month obscuring the analysis. This analysis was only conducted on months where a significant flow event occurred (generally above Minor flood levels).

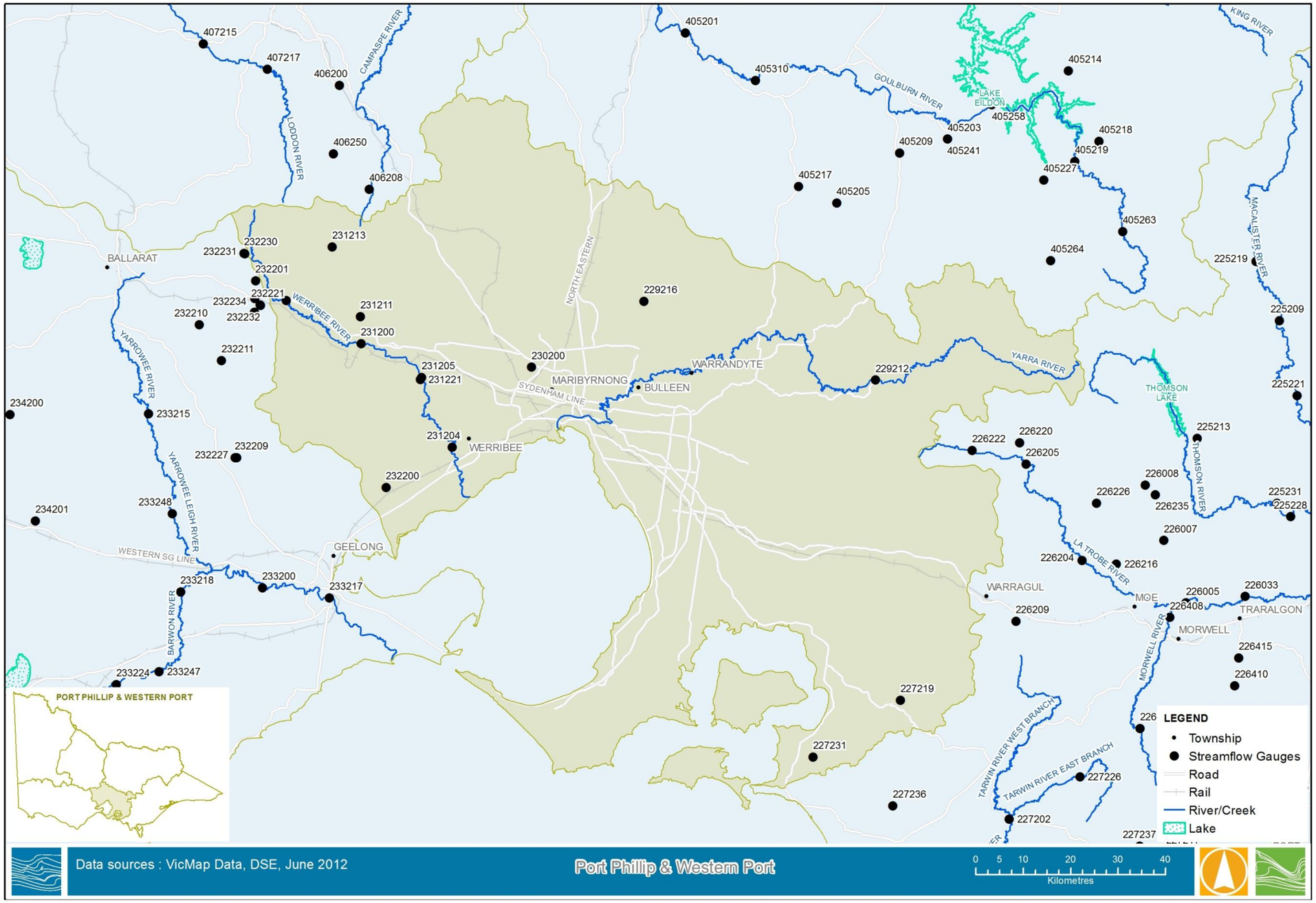


Figure 7-9 Port Phillip and Western Port region streamflow gauges analysed

Table 7-2 Werribee River Bureau of Meteorology flood warning gauge summary

River Basin		Werribee	Lederderg	Werribee
Location		Ballan	Sardine Creek	Melton Res
Flood Class Level	Minor	1.20	2.10	2.20
	Moderate	2.10	2.70	6.00
	Major	3.00	3.00	7.20
Sep-2010	Peak (m)	2.11	0.00	0.00
	Warning	Moderate	<Minor	<Minor
Oct-2010	Peak (m)	-	-	-
	Warning	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	2.31	2.53	3.53
	Warning	Moderate	Minor	Minor
Dec-2010	Peak (m)	-	-	-
	Warning	<Minor	<Minor	<Minor
Jan-2011	Peak (m)	2.78	3.87	5.24
	Warning	Moderate	Major	Minor
Feb-2011	Peak (m)	1.92	1.14	2.42
	Warning	Minor	<Minor	Minor
Historic Record	Peak (m)	-	3.80	8.40
	Date	-	Oct-2000	Oct-1983
	Start Of Record	-	1959	1965
	New Record Set	-	Yes	No
	New Record Date	-	Jan-2011	-
	Peak (m)	-	3.87	-
	Increase (m)	-	0.07	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 7-3 Yarra and Maribyrnong Rivers instantaneous flow and level gauge summary

River Basin		Plenty	Maribyrnong
Gauge Number		229216	230200
Gauge Location		Mernda	Keilor
September 2010	Date/Time of Peak	5/09/2010 4:36 AM	5/09/2010 6:45 PM
	Time Diff. (hrs)		
	Peak Level (m)	2.01	3.79
	Peak Flow (m3/s)	25	223
November 2010	Date/Time of Peak	28/11/2010 12:30 PM	28/11/2010 2:15 PM
	Time Diff. (hrs)		
	Peak Level (m)	3.11	4.49
	Peak Flow (m3/s)	92	287
December 2010	Date/Time of Peak	9/12/2010 8:48 AM	10/12/2010 12:45 AM
	Time Diff. (hrs)		
	Peak Level (m)	2.07	2.57
	Peak Flow (m3/s)	27	126
January 2011	Date/Time of Peak	15/01/2011 4:30 AM	15/01/2011 2:15 AM
	Time Diff. (hrs)		
	Peak Level (m)	1.69	5.61
	Peak Flow (m3/s)	16	423
February 2011	Date/Time of Peak	5/02/2011 7:36 PM	6/02/2011 7:00 AM
	Time Diff. (hrs)		
	Peak Level (m)	2.87	1.72
	Peak Flow (m3/s)	73	71

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

Table 7-4 Werribee River and Little River instantaneous flow and level gauge summary

River Basin		Lerderderg	Lerderderg	Werribee	Werribee	Werribee	Werribee	Little
Gauge Number		231213	231211	231225	231200	231205	231204	232200
Gauge Location		Sardine Creek Obrien Crossing	U/S Goodman Creek Junction	Ballan (U/S old Western Highway)	Bacchus Marsh	Melton Reservoir	Werribee (diversion weir)	Little River
November 2010	Date/Time of Peak	28/11/2010 3:30 AM	28/11/2010 4:45 AM	28/11/2010 6:00 AM	28/11/2010 10:45 AM	28/11/2010 10:00 AM	28/11/2010 3:30 PM	
	Time Diff. (hrs)		1		5	0	6	
	Peak Level (m)	2.55	1.99	2.40	1.36	3.54	1.57	
	Peak Flow (m3/s)	80	95	58	49	228	254	
January 2011	Date/Time of Peak	12/01/2011 5:15 PM	14/01/2011 12:00 PM	14/01/2011 4:00 PM	14/01/2011 2:15 PM	14/01/2011 6:00 PM	14/01/2011 10:00 PM	14/01/2011 5:15 AM
	Time Diff. (hrs)		43		-2	1	4	
	Peak Level (m)	1.27	3.91	2.98	2.97	5.24	2.07	3.03
	Peak Flow (m3/s)	10	421	99	213	424	480	66
February 2011	Date/Time of Peak	5/02/2011 1:00 PM	5/02/2011 11:45 AM	5/02/2011 10:45 AM	5/02/2011 10:00 AM	5/02/2011 1:30 PM	5/02/2011 8:30 PM	5/02/2011 3:30 AM
	Time Diff. (hrs)		-1		-1	0	7	
	Peak Level (m)	1.08	0.88	2.24	2.18	2.43	1.29	5.41
	Peak Flow (m3/s)	4	13	48	121	124	156	232

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to spatial and temporal distribution of rainfall and impact on tributary flows.*

7.5 Summary

The IFD analysis on rainfall across the region revealed that the AEP of all the rainfall events at the majority of rainfall gauges was generally higher than 50% AEP for the 24, 48 and 72 hour durations. The exception was February 2011 which was estimated at between 5 to 2 % at the 24 hour duration at Eltham, less than 1% AEP at Berwick for the 24 hour duration, and around 10% AEP at Little River for the 24 hour duration. For some of the storm events that caused flash flooding, where rainfall intensity is high and durations generally much less than 24 hours, it is suggested that an IFD analysis on sub-daily rainfall data may reveal storms to have AEPs less than that suggested from the daily rainfall analysis.

With a lack of flood warning information and flood frequency information for river gauging sites within the region (this data is held by Melbourne Water), a full analysis was not undertaken for this region. As discussed previously, DSE advised that this project was to utilise readily available gauge data only, as many government authorities were overburdened at the time of compiling this report with data requests for multiple high level reviews.

8. GIPPSLAND REGION HYDROLOGICAL ANALYSIS

8.1 Overview of Flooding

August 2010 – Widespread rainfall with the highest totals to the west and far east of the region. No flooding reported.

September 2010 – High rainfall totals on the ranges. 'Moderate' flood levels exceeded in the Mitchell River and 'Major' flood level exceeded at Licola on the Macalister River.

October 2010 – Widespread rainfall with high totals across the region. No known flooding issues.

November 2010 – High rainfall totals to the west of the region. 'Major' flood level exceeded on the Macalister River at Licola.

December 2010 – Widespread rainfall with the highest totals to the west and far east of the region. No flooding reported other than 'Major' flood level exceeded at Licola on the Macalister River.

January 2011 – Widespread rainfall. No flooding reported.

February 2011 – Widespread rainfall with high totals across the region. Some flash flooding observed in the west of the region around Warrigal, Longwarry and Drouin.

8.2 Regional Description

The Gippsland region includes the Genoa, Cann, Snowy, Tambo, Mitchell, Avon, Macalister, Thomson, Latrobe and South Gippsland catchments. Figure 8-1 shows the major waterways in the region.

Genoa River is located in the State's far east. It rises in New South Wales and has a predominantly forested catchment. The river flows south west through Coopracambra National Park and surrounding State forest, past the township of Genoa and enters Mallacoota inlet at Mallacoota.

The headwaters of Cann River are in the hilly slopes in the western part of Coopracambra National Park. The river flows south within a well defined valley to the Township of Cann River before entering State forest and flowing into Tamboon Inlet.

The Snowy River starts on the slopes of Mt Kosciuszko in New South Wales and drains the eastern slopes of the Snowy Mountains. The Snowy River winds its way south into Victoria and flows through the Snowy River National Park and State forest before flowing through Orbost and discharging into Bass Strait at Marlo.

The headwaters of the Tambo River are on the southern slopes of the Great Dividing Range. The river flows south through Swifts Creek, Ensay, Bruthen, and Tambo Upper before discharging into Lake King.

The Mitchell River is Victoria's largest unregulated river. Its tributaries rise on the southern side of the Great Dividing Range in an area stretching from near Mt Hotham to near Mt Buller. The river flows through the Mitchell River National Park to Glenaladale where the river turns to the east as it meets the floodplain. It flows through Bairnsdale on its way to Lake King.

The Avon, Macalister, Thomson and Latrobe rivers all flow from the southern slopes of the Great Dividing Range to Lake Wellington. The Avon River flows down a narrow valley in the Avon Wilderness Park to Valencia Creek and on to Stratford before flowing into Lake Wellington. The Macalister River flows down a relatively narrow valley before flowing into Lake Glenmaggie. From here the river flows south east through Maffra before it joins with the Thomson River north of Sale. The Thomson River flows into Lake Thomson from the north. It then continues in a south easterly direction through Hayfield, joins with the Macalister River upstream of Sale and flows into the

Latrobe River at Longford. The Latrobe River flows west from the Bunyip State Park through the Latrobe Valley, past Moe and into Lake Narracan. The river then continues east past Traralgon, Rosedale and Longford (where it joins with the Thomson River) and into Lake Wellington.

The South Gippsland catchment contains a number of smaller creeks and rivers. It covers an area from the Bass River in the west which discharges into Westernport Bay at Bass, to Merriman Creek in the east which flows into Bass Strait at Seaspray. The main waterways in this catchment are the Bass, Powlett, Tarwin, Franklin, Anges, Albert, Jack, and Tarra rivers together with Merriman and other significant creeks.

Many of the rivers mentioned above flow into the Gippsland Lakes, a series of connected lakes spanning from Lake Wellington in the west (near Sale) to Lakes Entrance in the east. At Lakes Entrance the lakes are now permanently open to the sea to allow boat passage with a seawall and regular dredging required to maintain the entrance condition. The Gippsland Lakes are subject to both riverine flooding from the tributary inflows and also oceanic forcing, meaning that the Gippsland Lakes are at a high flood risk.

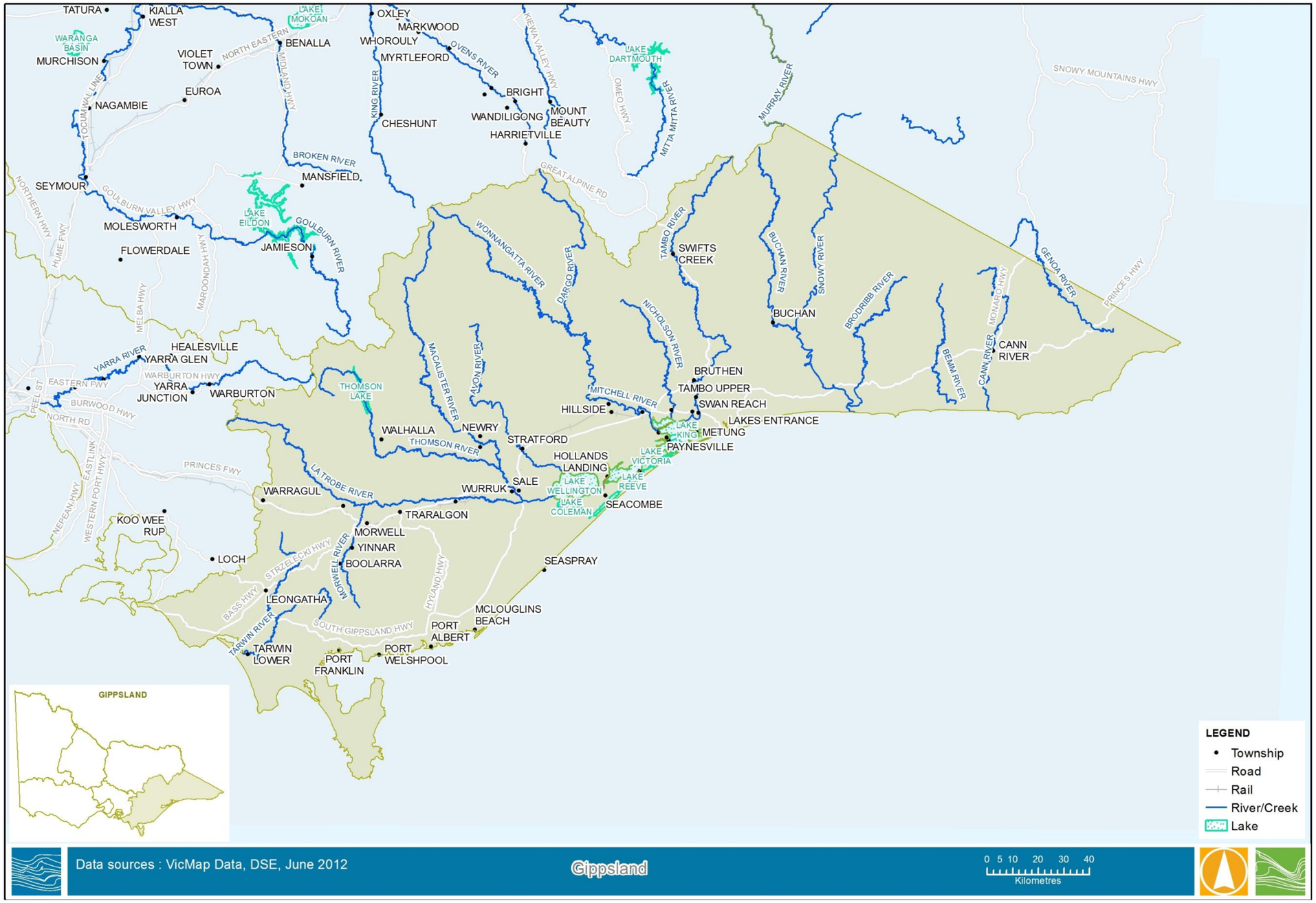


Figure 8-1 Gippsland region

8.3 Rainfall

Section 2.1 provides a broad overview of the synoptic conditions that produced the rainfall events over the spring-summer 2010-11 period. This Section includes more detail about specific rainfall gauges within the Gippsland region. It should be noted that daily rainfall gauges typically record rainfall totals over a 24 hour period to 9 am on the date recorded.

Table 8-1 below summarises the maximum daily rainfall and monthly totals for numerous rainfall gauges across the region and compares it against the historical monthly average over the spring-summer period as well as against the historical monthly and daily maximum rainfall totals. A high proportion of the gauges selected for analysis broke daily and monthly maximum rainfall records during the spring-summer 2010-11 period.

For a selected number of gauges an Intensity-Frequency-Duration (IFD) analysis was undertaken on the daily rainfall totals at 24, 48 and 72 hour durations. Using the geographical coordinates for the rainfall gauges analysed, the raw polynomial coefficients were taken from the Bureau of Meteorology's online IFD Data System[13], and used as input to an IFD spreadsheet tool developed by Water Technology, plotting the IFD curves for the rainfall gauge site. This was overlayed with the maximum 24, 48 and 72 hour rainfall totals for each month.

The gauges selected were chosen to provide a spread across the region with preference for gauges in proximity to areas of significant flooding. Note that the frequency attributed to the rainfall event does not necessarily correspond to the frequency of the flood event due to antecedent catchment conditions, timing of tributary flows etc. It must also be noted that the frequency of the event may differ when durations shorter than 24 hours are considered, however with daily rainfall gauges these shorter durations can not be assessed. Figure 8-3 to Figure 8-8 below show the IFD analysis undertaken.

Figure 8-2 below shows the location of the rainfall gauges analysed for both daily and monthly totals and also those gauges where IFD analysis was completed.

