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Changes to the Intensity-Frequency-Duration (IFD) Design Rainfalls Across Australia

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The Bureau of Meteorology has recently released new Intensity-Frequency-Duration (IFD) design rainfall information for Australia. These new IFDs will replace those previously provided in Australian Rainfall and Runoff (AR&R87) which were developed nearly 30 years ago. The new IFDs are based on a greatly expanded rainfall database and their development uses more statistically rigorous methods that are more appropriate to