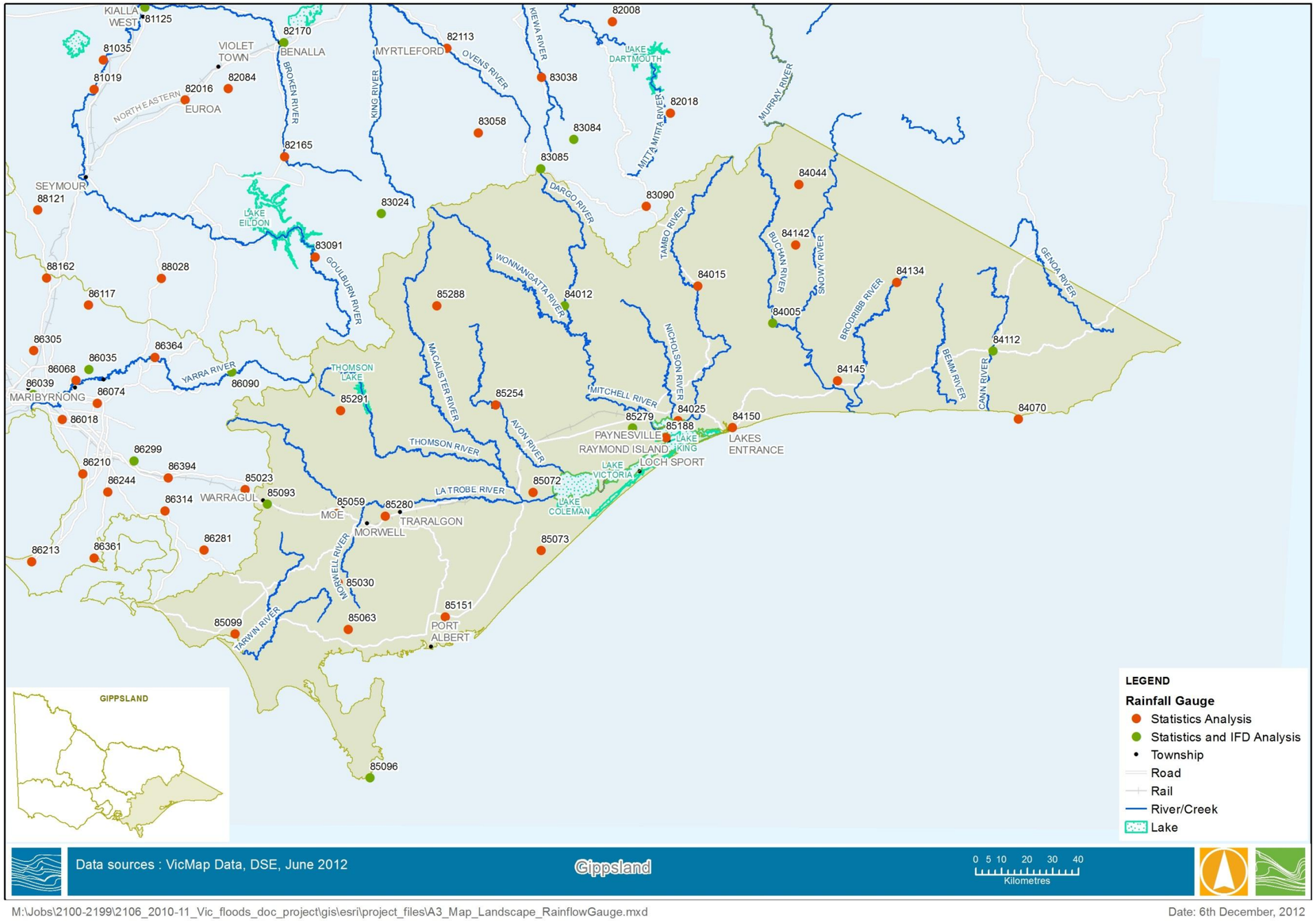
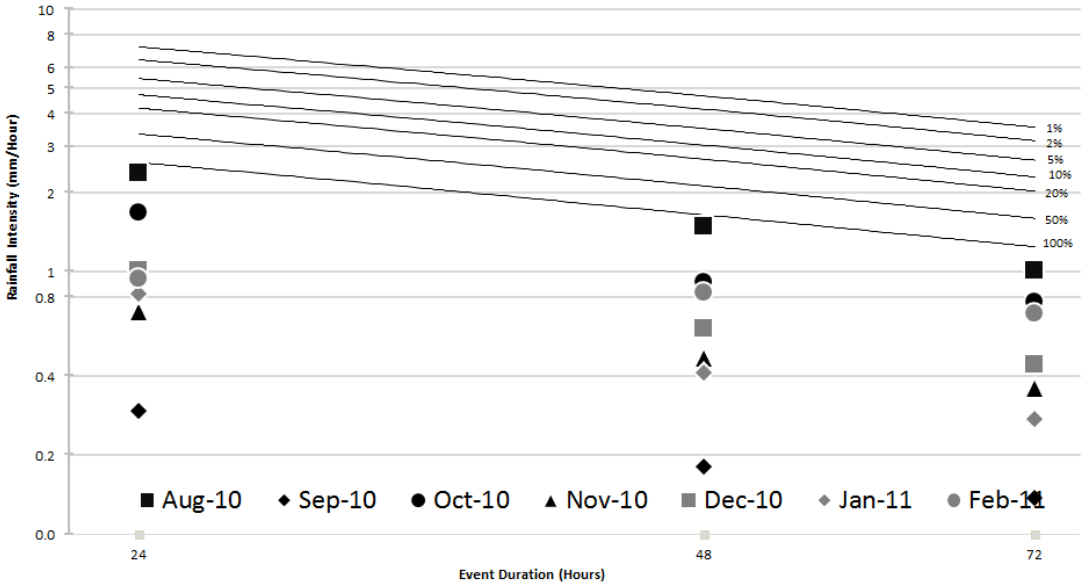


Figure 8-2 Gippsland region rainfall gauges analysed

Table 8-1 Gippsland region observed rainfall summary

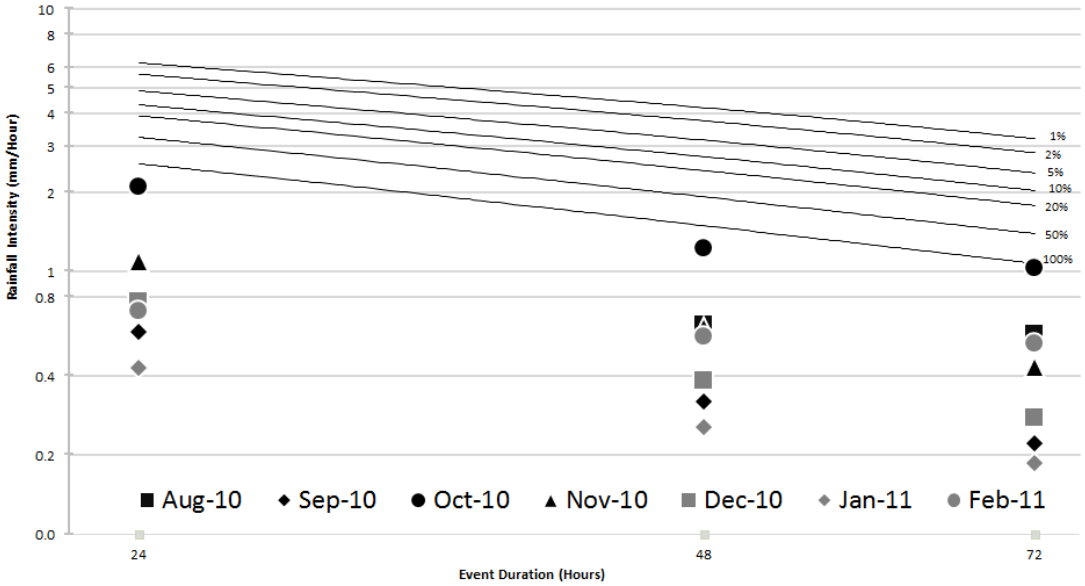
Location	Station Number	August 2010		September 2010		October 2010		November 2010		December 2010		January 2011		February 2011		Record Statistics			
		Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Total	Daily Max.	Monthly Avg.	Monthly Max.	Daily Max.	Start of record
Bairnsdale Airport	85279	50.2	12.8 (2nd)	25.6	7.4 (2nd)	93.6	39.2 (16th)	55.6	24.8 (28th)	92.2	25.8 (9th)	31.2	5.0 (25th)	76.6	20.6 (6th)	36.4-81.9	322.6 (Jun 2007)	119.9 (15/05/1944)	1942
Black Mountain	84044	98.4	48.6 (3rd)	29	9.8 (2nd)	112.6	53.0 (16th)	62	16.4 (8th)	141	27.8 (9th)	41.2	16.6 (10th)	119.6	24.0 (5th)	48.3-78.3	223.3 (Jan 1934)	85.4 (24/06/1998)	1920
Boolarra South	85030	156	27.6 (2nd)	101.4	17.2 (5th)	118.4	24.6 (31st)	11.2	45.2 (28th)	121.2	18.8 (9th)	59.6	16.0 (12th)	181.2	65.0 (5th)	62.5-120.8	195.0 (Jun 2007)	83.8 (03/02/2005)	2002
Buchan	84005	128	56.8 (3rd)	28.2	7.0 (2nd)	111.6	40.2 (16th)	63.4	16.8 (27th)	105	24.0 (9th)	49	18.1 (26th)[1]	96.2	22.4 (5th)	58.8-78.6	360.4 (Dec 1893)	161.3 (28/01/1920)	1883
Cann River	84112	116.9	41.2 (13th)	27.4	5.8 (11th)	84.9	26.8 (16th)	48	9.0 (15th)	103.6	31.6 (9th)	38.8	11.2 (23rd)	78.2	13.6 (18th)	58.9-95.5	374.8 (Jun 1978)	132.4 (17/11/1988)	1973
Dargo	84012	92.2	18.6 (12th)	35.2	14.0 (2nd)	113.8	50.0 (16th)	102.9	26.2 (28th)	55.5	18.4 (9th)	41.8	10.2 (26th)	91.4	16.8 (6th)	49.9-78.3	257.8 (Jun 1998)	132.2 (22/04/1990)	1939
East Sale Airport	85072	40	9.0 (2nd)	15.6	2.2 (11th)	60.4	22.2 (16th)	64	40.4 (28th)	83	36.4 (9th)	39.4	12.0 (13th)	96.8	35.0 (5th)	41.4-63.8	204.6 (Sep 1993)	112.8 (19/02/1951)	1943
Ensay	84015	74.8	27.4 (3rd)	29.4	11.4 (24th)	91.4	41.0 (16th)	63.6	15.0 (14th)	102.8	30.0 (9th)	28	10.0 (26th)	85.4	27.0 (6th)	48.3-74.7	337.6 (Jun 1998)	118.4 (28/01/1920)	1909
Gelantipy	84142	140.2	82.8 (3rd)	37.6	10.8 (2nd)	136.8	64.6 (16th)	64.8	6.8 (3rd)	131.8	39.4 (9th)	33	12.2 (10th)	124.4	12.2 (10th)	51.4-98.7	274.2 (Jul 2011)	98.6 (10/07/2005)	1992
Goongerah	84134	154.6	85.6 (3rd)	37.2	8.6 (7th)	88	41.8 (16th)	59.4	13.0 (29th)	107.4	34.0 (9th)	22.6	5.4 (26th)	97.6	23.6 (5th)	62.0-107.2	356.8 (Nov 1988)	170.6 (17/11/1988)	1980
Lakes Entrance (Eastern Beach Road)	84150	84.7	18.9 (2nd)	33	6.0 (2nd)	136.8	43.6 (14th)	66.4	20.6 (28th)	68.6	16.2 (20th)	35	9.8 (23rd)	83.6	17.4 (6th)	28.4-88.9	297.6 (Jun 2007)	77.8 (19/06/2007)	2006
Moe Gippsland Water	85059	109.5	38.0 (2nd)	83.5	14.0 (5th)	124.1	27.0 (16th)	82.7	37.8 (28th)	108.2	23.0 (20th)	44.4	11.5 (13th)	164.1	24.8 (19th)	55.0-96.6	310.0 (Jun 1952)	123.6 (23/03/2011)	1897
Morwell (Latrobe Valley Airport)	85280	66.8	24.2 (2nd)	52.8	7.6 (2nd)	92.6	24.8 (16th)	86.8	35.4 (28th)	75.6	20.4 (8th)	44	12.2 (14th)	145	53.4 (5th)	46.2-77.3	203.2 (Dec 1985)	70.0 (12/04/2011)	1984
Mount Baw Baw	85291	255	42.4 (12th)	148	25.8 (5th)	184.2	36.8 (16th)	163	47.8 (28th)	188	43.8 (20th)	56.4	13.6 (15th)	198	51.8 (6th)	94.7-161.5	376.4 (Sep 2009)	161.0 (03/02/2005)	1991
Mount Best (Upper Toora)	85063	146.4	26.0 (2nd)	83	17.2 (5th)	99.8	21.0 (16th)	100.6	42.6 (28th)	151.8	45.2 (3rd)	70.8	14.2 (11th)	131.2	56.8 (5th)	64.8-116.0	502.5 (Jun 1952)	181.6 (22/03/1983)	1903
Mount Tamboritha	85288	121.6	19.6 (3rd)	83.6	32.4 (5th)	123.2	49.6 (16th)	201.6	62.6 (27th)	124.4	59.2 (9th)	75.4	22.0 (13th)	149.8	26.0 (4th)	54.1-94.0	361.2 (Apr 1990)	180.6 (22/04/1990)	1989
Nicholson (Yendalock)	84025	60	14.4 (3rd)	21.4	5.0 (2nd)	101.4	36.2 (16th)	52.2	20.4 (14th)	75.2	17.4 (9th)	34.2	7.4 (23rd)	78	15.0 (6th)	45.2-65.8	330.5 (Dec 1935)	152.9 (26/12/1935)	1905
Orbost	84145	93.6	47.8 (3rd)	33.2	9.2 (7th)	97.2	39.8 (16th)	43.6	12.6 (28th)	127.4	32.6 (20th)	34.4	8.4 (26th)	101.6	24.4 (5th)	39.2-77.4	303.2 (Jun 2007)	88.0 (11/08/2011)	2000
Paynesville	85188	72.2	13.1 (3rd)	27.4	7.6 (2nd)	126.4	32.0 (16th)	58.6	24.0 (28th)	74.2	20.6 (9th)	36.2	6.4 (12th)	62.2	16.4 (6th)	44.7-71.8	340.6 (Jun 1998)	185.0 (24/06/1998)	1969
Point Hicks (Lighthouse)	84070	80.6	20.8 (3rd)	40.8	10.6 (30th)	78	33.2 (16th)	83.2	16.6 (14th)	113.2	35.0 (9th)	35.6	13.8 (23rd)	71.2	13.8 (6th)	58.6-105.2	349.1 (May 1978)	249.0 (20/05/1978)	1962
Pound Creek	85099	123.8	28.4 (2nd)	69	9.2 (5th)	102.6	35.0 (31st)	72	26.0 (28th)	75	19.8 (12th)	39.6	12.2 (15th)	114	43.0 (5th)	34.0-96.6	126.8 (Aug 2009)	44.6 (22/12/2007)	2007
Seaspray (Burong)	85073	51.2	12.0 (11th)	16.8	3.0 (4th)	60.8	22.6 (16th)	65	35.0 (28th)	67.4	27.0 (9th)	36.4	10.4 (15th)	100	33.4 (5th)	41.7-57.6	239.2 (Mar 1906)	148.6 (30/06/1967)	1898
Valencia Creek (Little Plain)	85254	56.8	18.2 (12th)	22	8.8 (2nd)	84.8	30.4 (14th)	81	42.6 (28th)	73.3	27.4 (9th)	50.2	11.0 (13th)	73.8	22.0 (6th)	41.7-78.8	258.2 (Apr 1990)	109.4 (03/02/2005)	1974
Warragul	85093	150.6	32.2 (2nd)	98	23.0 (5th)	132	37.0 (31st)	107.2	35.4 (28th)	129	34.0 (9th)	58	12.4 (15th)	197.4	88.0 (5th)	52.7-106.1	258.9 (Apr 1935)	189.7 (01/12/1934)	1888
Willsons Promontory Lighthouse	85096	240	42.0 (25th)	94.2	21.4 (7th)	72.2	15.6 (7th)	111.2	32.6 (28th)	108.2	30.6 (9th)	52	9.6 (12th)	114	61.4 (19th)	47.0-122.1	499.5 (Mar 1941)	123.2 (20/05/1988)	1872
Yarram Airport	85151	78.8	27.6 (11th)	27.8	4.2 (29th)	51.4	12.6 (16th)	105.6	59.2 (28th)	68	22.6 (20th)	44.4	17.2 (10th)	106	45.8 (5th)	32.5-94.9	121.4 (Mar 2011)	71.0 (23/03/2011)	2007

[1] *Note: Gauge recordings were aggregated over a number of days. Daily totals were disaggregated using the daily rainfall pattern from the nearest gauge of complete record.*
[2] *Note: Records of data were incomplete for the month. The total and highest daily rainfall cannot be determined using incomplete data.*
[3] *Note: Gauge broke daily or monthly statistical records over the period.*
[4] *Note: Analysis carried out early May 2012, any events after that not captured in historical records columns.*



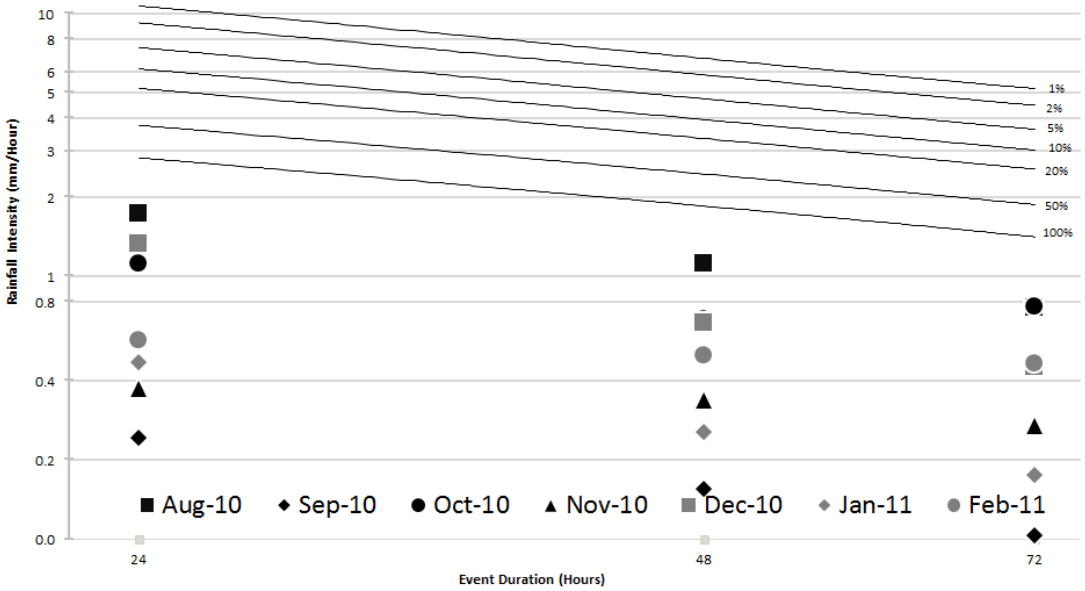
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	56.8	2.4	3/08/2010	>100%	70.8	1.5	3/08/2010	>100%	72.0	1.0	3/08/2010	>100%
Sep 10	7.0	0.3	2/09/2010	>100%	8.6	0.2	2/09/2010	>100%	9.8	0.1	4/09/2010	>100%
Oct 10	40.2	1.7	16/10/2010	>100%	43.4	0.9	17/10/2010	>100%	55.2	0.8	16/10/2010	>100%
Nov 10	16.8	0.7	27/11/2010	>100%	22.4	0.5	28/11/2010	>100%	25.8	0.4	28/11/2010	>100%
Dec 10	24.0	1.0	9/12/2010	>100%	29.0	0.6	20/12/2010	>100%	31.8	0.4	21/12/2010	>100%
Jan 11	19.6	0.8	26/01/2011	>100%	19.6	0.4	26/01/2011	>100%	19.6	0.3	26/01/2011	>100%
Feb 11	22.4	0.9	5/02/2011	>100%	39.8	0.8	6/02/2011	>100%	49.4	0.7	6/02/2011	>100%

Figure 8-3 084005 Buchan Rainfall Intensity-Frequency-Duration Analysis



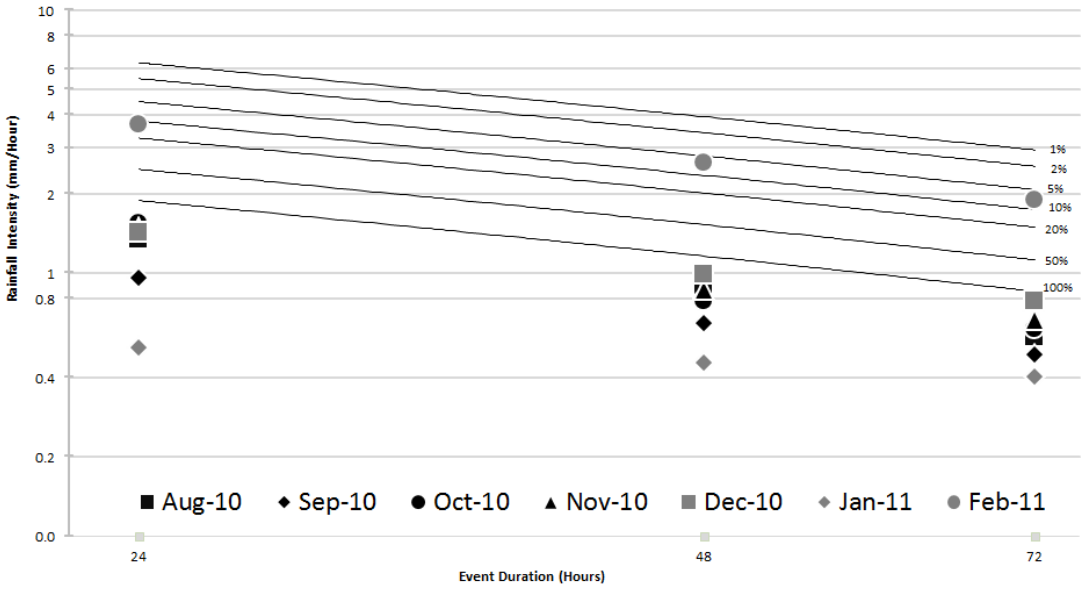
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	18.6	0.8	12/08/2010	>100%	30.0	0.6	3/08/2010	>100%	41.2	0.6	3/08/2010	>100%
Sep 10	14.0	0.6	2/09/2010	>100%	15.2	0.3	3/09/2010	>100%	15.8	0.2	4/09/2010	>100%
Oct 10	50.0	2.1	16/10/2010	>100%	58.6	1.2	16/10/2010	>100%	74.0	1.0	16/10/2010	>100%
Nov 10	26.2	1.1	28/11/2010	>100%	29.2	0.6	15/11/2010	>100%	31.2	0.4	16/11/2010	>100%
Dec 10	18.4	0.8	9/12/2010	>100%	18.4	0.4	9/12/2010	>100%	19.8	0.3	9/12/2010	>100%
Jan 11	10.2	0.4	26/01/2011	>100%	12.2	0.3	26/01/2011	>100%	13.4	0.2	27/01/2011	>100%
Feb 11	16.8	0.7	6/02/2011	>100%	27.0	0.6	6/02/2011	>100%	38.0	0.5	6/02/2011	>100%

Figure 8-4 084012 Dargo Rainfall Intensity-Frequency-Duration Analysis



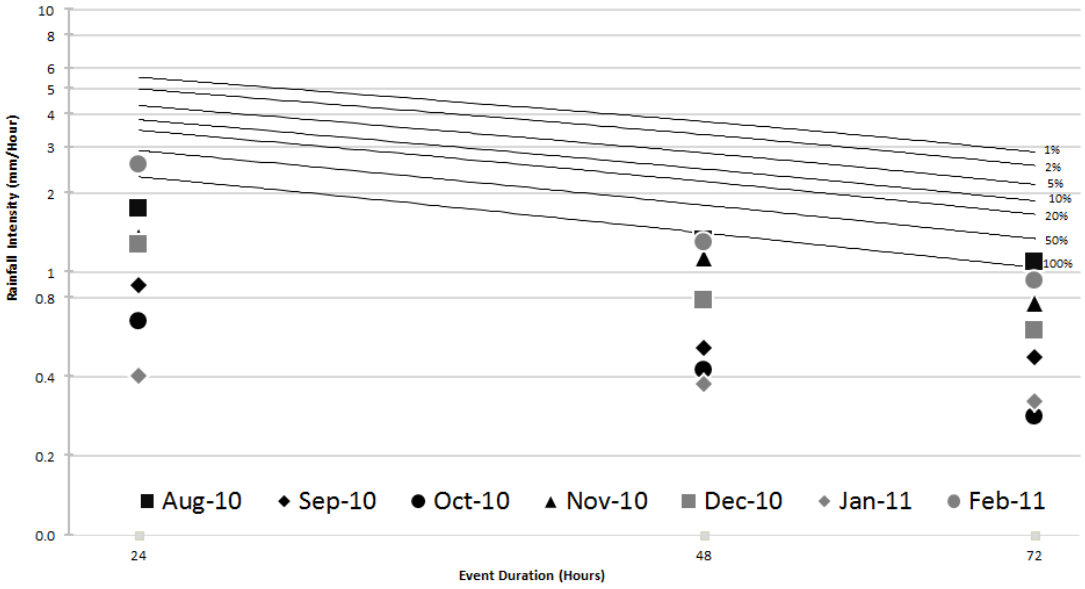
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	41.2	1.7	13/08/2010	>100%	53.2	1.1	13/08/2010	>100%	54.6	0.8	13/08/2010	>100%
Sep 10	5.8	0.2	11/09/2010	>100%	7.4	0.2	11/09/2010	>100%	7.4	0.1	11/09/2010	>100%
Oct 10	26.8	1.1	16/10/2010	>100%	32.8	0.7	16/10/2010	>100%	55.2	0.8	16/10/2010	>100%
Nov 10	9.0	0.4	15/11/2010	>100%	16.2	0.3	15/11/2010	>100%	19.4	0.3	16/11/2010	>100%
Dec 10	31.6	1.3	9/12/2010	>100%	31.6	0.7	9/12/2010	>100%	32.4	0.5	11/12/2010	>100%
Jan 11	11.2	0.5	23/01/2011	>100%	12.2	0.3	27/01/2011	>100%	12.6	0.2	27/01/2011	>100%
Feb 11	13.6	0.6	18/02/2011	>100%	23.8	0.5	5/02/2011	>100%	33.2	0.5	6/02/2011	>100%

Figure 8-5 084115 Cann River Rainfall Intensity-Frequency-Duration Analysis



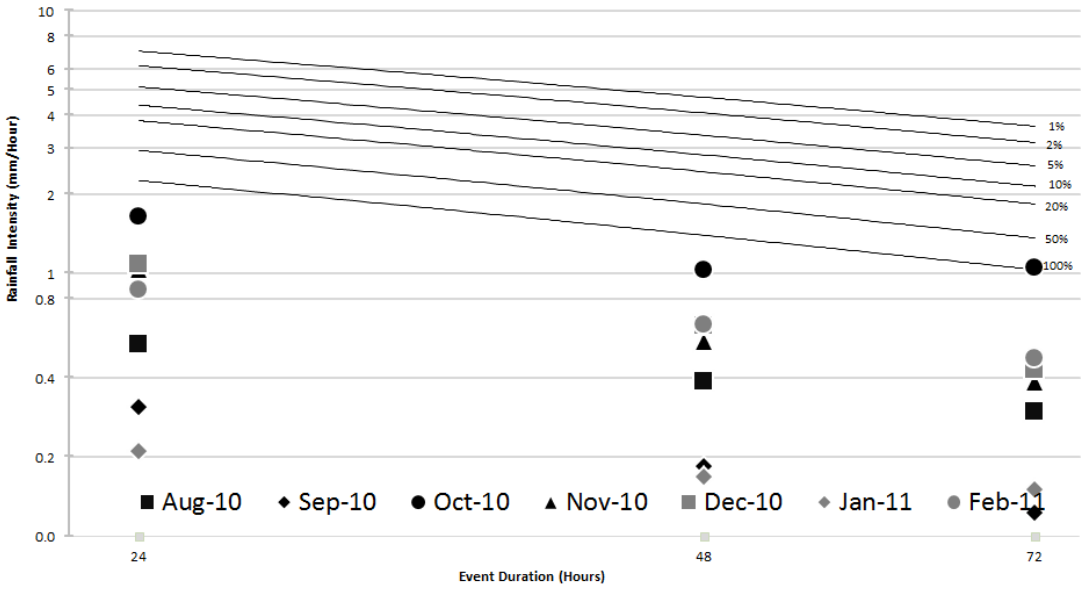
Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	32.2	1.3	2/08/2010	>100%	39.8	0.8	2/08/2010	>100%	40.8	0.6	2/08/2010	>100%
Sep 10	23.0	1.0	5/09/2010	>100%	30.8	0.6	6/09/2010	>100%	35.2	0.5	7/09/2010	>100%
Oct 10	37.0	1.5	31/10/2010	>100%	37.4	0.8	31/10/2010	>100%	43.8	0.6	16/10/2010	>100%
Nov 10	35.4	1.5	28/11/2010	>100%	41.6	0.9	1/11/2010	>100%	47.6	0.7	28/11/2010	>100%
Dec 10	34.0	1.4	9/12/2010	>100%	47.4	1.0	10/12/2010	>100%	56.0	0.8	10/12/2010	>100%
Jan 11	12.4	0.5	15/01/2011	>100%	21.8	0.5	15/01/2011	>100%	29.0	0.4	15/01/2011	>100%
Feb 11	88.0	3.7	5/02/2011	10%-20%	125.4	2.6	6/02/2011	10%-5%	135.6	1.9	6/02/2011	10%-5%

Figure 8-6 085093 Warragul Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	42.0	1.8	25/08/2010	>100%	63.4	1.3	26/08/2010	>100%	78.4	1.1	27/08/2010	100%-50%
Sep 10	21.4	0.9	7/09/2010	>100%	24.6	0.5	7/09/2010	>100%	34.0	0.5	7/09/2010	>100%
Oct 10	15.6	0.7	7/10/2010	>100%	20.2	0.4	8/10/2010	>100%	20.2	0.3	8/10/2010	>100%
Nov 10	32.6	1.4	28/11/2010	>100%	54.4	1.1	14/11/2010	>100%	54.8	0.8	15/11/2010	>100%
Dec 10	30.6	1.3	9/12/2010	>100%	37.4	0.8	9/12/2010	>100%	43.2	0.6	10/12/2010	>100%
Jan 11	9.6	0.4	12/01/2011	>100%	18.0	0.4	13/01/2011	>100%	23.0	0.3	14/01/2011	>100%
Feb 11	61.4	2.6	19/02/2011	100%-50%	62.2	1.3	19/02/2011	>100%	66.8	0.9	21/02/2011	>100%

Figure 8-7 085096 Wilson Promontory Lighthouse Rainfall Intensity-Frequency-Duration Analysis



Month	24 hour event				48 hour event				72 hour event			
	Rainfall (mm)	Rainfall (mm/hr)	24 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	48 hours to 9am	AEP	Rainfall (mm)	Rainfall (mm/hr)	72 hours to 9am	AEP
Aug 10	12.8	0.5	2/08/2010	>100%	18.6	0.4	12/08/2010	>100%	21.4	0.3	13/08/2010	>100%
Sep 10	7.4	0.3	2/09/2010	>100%	8.8	0.2	2/09/2010	>100%	8.8	0.1	2/09/2010	>100%
Oct 10	39.2	1.6	16/10/2010	>100%	49.0	1.0	16/10/2010	>100%	75.2	1.0	16/10/2010	100%-50%
Nov 10	24.8	1.0	28/11/2010	>100%	26.4	0.6	28/11/2010	>100%	27.8	0.4	28/11/2010	>100%
Dec 10	25.8	1.1	9/12/2010	>100%	30.2	0.6	10/12/2010	>100%	30.8	0.4	10/12/2010	>100%
Jan 11	5.0	0.2	25/01/2011	>100%	8.0	0.2	13/01/2011	>100%	10.8	0.2	14/01/2011	>100%
Feb 11	20.6	0.9	6/02/2011	>100%	30.4	0.6	6/02/2011	>100%	34.0	0.5	6/02/2011	>100%

Figure 8-8 085279 Bairnsdale Airport Rainfall Intensity-Frequency-Duration Analysis

8.4 Streamflow

Two separate streamflow analyses were undertaken. The first was based on information provided by the Bureau of Meteorology for flood warning gauges over the spring-summer 2010-11 period (excluding August 2010), the second based on instantaneous flow and level data obtained from DSE on 268 streamflow gauges. These analyses are summarised below in Table 8-2 to Table 8-11.

The streamflow gauge analysis for flood warning gauges included a summary of flood class levels, peak level and flood class and where available frequency of flooding. This analysis was based on information provided by the Bureau of Meteorology, with no attempt to infill missing data. The frequency of flooding was provided for gauges where a flood frequency analysis had been undertaken in the past and as documented in the Victorian Strategic Flood Intelligence Report[14]. The flood frequency analysis included in the above mentioned VICSES document includes flood frequency analysis from two distinct sources. The first source included flood frequency analysis undertaken by Thiess for the Victorian Flood Warning Station Information Manual[15], covering the majority of flood warning gauges. The second source of flood frequency analysis was for gauges analysed as part of recent flood studies. The accuracy of the flood frequencies may differ given the source and the length of data record available.

The DSE instantaneous streamflow gauge analysis concentrated on peak levels and flows and timing of peaks. Travel times were calculated between peaks. These travel times were found to be inconsistent in some cases (i.e. downstream gauges sometimes peaking earlier). Each case was assessed and it is likely that this was due to the spatial and temporal distribution of rainfall, the effect of storages attenuating or totally storing upstream flows, the timing of tributary flows or the occurrence of multiple peaks within a month obscuring the analysis. This analysis was only conducted on months where a significant flow event occurred (generally above Minor flood levels).

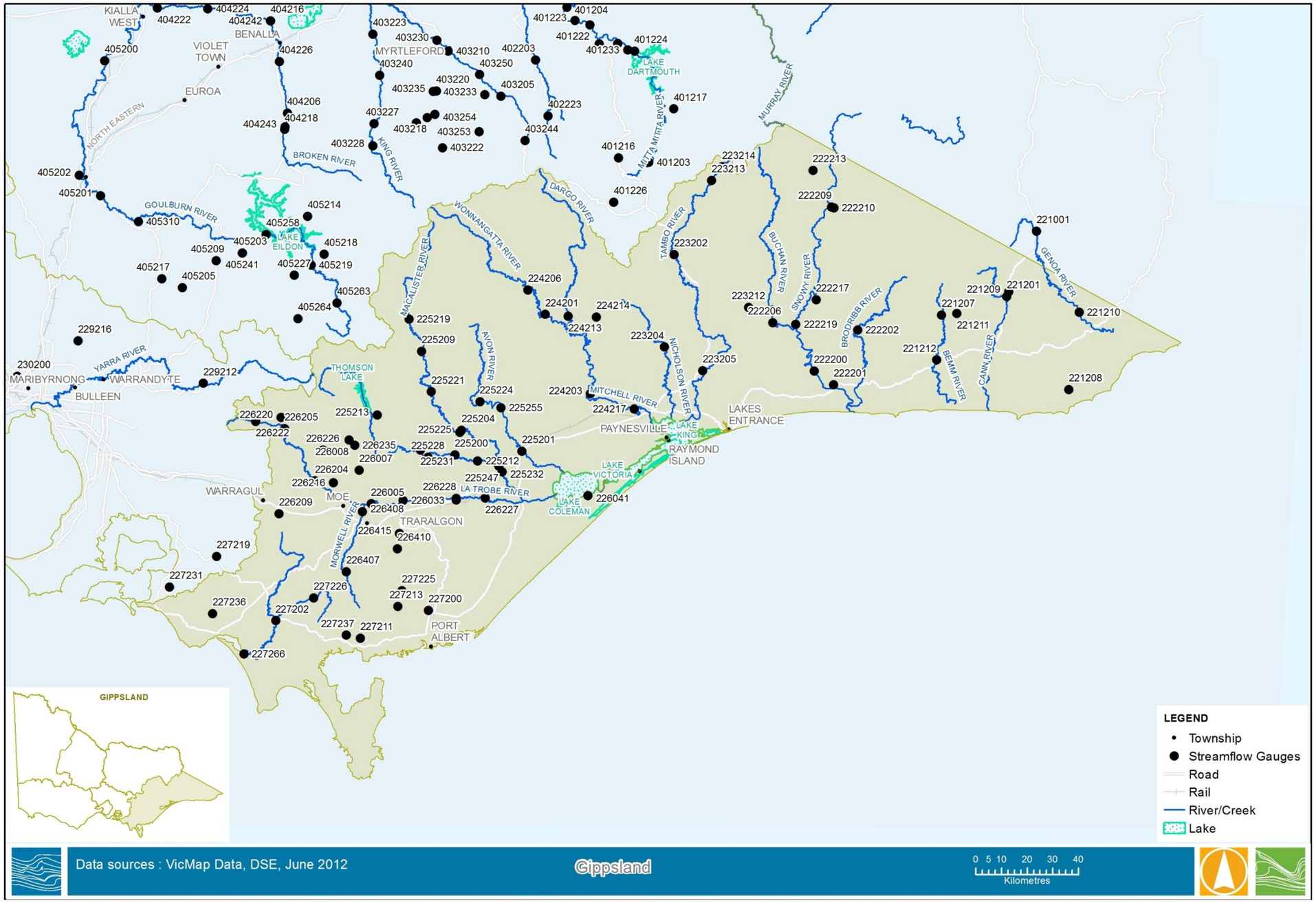


Figure 8-9 Gippsland region streamflow gauges analysed

Table 8-2 Cann and Genoa Rivers Bureau of Meteorology flood warning gauge summary

River Basin		Cann East Branch	Cann West Branch	Genoa
Location		Chandlers Creek	Weeragua	The Gorge
Flood Class Level	Minor	2.00	3.00	2.20
	Moderate	2.30	3.50	3.20
	Major	2.80	4.00	4.40
Sep-2010	Peak (m)	-	-	-
	Warning	<Minor	<Minor	<Minor
Oct-2010	Peak (m)	-	-	-
	Warning	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	-	-	-
	Warning	<Minor	<Minor	<Minor
Dec-2010	Peak (m)	-	-	-
	Warning	<Minor	<Minor	<Minor
Jan-2011	Peak (m)	-	-	-
	Warning	<Minor	<Minor	<Minor
Feb-2011	Peak (m)	-	-	-
	Warning	<Minor	<Minor	<Minor
Historic Record	Peak (m)	3.74	4.68	4.84
	Date	Jun-1978	Jun-1998	Jun-1978
	Start Of Record	1972	1957	1972
	New Record Set	No	No	No
	New Record Date	-	-	-
	Peak (m)	-	-	-
	Increase (m)	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 8-3 Snowy River Bureau of Meteorology flood warning gauge summary

River Basin		Bombala	Snowy	Buchan	Snowy	Snowy	Snowy
Location		Bombala	McKillop's Bridge	Buchan	Basin Creek	Jarrahmond	Orbost
Flood Class Level	Minor	3.00	2.50	2.50	3.50	3.90	4.00
	Moderate	5.00	6.00	3.50	5.50	6.20	6.00
	Major	8.00	8.00	4.00	6.60	7.40	7.00
Sep-2010	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Oct-2010	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Dec-2010	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Jan-2011	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Feb-2011	Peak (m)	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Historic Record	Peak (m)	4.63	10.58	3.05	9.70	7.90	9.40
	Date	Jun-1997	Jun-1978	Apr-1950	Jul-1991	Jun-1974	Feb-1971
	Start Of Record	1995	1975	1904	1978		1969
	New Record Set	Yes	No	No	No	No	No
	New Record Date	Mar-2011	-	-	-	-	-
	Peak (m)	7.04	-	-	-	-	-
	Increase (m)	2.41	-	-	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 8-4 Mitchell River Bureau of Meteorology flood warning gauge summary

River Basin		Wonnongatta	Mitchell	Mitchell
Location		Waterford	Glenaladale	Bairnsdale
Flood Class Level	Minor	3.50	3.00	4.00
	Moderate	4.50	4.50	5.50
	Major	-	5.50	6.50
Sep-2010	Peak (m)	6.17	5.16	6.36
	Warning	Moderate	Moderate	Moderate
	AEP (%)	~10%	~20%	
Oct-2010	Peak (m)	-		-
	Warning	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	-		-
	Warning	<Minor	<Minor	<Minor
Dec-2010	Peak (m)	4.32	3.40	4.56
	Warning	Minor	Minor	Minor
Jan-2011	Peak (m)	-		-
	Warning	<Minor	<Minor	<Minor
Feb-2011	Peak (m)	-		-
	Warning	<Minor	<Minor	<Minor
Historic Record	Peak (m)	8.55	7.92	7.84
	Date	Apr-1990	Jun-1998	Apr-1990
	Start Of Record	1965	1937	
	New Record Set	No	No	No
	New Record Date	-	-	-
	Peak (m)	-	-	-
	Increase (m)	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 8-5 Macalister and Avon Rivers Bureau of Meteorology flood warning gauge summary

River Basin		Macalister	Macalister	Avon	Avon
Location		Licola	Lake Glenmaggie D/S	The Channel	Stratford
Flood Class Level	Minor	-	2.30	5.00	4.50
	Moderate	-	4.20	6.90	6.00
	Major	-	5.20	7.50	6.50
Sep-2010	Peak (m)	3.57	4.05	-	-
	Warning	Major	Minor	<Minor	<Minor
	AEP (%)	~10%			
Oct-2010	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	2.99	2.58	-	-
	Warning	Major	Minor	<Minor	<Minor
Dec-2010	Peak (m)	3.32	2.44	-	-
	Warning	Major	Minor	<Minor	<Minor
	AEP (%)	20-10%			
Jan-2011	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Feb-2011	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Historic Record	Peak (m)	3.83	8.64	11.23	9.00
	Date	Apr-1990	Jan-1971	Apr-1990	Apr-1990
	Start Of Record	1952		1972	1976
	New Record Set	No	No	No	No
	New Record Date	-	-	-	-
	Peak (m)	-	-	-	-
	Increase (m)	-	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 8-6 Thomson River Bureau of Meteorology flood warning gauge summary

River Basin		Thomson	Thomson	Thomson	Thomson
Location		Cooper's Creek	U/S Cowwarr Weir	Wandocka	Sale Warf
Flood Class Level	Minor	2.30	3.65	6.20	2.40
	Moderate	3.50	4.50	6.50	3.00
	Major	5.00	5.50	6.70	4.00
Sep-2010	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Oct-2010	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Dec-2010	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Jan-2011	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Feb-2011	Peak (m)	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor
Historic Record	Peak (m)	6.40	8.89	6.90	-
	Date	Jun-1978	Jun-1978	Apr-1990	-
	Start Of Record	1972	1976	1963	-
	New Record Set	No	No	No	-
	New Record Date	-	-	-	-
	Peak (m)	-	-	-	-
	Increase (m)	-	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report*[14].

Table 8-7 Latrobe River Bureau of Meteorology flood warning gauge summary

River Basin		Latrobe	Moe	Tanjil	Tanjil	Latrobe	Traralgon	Latrobe
Location		Willowgrove	Darnum	Tanjil Junction	Tanjil South	Thom's Bridge	Traralgon	Rosedale
Flood Class Level	Minor	5.50	3.50	1.50	2.50	4.00	3.50	4.00
	Moderate	-	4.30	2.50	3.00	5.00	4.00	4.80
	Major	-	4.60	3.50	3.50	6.50	4.50	5.50
Sep-2010	Peak (m)	-	-	-	-	3.82	-	3.99
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Oct-2010	Peak (m)	-	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Nov-2010	Peak (m)	-	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Dec-2010	Peak (m)	-	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Jan-2011	Peak (m)	-	-	-	-	-	-	-
	Warning	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor	<Minor
Feb-2011	Peak (m)	-	-	-	-	4.70	-	4.08
	Warning	<Minor	<Minor	<Minor	<Minor	Minor	<Minor	Minor
Historic Record	Peak (m)	3.63	4.93	4.45	3.33	6.31	4.84	5.46
	Date	Nov-1934	Jul-1996	Sep-1993	Nov-1971	Nov-1995	Jun-2007	Oct-1953
	Start Of Record	1930	1960	1960	1955	1962	1998	1936
	New Record Set	No	No	No	No	No	No	No
	New Record Date	-	-	-	-	-	-	-
	Peak (m)	-	-	-	-	-	-	-
	Increase (m)	-	-	-	-	-	-	-

[1]*Note: This summary is based on data received from the Bureau of Meteorology. Water Technology has attempted to quality check the data received but can not guarantee the accuracy of the information. No attempt has been made to infill missing data.*
[2]*Note: Flood frequency was determined from information in the Victorian Strategic Flood Intelligence Report[14].*

Table 8-8 Mitchell River instantaneous flow and level gauge summary

River Basin		Wonnangatta	Wonnangatta	Dargo	Wentworth	Mitchell	Mitchell
Gauge Number		224206	224201	224213	224214	224203	224217
Gauge Location		Crooked River	Waterford	Lower Dargo Road	Tabberabbera	Glenaladale	Rosehill
September 2010	Date/Time of Peak	5/09/2010 10:45 AM	5/09/2010 3:00 PM	5/09/2010 3:30 PM	5/09/2010 4:00 PM	6/09/2010 12:15 AM	6/09/2010 12:30 PM
	Time Diff. (hrs)		4				12
	Peak Level (m)	245.27	181.50	4.53	1.49	34.11	8.13
	Peak Flow (m3/s)	267	458	163	1	643	391
December 2010	Date/Time of Peak	9/12/2010 7:15 AM	9/12/2010 12:00 PM	9/12/2010 10:15 AM	9/12/2010 3:00 PM	9/12/2010 9:45 PM	10/12/2010 12:00 PM
	Time Diff. (hrs)		5				14
	Peak Level (m)	244.27	179.66	2.87	1.57	32.35	6.79
	Peak Flow (m3/s)	134	219	46	2	277	236

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

Table 8-9 Macalister River instantaneous flow and level gauge summary

River Basin		Macalister	Macalister	Macalister	Macalister	Macalister
Gauge Number		225219	225209	225221	225204	225247
Gauge Location		Glencairn	Licola	Stringybark Creek	Glenmaggie (tail gauge)	Riverslea
September 2010	Date/Time of Peak	5/09/2010 5:15 AM	5/09/2010 2:15 AM	5/09/2010 7:30 AM	5/09/2010 11:45 AM	7/09/2010 12:00 AM
	Time Diff. (hrs)		-3	5	4	36
	Peak Level (m)	296.65	5.53	107.90	51.08	5.68
	Peak Flow (m3/s)	216	288	400	258	26
November 2010	Date/Time of Peak	28/11/2010 1:15 PM	28/11/2010 2:30 PM	28/11/2010 5:00 PM	28/11/2010 3:15 PM	30/11/2010 10:45 PM
	Time Diff. (hrs)		1	3	-2	56
	Peak Level (m)	295.34	4.99	106.97	49.53	5.11
	Peak Flow (m3/s)	79	128	164	100	26
December 2010	Date/Time of Peak	8/12/2010 11:30 PM	9/12/2010 12:15 AM	9/12/2010 4:00 AM	10/12/2010 11:00 AM	11/12/2010 9:30 AM
	Time Diff. (hrs)		1	4	31	23
	Peak Level (m)	296.36	5.33	107.55	49.51	5.90
	Peak Flow (m3/s)	184	223	304	98	26

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

[4]*Note: Some negative travel times due to spatial and temporal variability in rainfall impacting on tributary flows and storages attenuating the upstream hydrograph.*

Table 8-10 Latrobe River tributaries instantaneous flow and level gauge summary

River Basin		Loch	Moe	Morwell	Morwell	Tyers West	Tyers	Tyers	Traralgon	Traralgon
Gauge Number		226220	226209	226407	226408	226008	226235	226007	226410	226415
Gauge Location		Noojee	Darnum	Boolarra	Yallourn	Morgans Mill	Junction	Browns	Koornalla	Traralgon South
September 2010	Date/Time of Peak	5/09/2010 1:04 PM	5/09/2010 2:45 PM	5/09/2010 3:45 PM	7/09/2010 5:15 PM	5/09/2010 2:30 AM	5/09/2010 2:00 PM	5/09/2010 10:30 PM	5/09/2010 8:00 PM	6/09/2010 3:15 AM
	Time Diff. (hrs)				50		12	8		7
	Peak Level (m)	0.49	3.68	99.71	3.13	0.71	1.19	170.78	1.76	62.95
	Peak Flow (m3/s)	3	34	8	20	7	8	11	10	10
October 2010	Date/Time of Peak	31/10/2010 3:52 PM	15/10/2010 10:00 PM	15/10/2010 9:00 PM	19/10/2010 3:00 AM	15/10/2010 8:00 PM	15/10/2010 9:00 PM	16/10/2010 4:45 AM	17/10/2010 2:30 PM	17/10/2010 6:00 PM
	Time Diff. (hrs)				78		1	8		4
	Peak Level (m)	0.55	2.48	99.21	2.74	0.85	1.51	171.22	1.38	62.27
	Peak Flow (m3/s)	4	14	3	13	9	14	19	4	4
February 2011	Date/Time of Peak	5/02/2011 8:27 PM	5/02/2011 8:00 PM	5/02/2011 3:45 PM	7/02/2011 10:00 AM	5/02/2011 7:00 PM	5/02/2011 8:30 PM	5/02/2011 8:15 PM	5/02/2011 3:45 PM	5/02/2011 9:15 PM
	Time Diff. (hrs)				42		2	0		5
	Peak Level (m)	0.66	3.87	99.91	2.54	0.55	1.10	170.85	1.47	62.28
	Peak Flow (m3/s)	7	38	11	11	5	7	11	5	4

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

Table 8-11 Latrobe River instantaneous flow and level gauge summary

River Basin		Latrobe	Latrobe	Latrobe	Latrobe	Latrobe	Latrobe	Latrobe	Latrobe	Lake Wellington
Gauge Number		226222	226205	226204	226005	226033	226224	226228	226227	226041
Gauge Location		Near Noojee (U/S Ada)	Noojee	Willow Grove	Thoms Bridge	Scarnes Bridge	Rosedale (Anabranch)	Rosedale (Main Stream)	Kilmany South	Bull Bay
September 2010	Date/Time of Peak	5/09/2010 5:45 PM	5/09/2010 8:45 PM	6/09/2010 7:45 AM	6/09/2010 8:15 AM	7/09/2010 6:00 AM	10/09/2010 12:00 PM	8/09/2010 9:30 AM	9/09/2010 3:00 PM	10/09/2010 1:30 PM
	Time Diff. (hrs)		3	11	1	22		28	29	23
	Peak Level (m)	0.55	1.36	1.97	3.87	24.97	11.24	13.71	7.47	0.47
	Peak Flow (m3/s)	2	8	13	91	87	0	71	60	0
October 2010	Date/Time of Peak	16/10/2010 5:30 AM	31/10/2010 8:30 PM	16/10/2010 3:00 PM	17/10/2010 1:00 AM	17/10/2010 2:00 PM	15/10/2010 8:00 PM	18/10/2010 2:15 PM	19/10/2010 5:30 AM	31/10/2010 7:30 AM
	Time Diff. (hrs)				10	13		24	15	290
	Peak Level (m)	0.55	1.45	2.25	3.18	24.75	11.61	13.66	7.49	0.30
	Peak Flow (m3/s)	2	9	17	68	80	0	69	62	0
February 2011	Date/Time of Peak	5/02/2011 3:45 PM	6/02/2011 1:30 AM	5/02/2011 6:45 PM	6/02/2011 9:15 AM	7/02/2011 9:15 PM	11/02/2011 4:00 PM	9/02/2011 4:15 AM	8/02/2011 10:30 PM	5/02/2011 2:15 AM
	Time Diff. (hrs)		10	-7	14	36		31	-6	-92
	Peak Level (m)	0.78	2.22	4.06	4.71	25.54	11.79	13.78	7.50	0.35
	Peak Flow (m3/s)	5	20	56	122	107	0	76	63	0

[1]*Note: Some gauges have missing instantaneous data.*

[2]*Note: Some months have multiple peaks with the spatial and temporal distribution of rainfall and tributary flows greatly influencing the timing and magnitude of the peak. In these instances the analysis of time of peak may be limited.*

[3]*Note: Only months with significant flows have been analysed.*

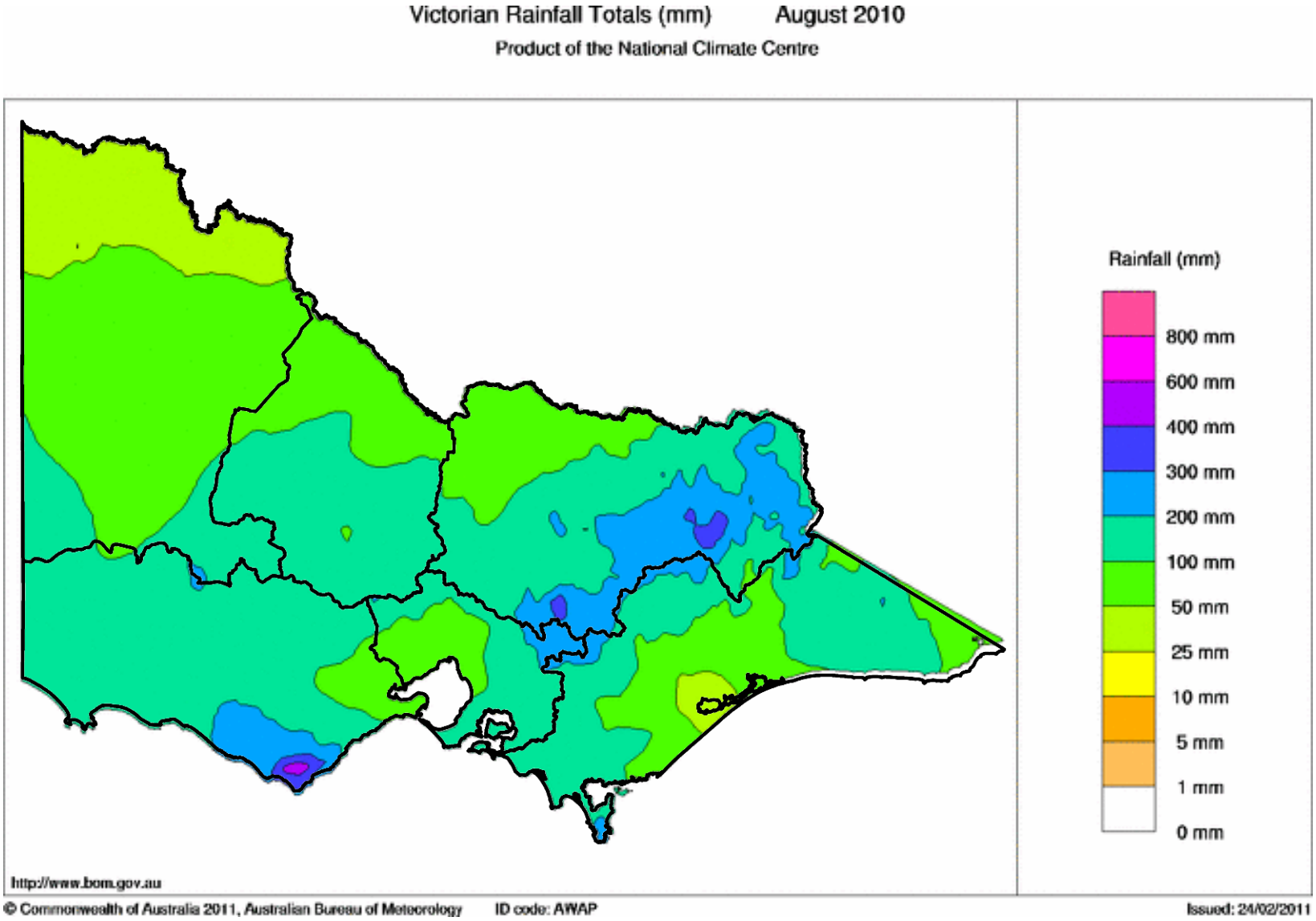
[4]*Note: Some negative travel times due to spatial and temporal variability in rainfall impacting on tributary flows and storages attenuating the upstream hydrograph.*

8.5 Summary

None of the rainfall gauges analysed recorded significant AEP events with the exception of the Warrigal gauge during the February 2011 rainfall event, with an estimated 10 to 5% AEP for the 48 and 72 hour durations.

Similarly, the streamflow records show that with the exception of the September 2010 event, which was estimated at between a 20 to 10% AEP flood for the Mitchell River and also for the Macalister River upstream of Glenmaggie Dam, all other events were not significant flood events.

APPENDIX A BUREAU OF METEOROLOGY RAINFALL MAPS


Victorian Rainfall Totals (mm) August 2010
Product of the National Climate Centre
Rainfall (mm)
800 mm
600 mm
400 mm
300 mm
200 mm
100 mm
50 mm
25 mm
10 mm
5 mm
1 mm
0 mm
http://www.bom.gov.au
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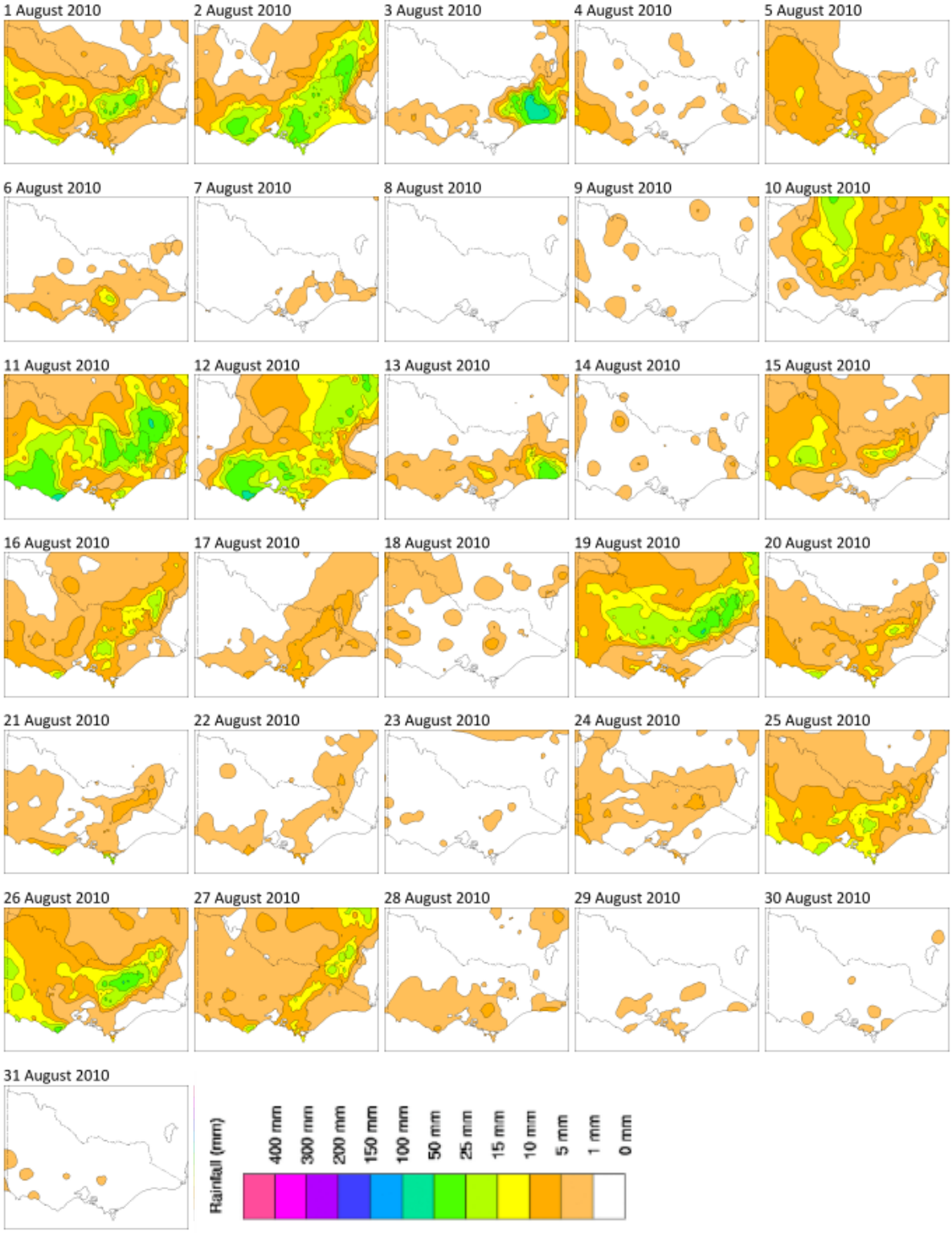
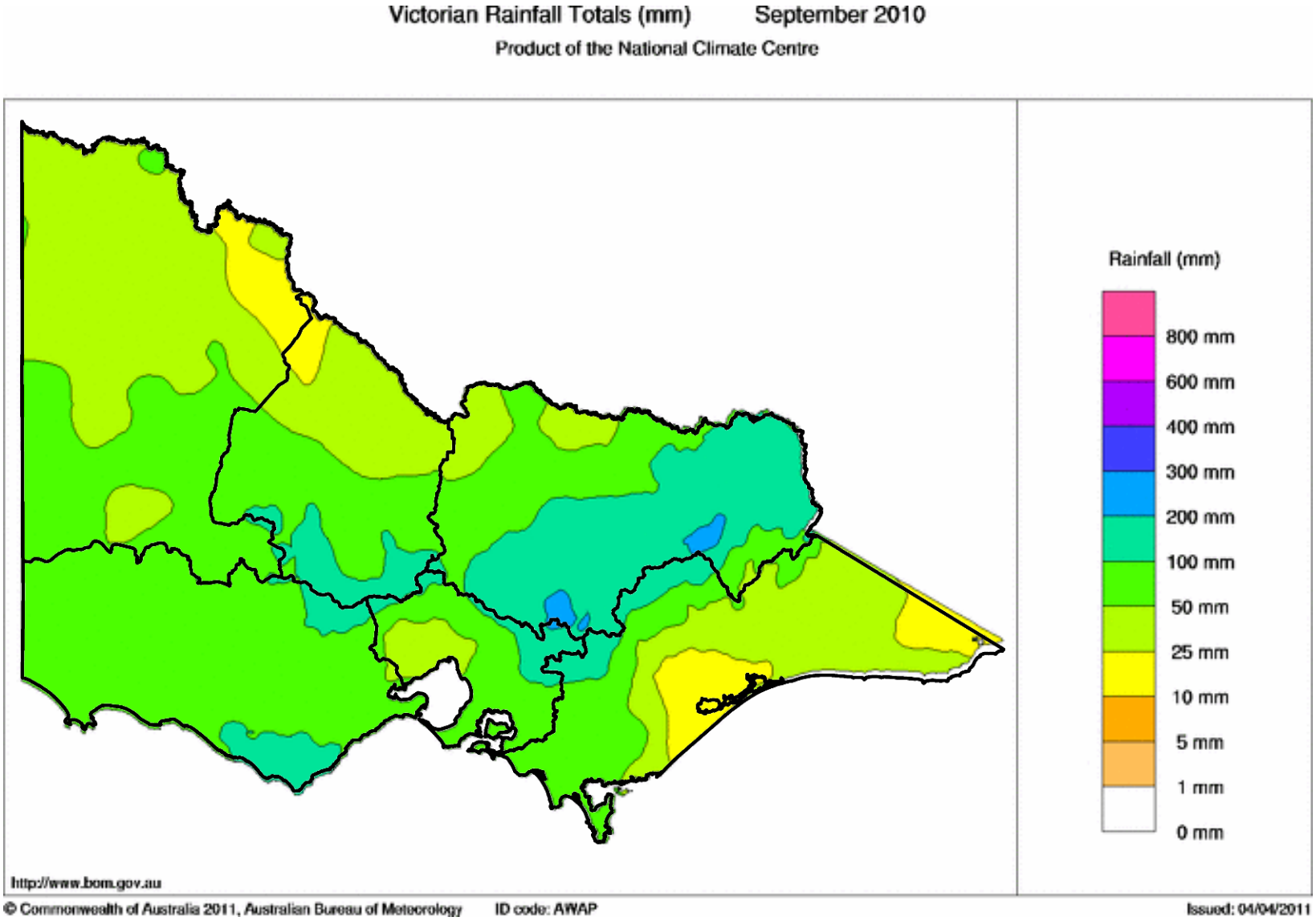
ID code: AWAP
Issued: 24/02/2011

Daily Rainfall – August 2010



These maps are presented to give a statewide overview of conditions on each day through the month. There could be discrepancies between the values shown on these maps and those at individual locations, as a result of the way the maps are generated.


Victorian Rainfall Totals (mm) September 2010
Product of the National Climate Centre
Rainfall (mm)
800 mm
600 mm
400 mm
300 mm
200 mm
100 mm
50 mm
25 mm
10 mm
5 mm
1 mm
0 mm
http://www.bom.gov.au
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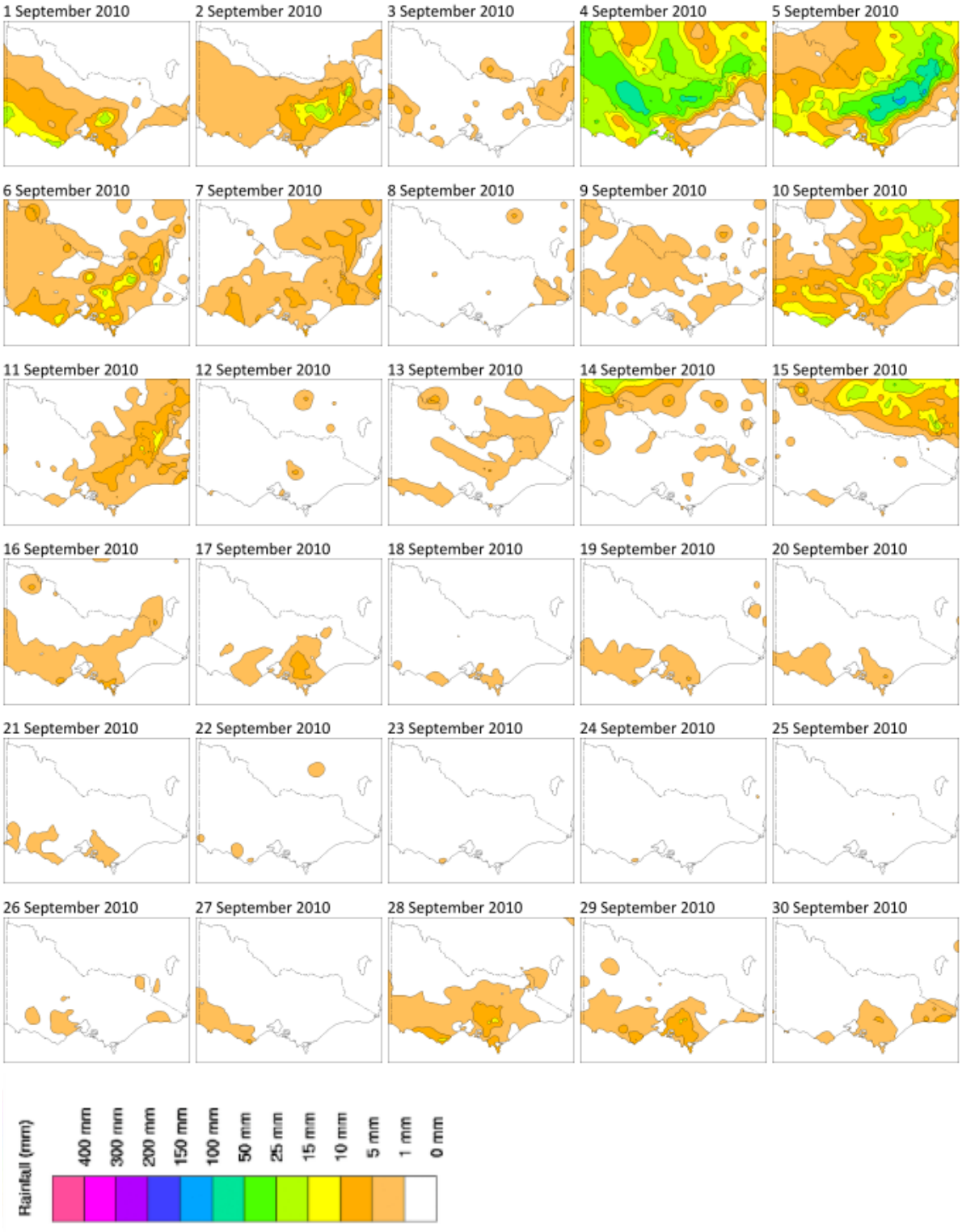
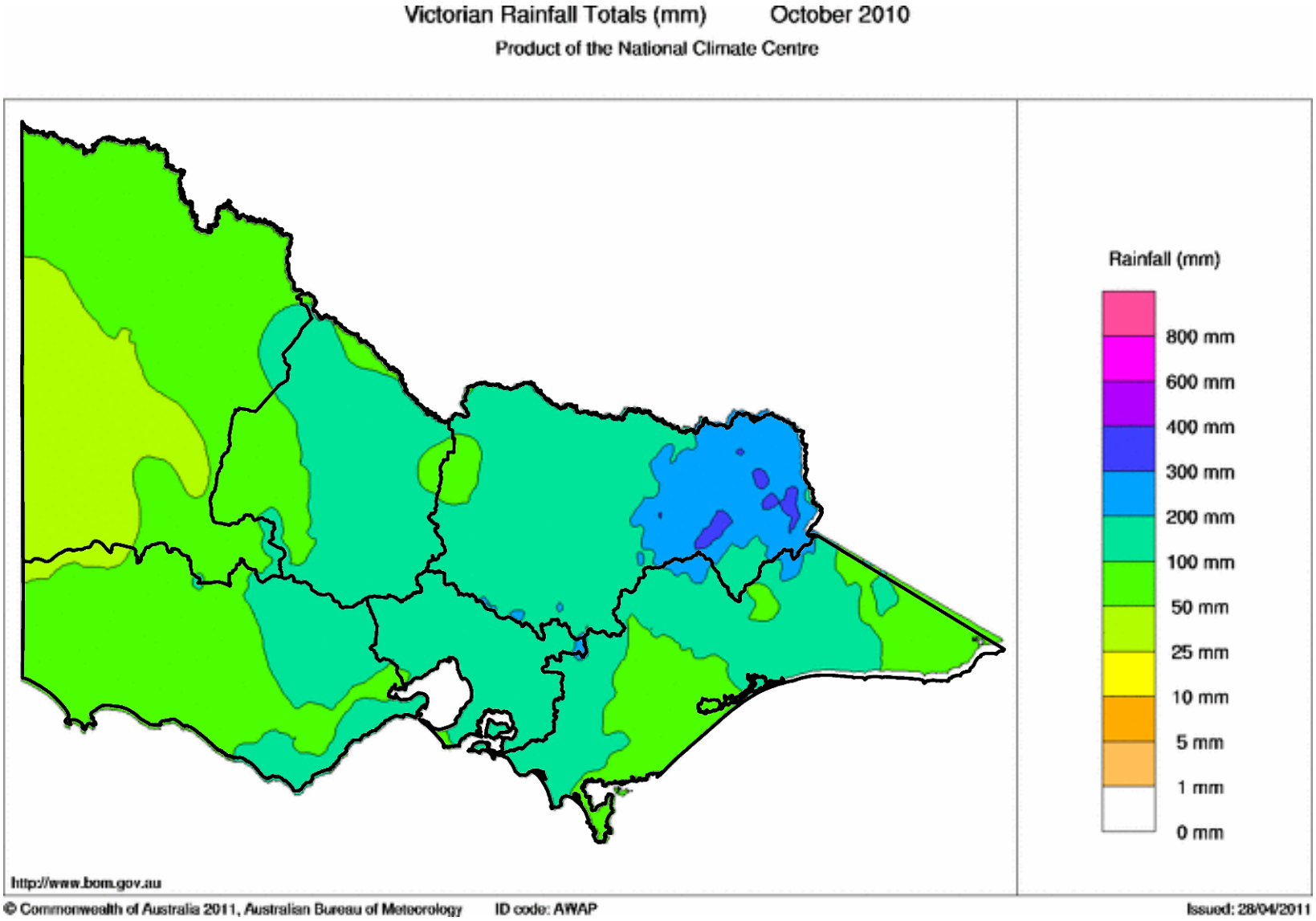
ID code: AWAP
Issued: 04/04/2011

Daily Rainfall – September 2010



These maps are presented to give a statewide overview of conditions on each day through the month. There could be discrepancies between the values shown on these maps and those at individual locations, as a result of the way the maps are generated.


Victorian Rainfall Totals (mm) October 2010
Product of the National Climate Centre
Rainfall (mm)
800 mm
600 mm
400 mm
300 mm
200 mm
100 mm
50 mm
25 mm
10 mm
5 mm
1 mm
0 mm
http://www.bom.gov.au
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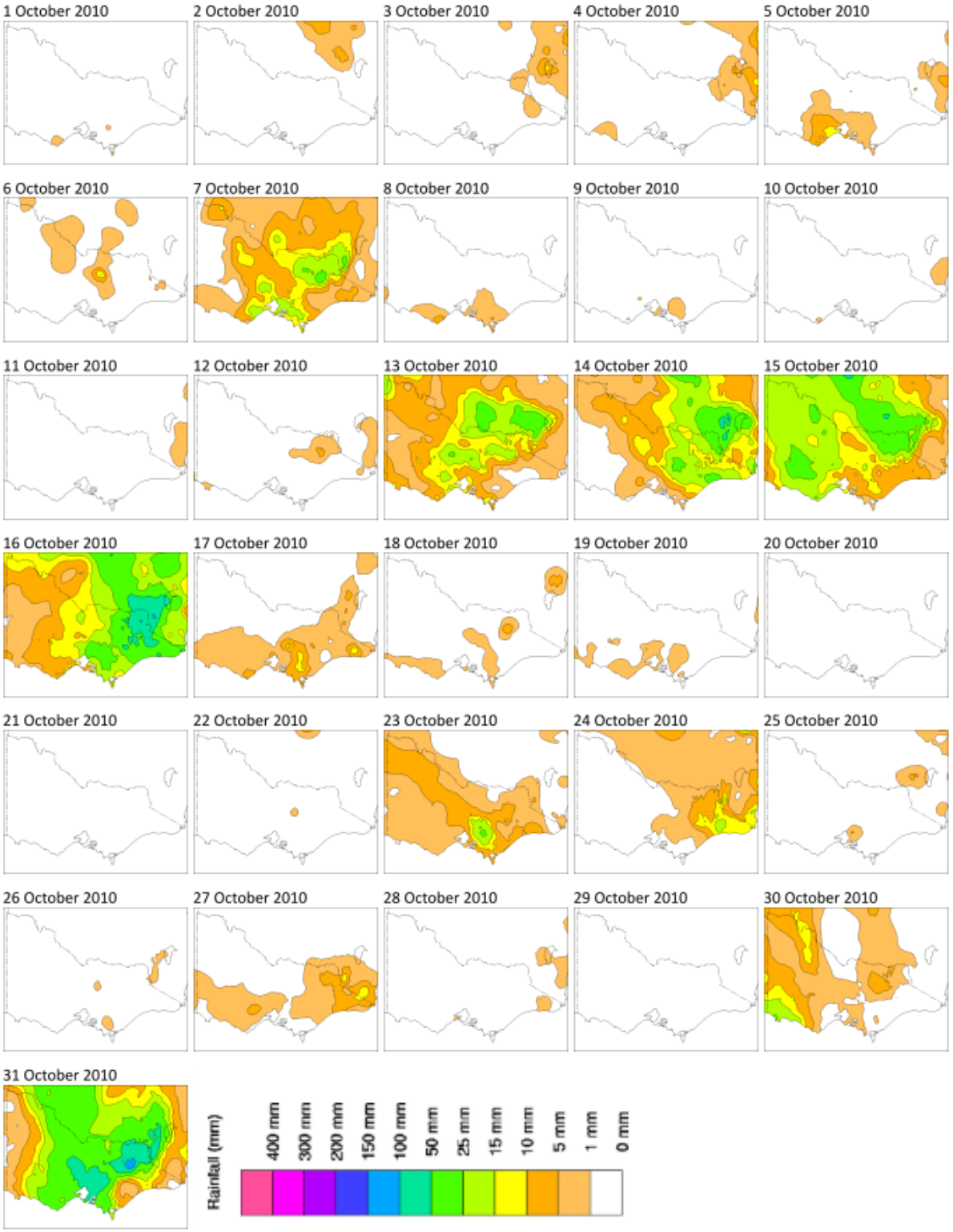
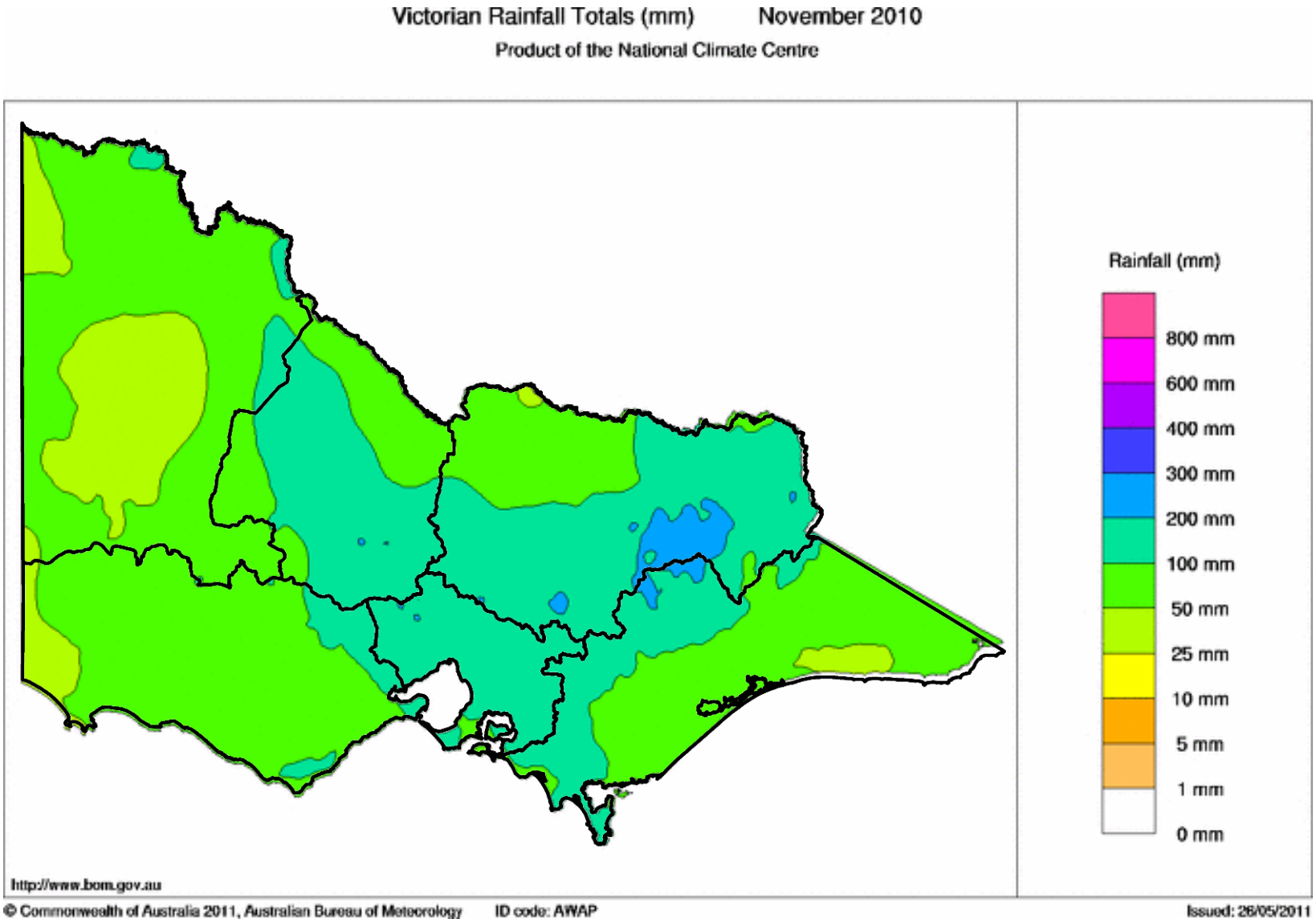
Issued: 28/04/2011

Daily Rainfall – October 2010



These maps are presented to give a statewide overview of conditions on each day through the month. There could be discrepancies between the values shown on these maps and those at individual locations, as a result of the way the maps are generated.


Victorian Rainfall Totals (mm) November 2010
Product of the National Climate Centre
Rainfall (mm)
800 mm
600 mm
400 mm
300 mm
200 mm
100 mm
50 mm
25 mm
10 mm
5 mm
1 mm
0 mm
http://www.bom.gov.au
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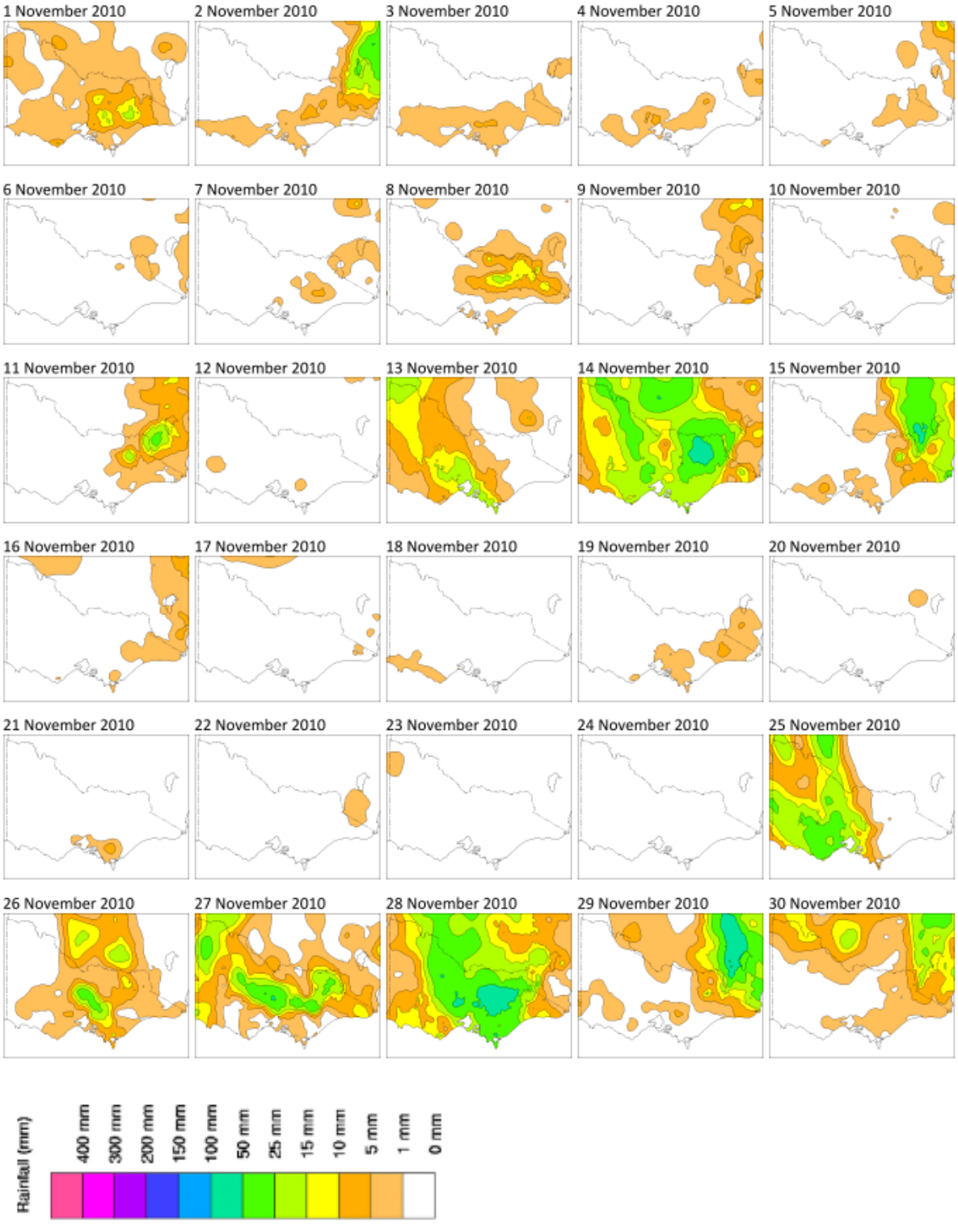
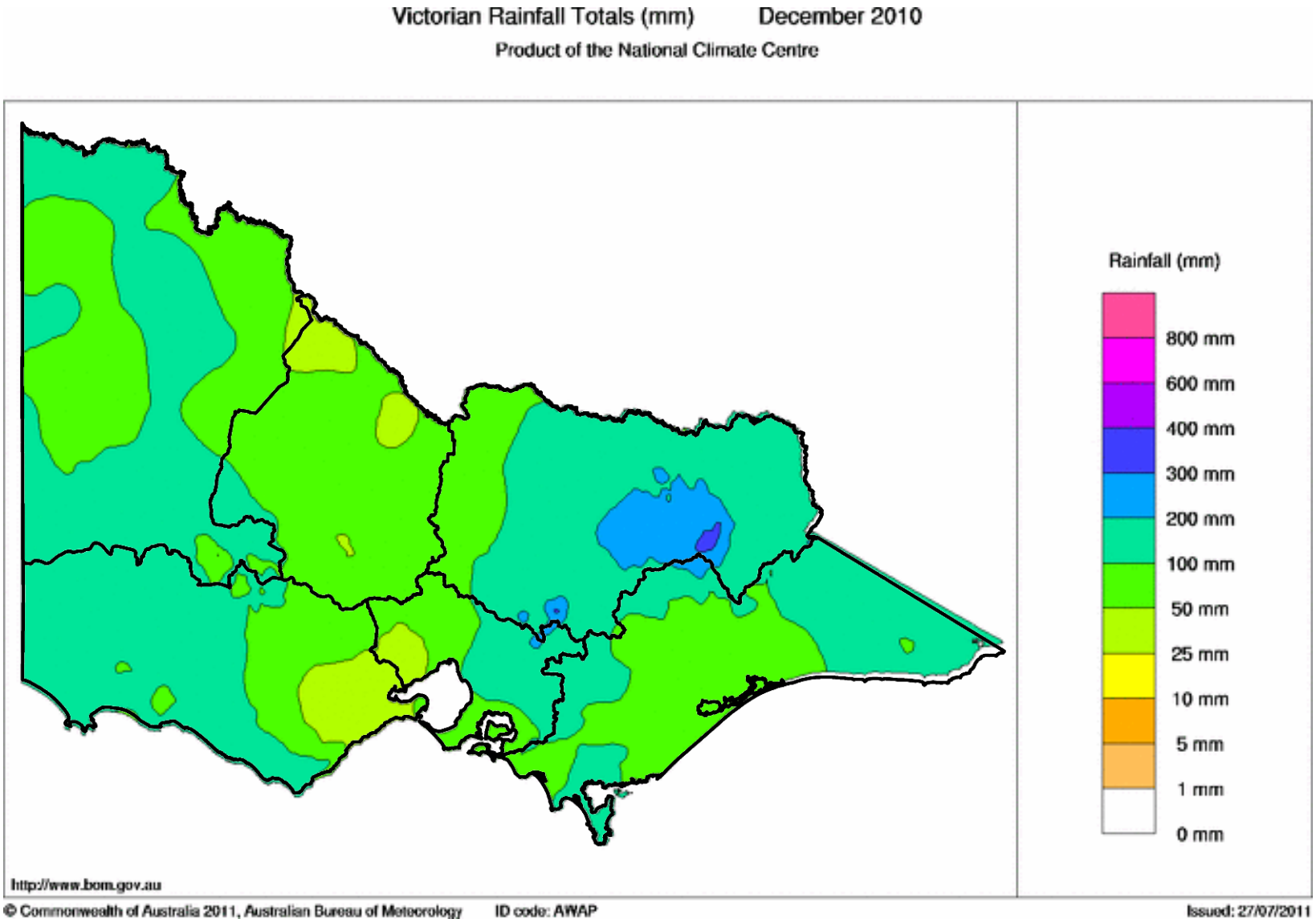
Daily Rainfall – November 2010



These maps are presented to give a statewide overview of conditions on each day through the month. There could be discrepancies between the values shown on these maps and those at individual locations, as a result of the way the maps are generated.


Victorian Rainfall Totals (mm) December 2010
Product of the National Climate Centre
Rainfall (mm)
800 mm
600 mm
400 mm
300 mm
200 mm
100 mm
50 mm
25 mm
10 mm
5 mm
1 mm
0 mm
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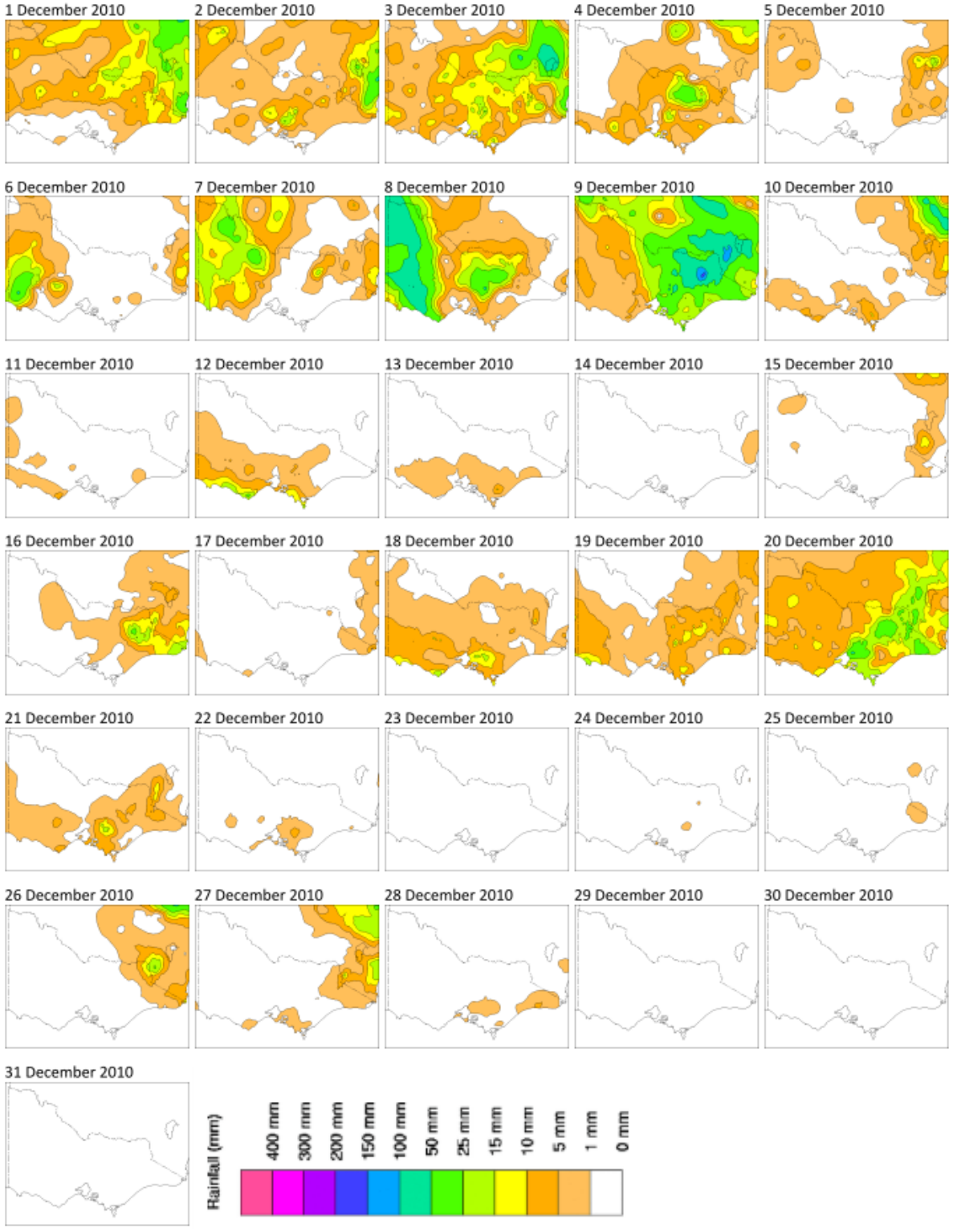
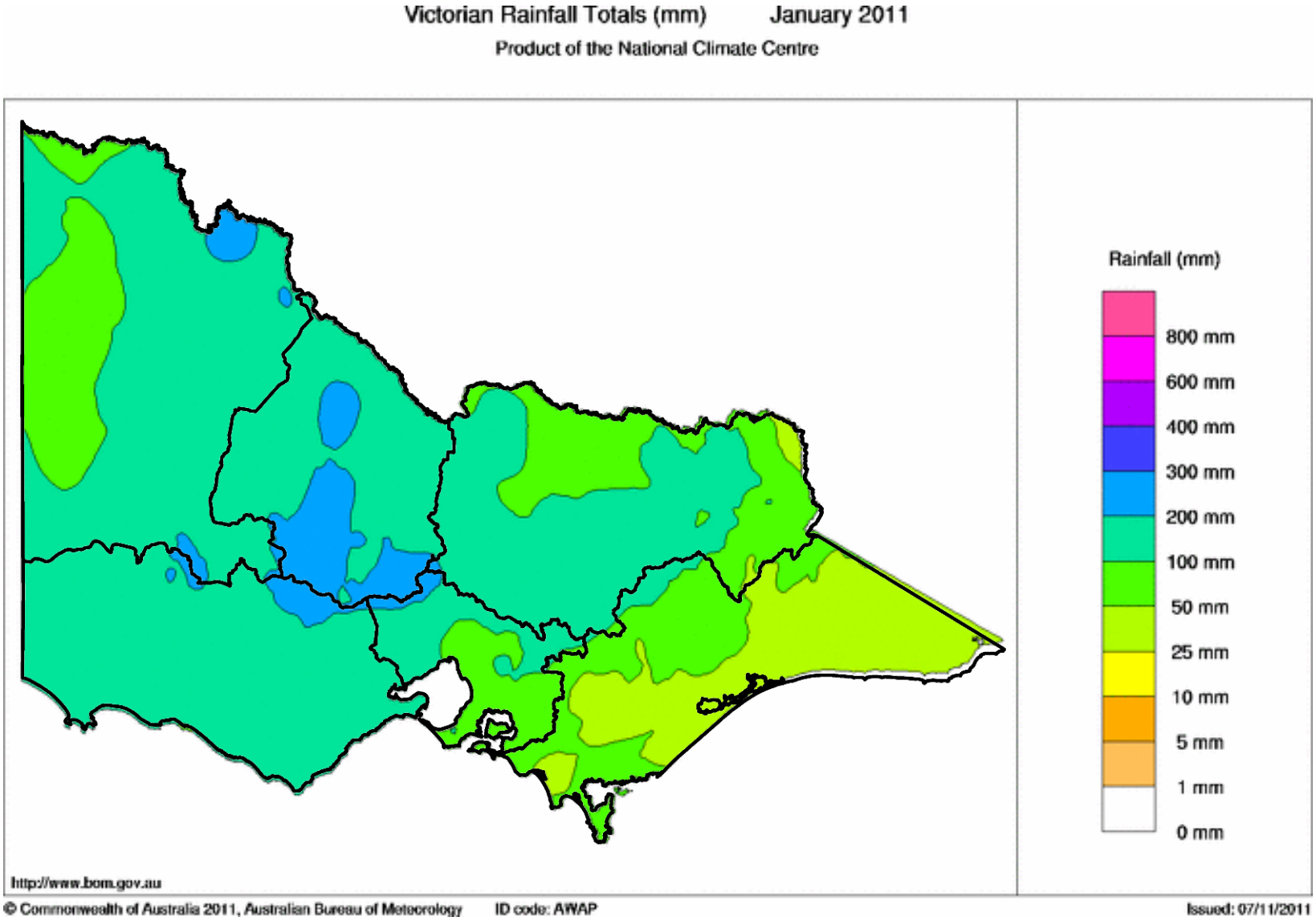
Daily Rainfall – December 2010



These maps are presented to give a statewide overview of conditions on each day through the month. There could be discrepancies between the values shown on these maps and those at individual locations, as a result of the way the maps are generated.


Victorian Rainfall Totals (mm) January 2011
Product of the National Climate Centre
Rainfall (mm)
800 mm
600 mm
400 mm
300 mm
200 mm
100 mm
50 mm
25 mm
10 mm
5 mm
1 mm
0 mm
http://www.bom.gov.au
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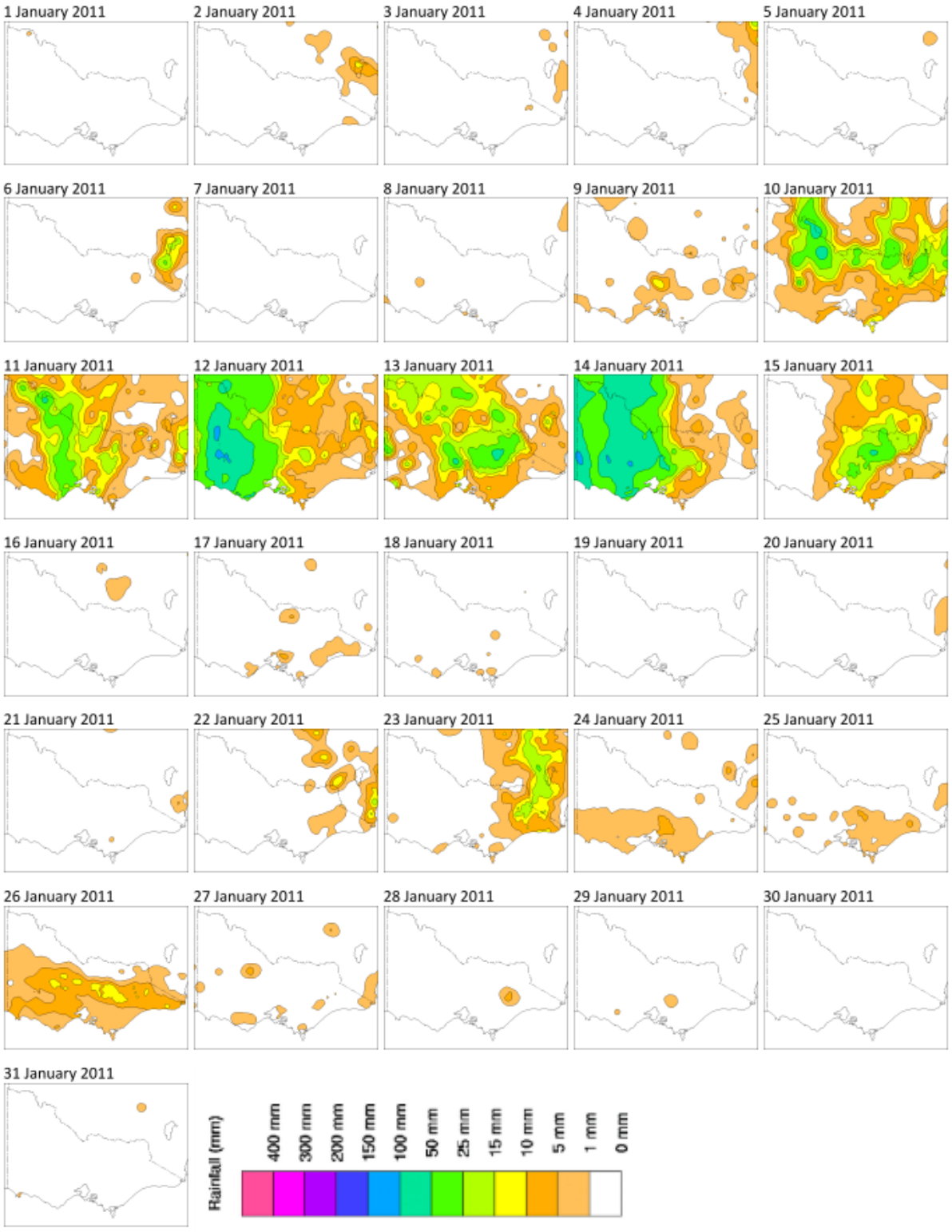
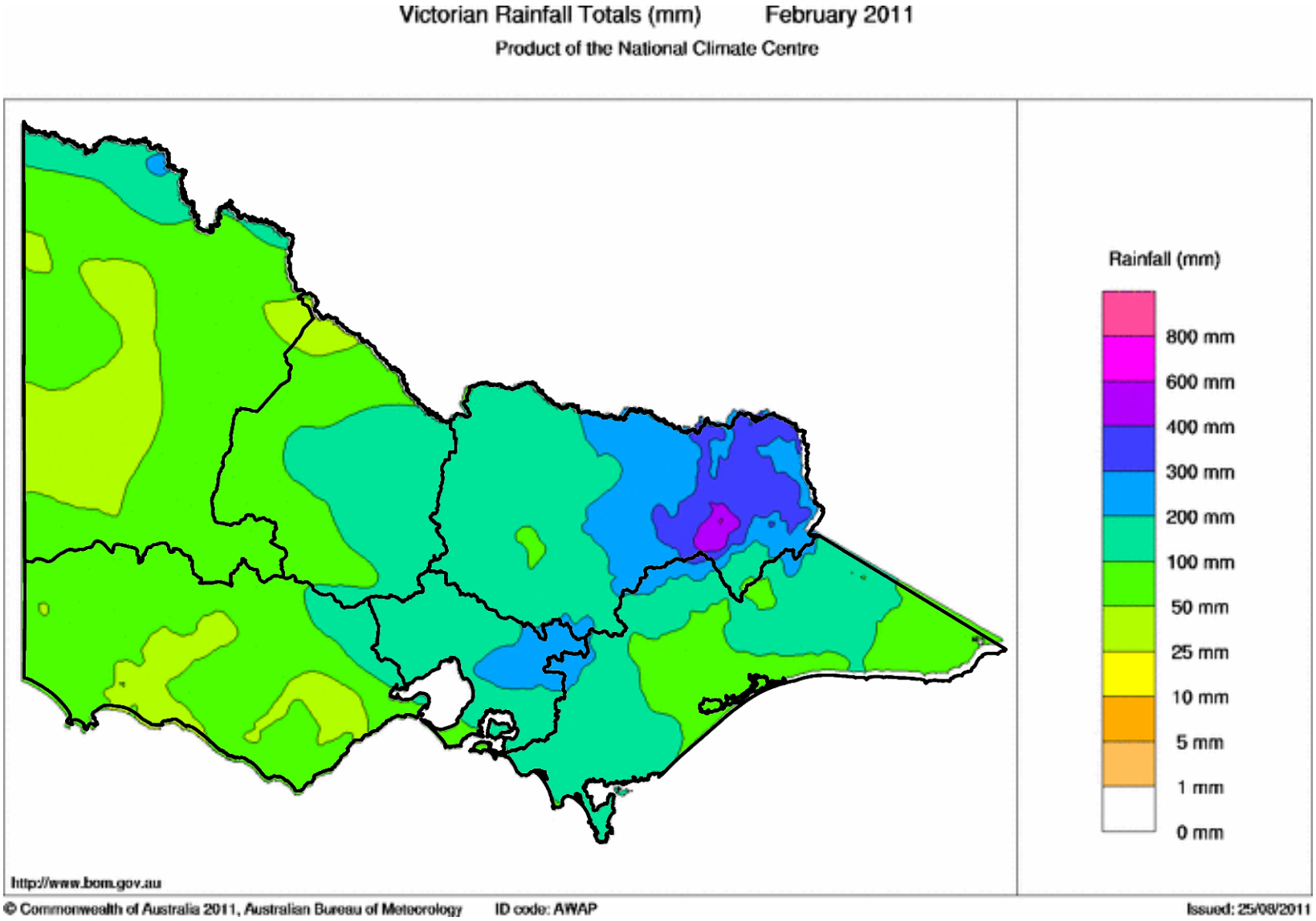
ID code: AWAP
Issued: 07/11/2011

Daily Rainfall – January 2011



These maps are presented to give a statewide overview of conditions on each day through the month. There could be discrepancies between the values shown on these maps and those at individual locations, as a result of the way the maps are generated.


Victorian Rainfall Totals (mm) February 2011
Product of the National Climate Centre
Rainfall (mm)
800 mm
600 mm
400 mm
300 mm
200 mm
100 mm
50 mm
25 mm
10 mm
5 mm
1 mm
0 mm
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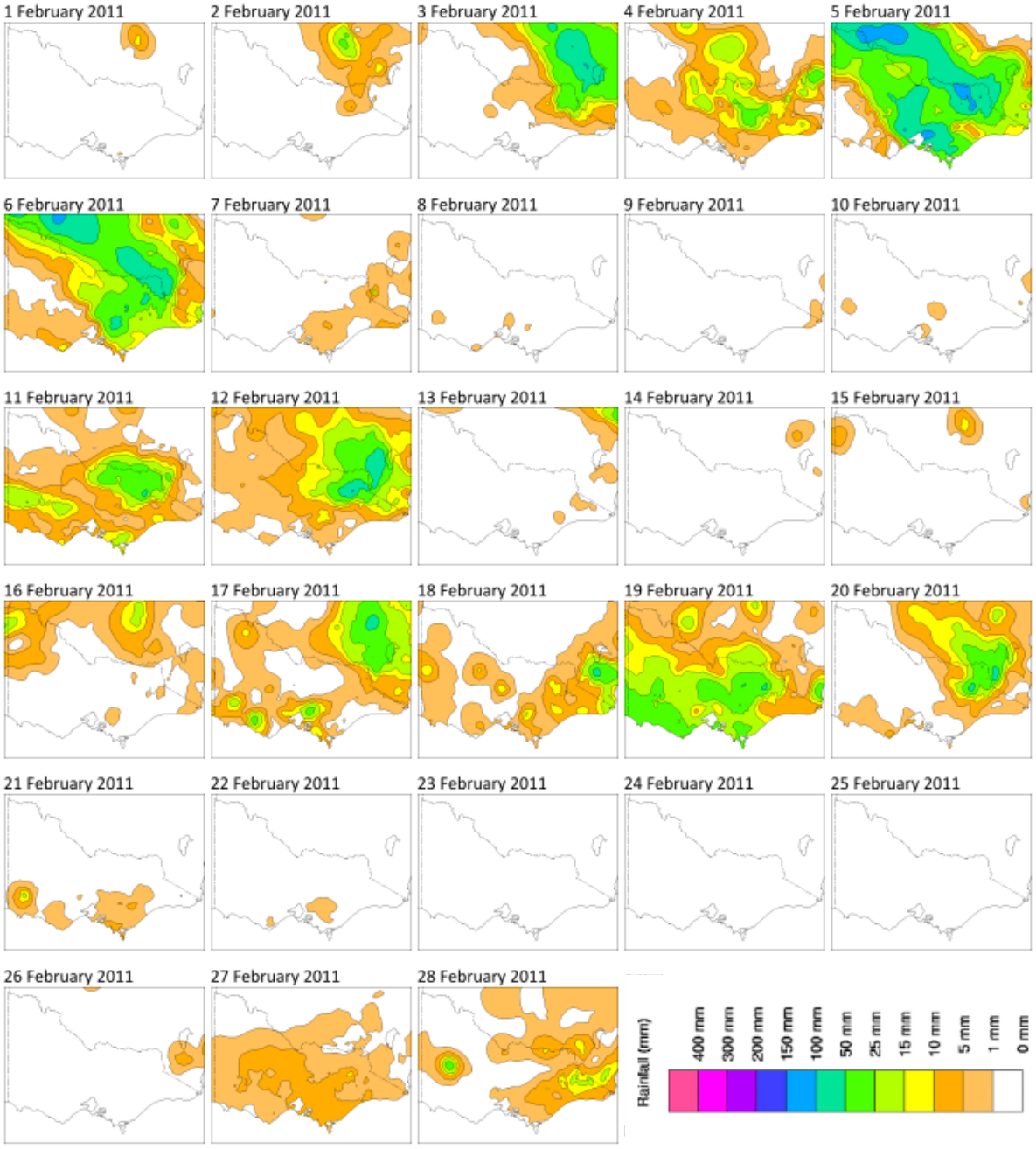
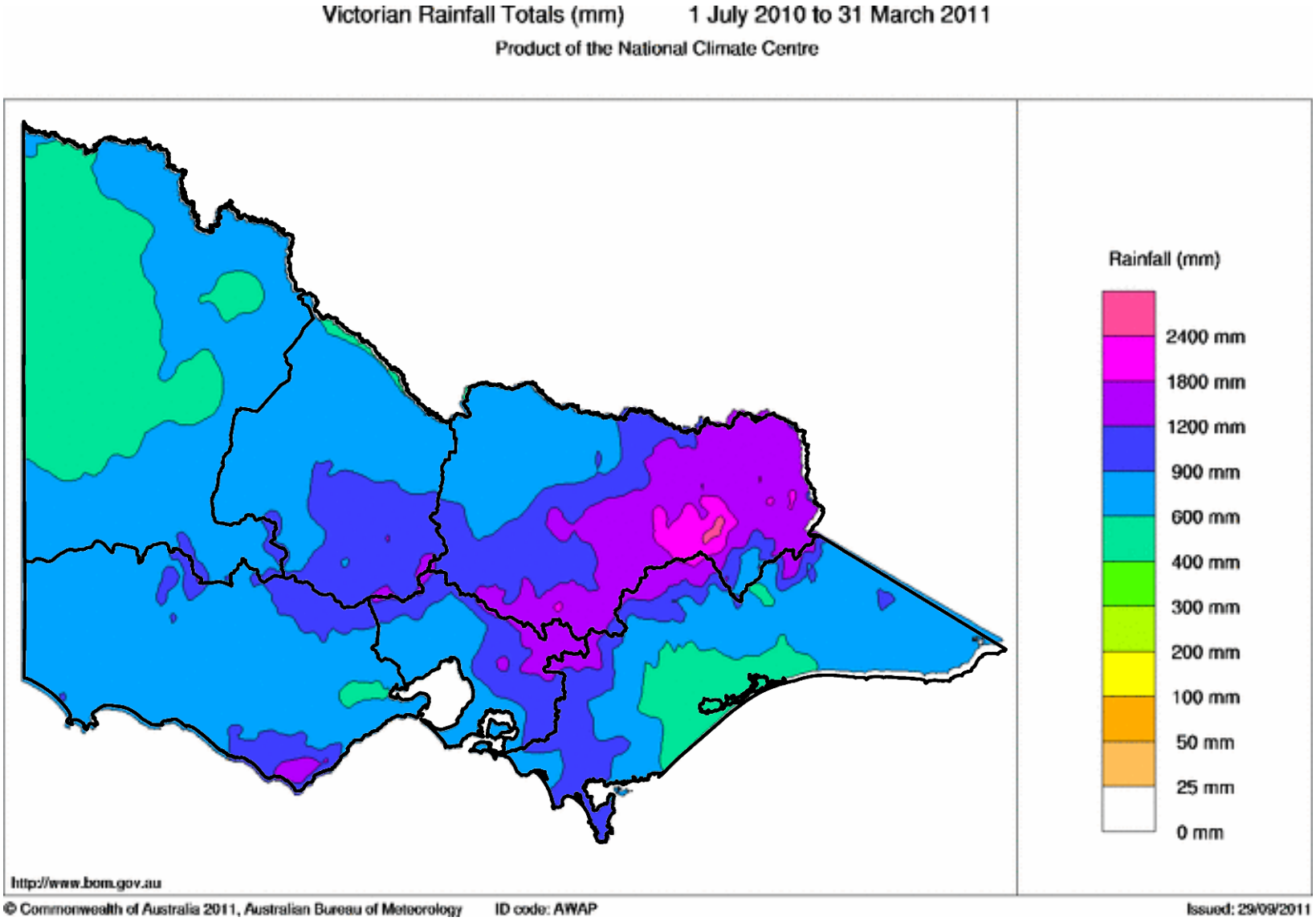
Issued: 25/08/2011

Daily Rainfall – February 2011



These maps are presented to give a statewide overview of conditions on each day through the month. There could be discrepancies between the values shown on these maps and those at individual locations, as a result of the way the maps are generated.


Victorian Rainfall Totals (mm) 1 July 2010 to 31 March 2011
Product of the National Climate Centre
Rainfall (mm)
2400 mm
1800 mm
1200 mm
900 mm
600 mm
400 mm
300 mm
200 mm
100 mm
50 mm
25 mm
0 mm
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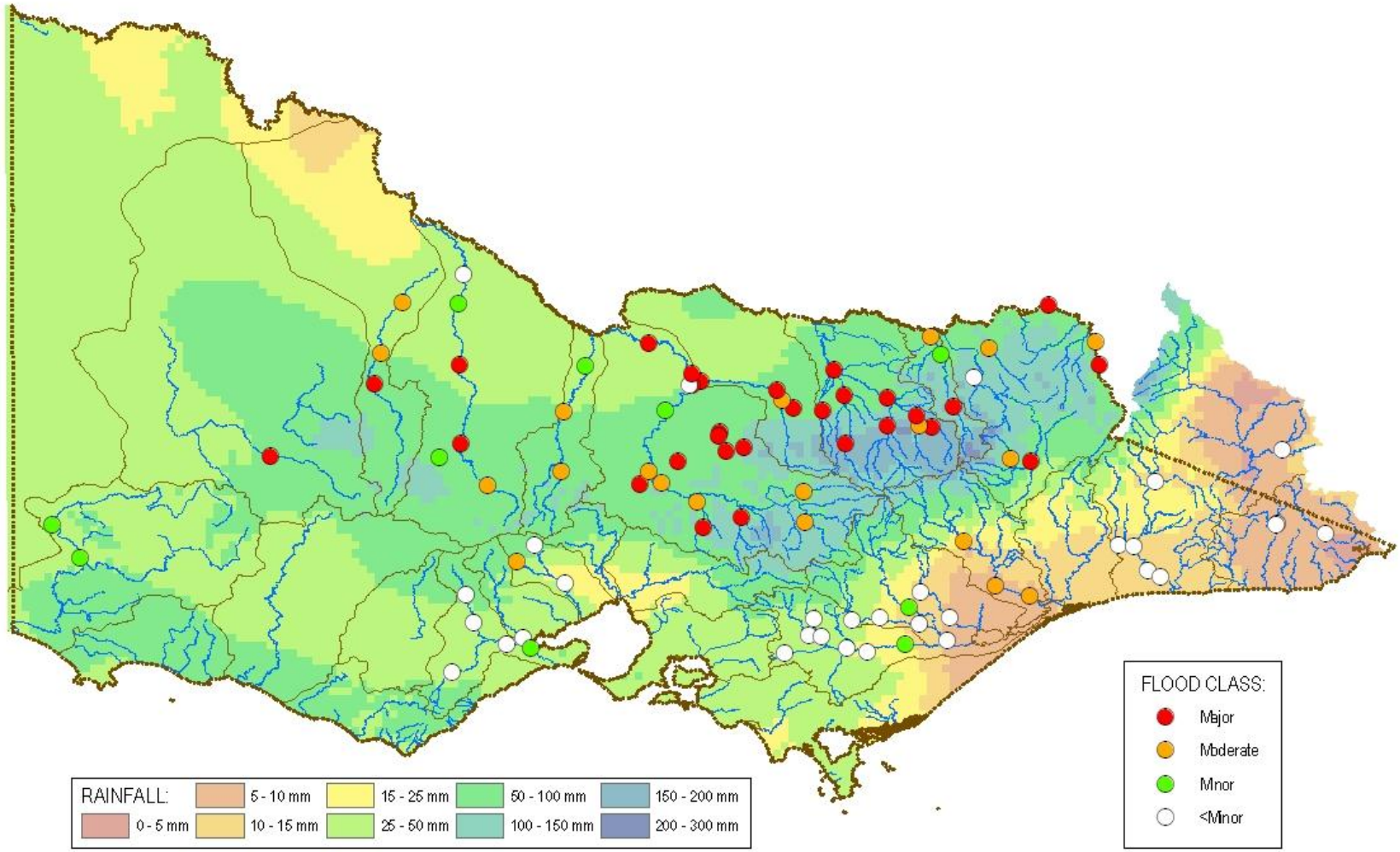
APPENDIX B FLOOD WARNING SUMMARY MAPS

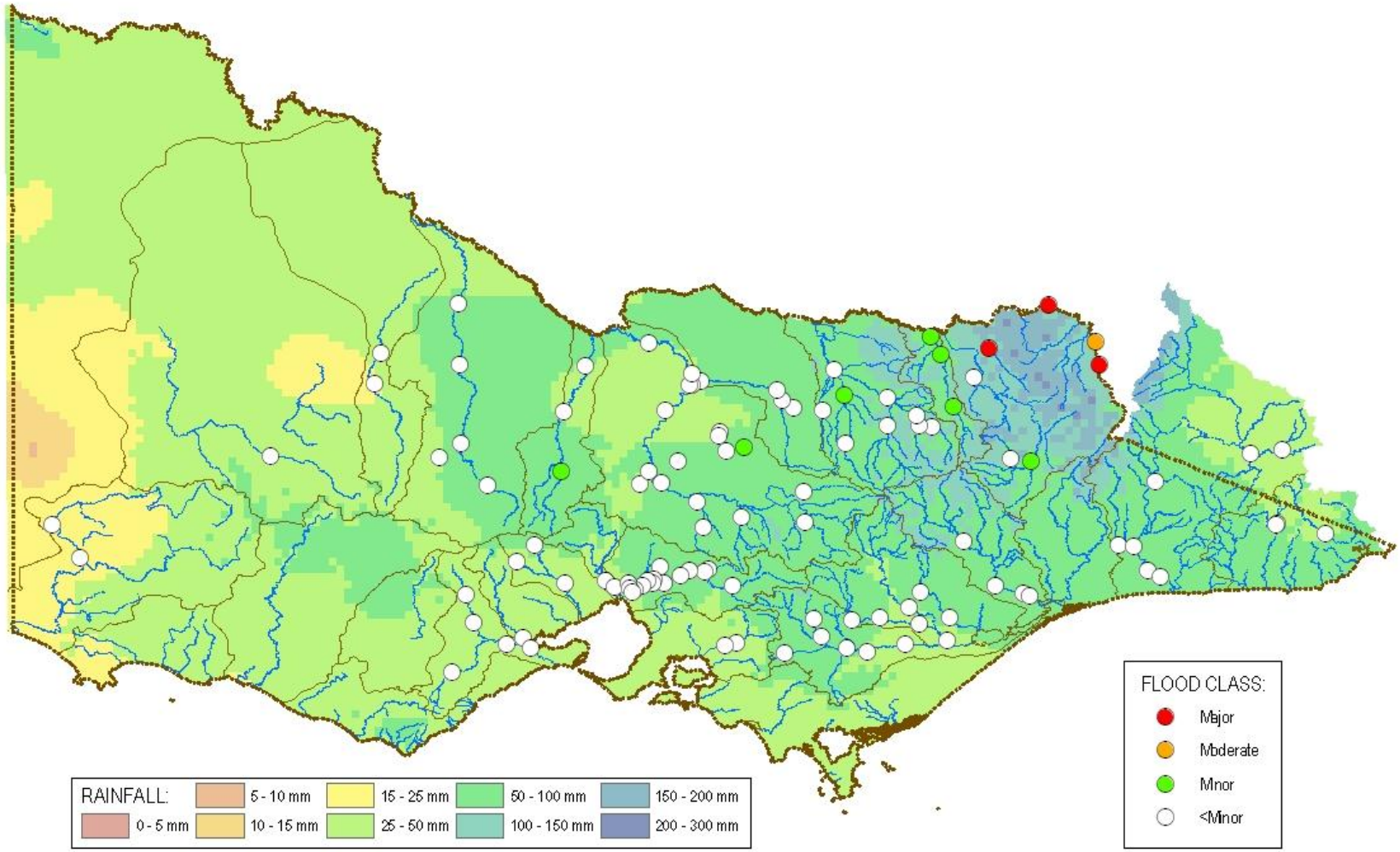
September 2010 Bureau of Meteorology Flood Warnings



Flood Warnings only issued at gauge locations where flood classes have been established

Note: Rainfall distribution shown in these maps generated by the Bureau of Meteorology is different from that of the previously presented maps. This is most likely due to a different interpolation method.

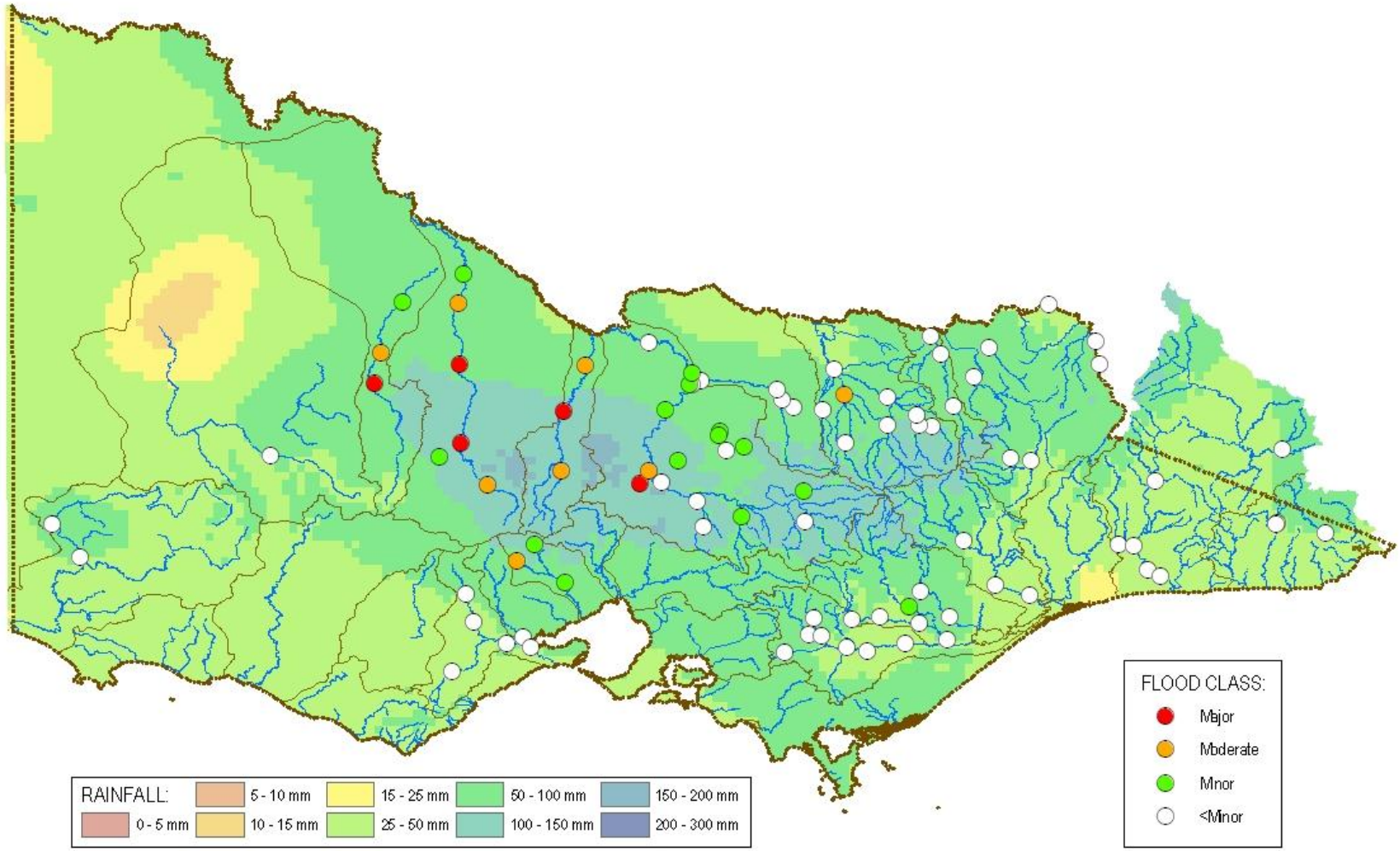
October 2010 Bureau of Meteorology Flood Warnings



Flood Warnings only issued at gauge locations where flood classes have been established

Note: Rainfall distribution shown in these maps generated by the Bureau of Meteorology is different from that of the previously presented maps. This is most likely due to a different interpolation method.

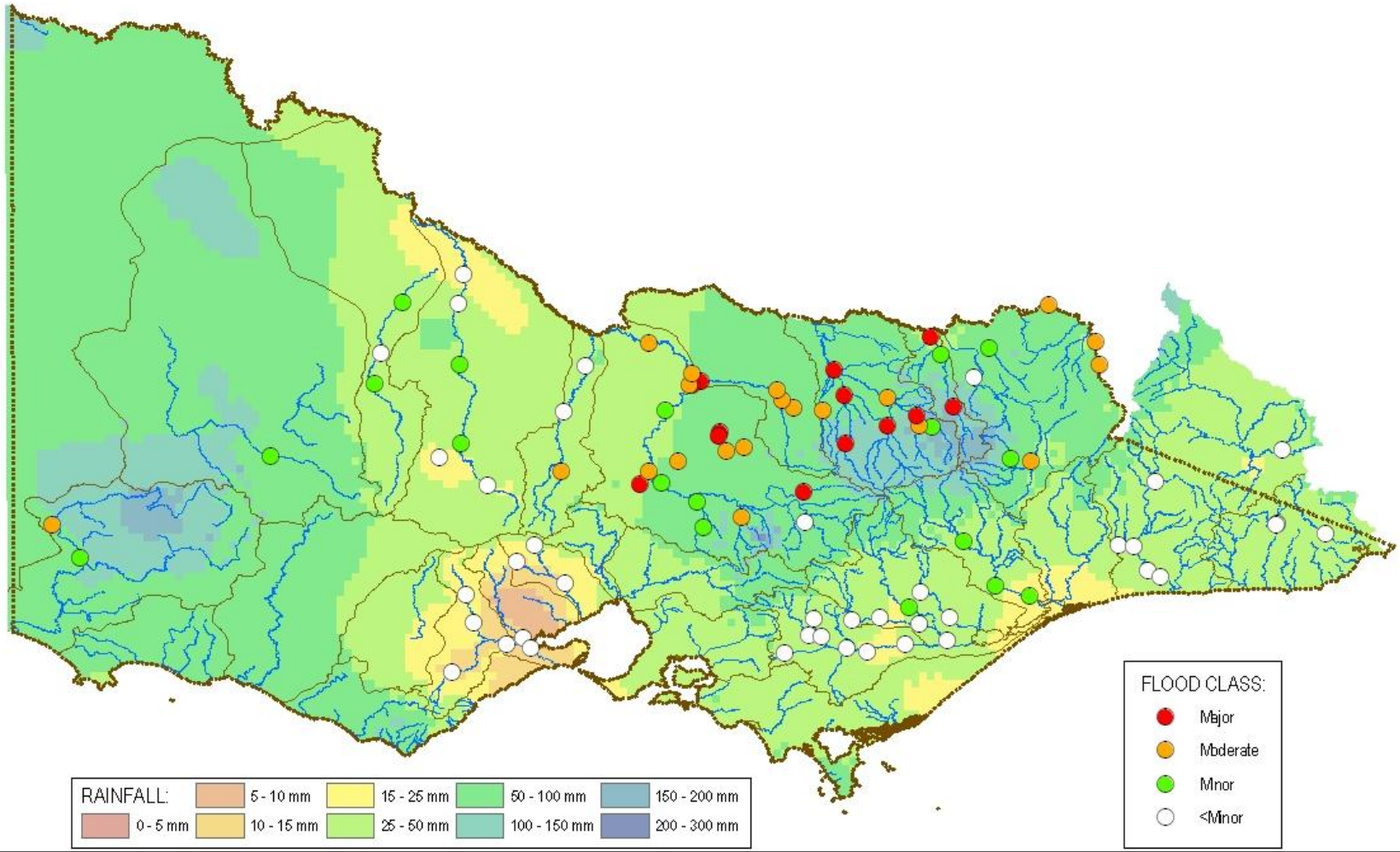
November 2010 Bureau of Meteorology Flood Warnings



Flood Warnings only issued at gauge locations where flood classes have been established

Note: Rainfall distribution shown in these maps generated by the Bureau of Meteorology is different from that of the previously presented maps. This is most likely due to a different interpolation method.

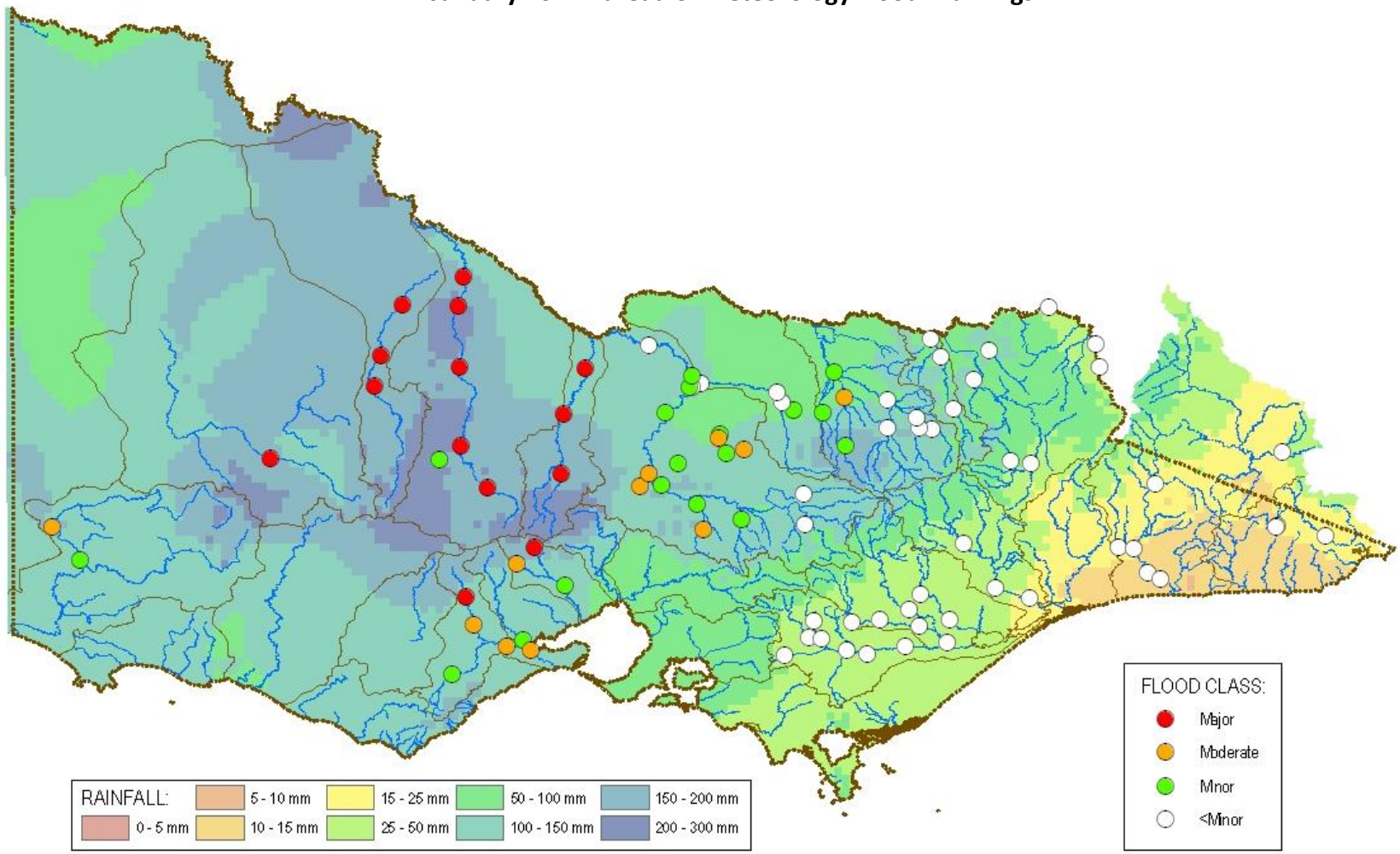
December 2010 Bureau of Meteorology Flood Warnings



Flood Warnings only issued at gauge locations where flood classes have been established

Note: Rainfall distribution shown in these maps generated by the Bureau of Meteorology is different from that of the previously presented maps. This is most likely due to a different interpolation method.

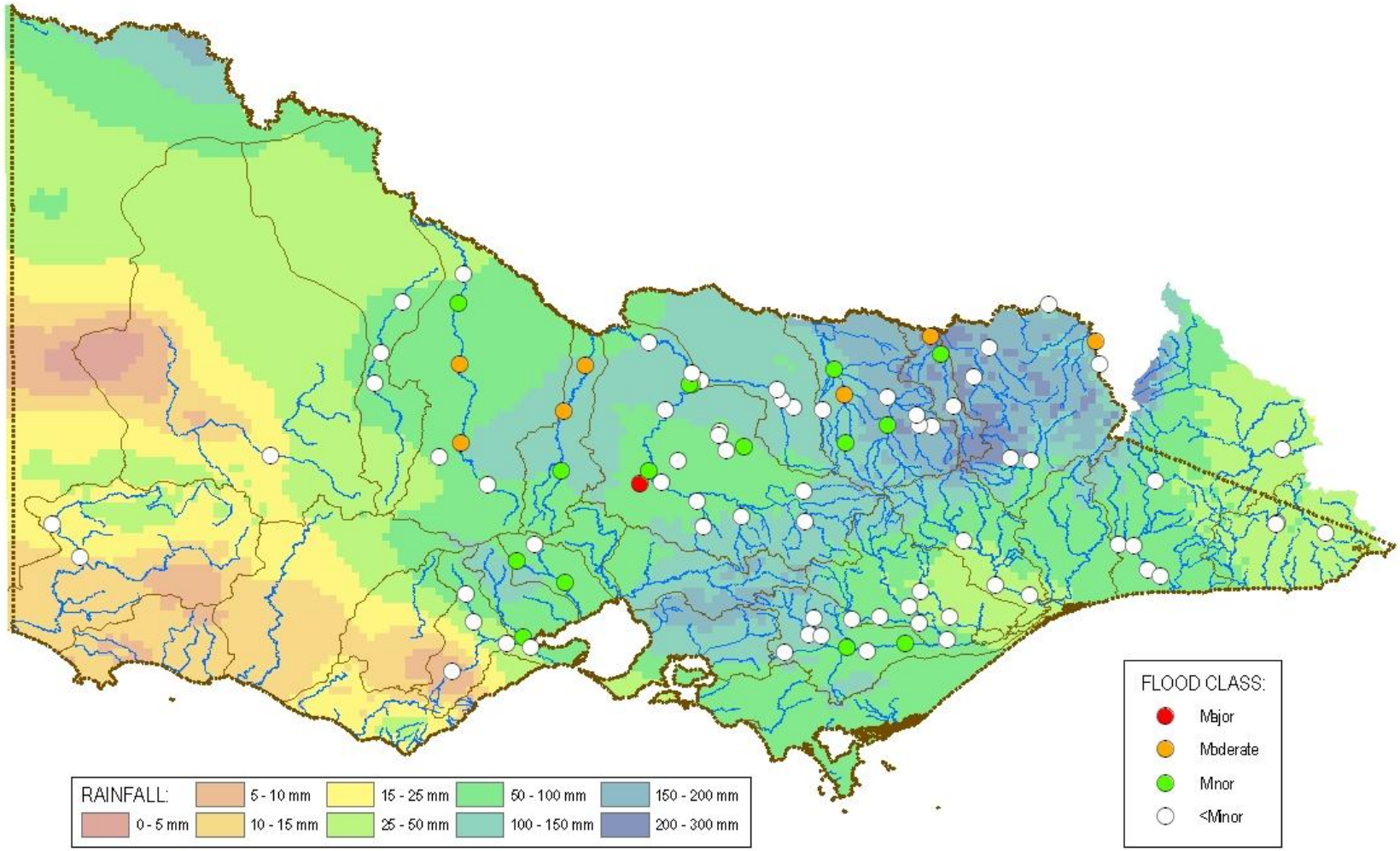
January 2011 Bureau of Meteorology Flood Warnings



Flood Warnings only issued at gauge locations where flood classes have been established

Note: Rainfall distribution shown in these maps generated by the Bureau of Meteorology is different from that of the previously presented maps. This is most likely due to a different interpolation method.

February 2011 Bureau of Meteorology Flood Warnings



Flood Warnings only issued at gauge locations where flood classes have been established

Note: Rainfall distribution shown in these maps generated by the Bureau of Meteorology is different from that of the previously presented maps. This is most likely due to a different interpolation method.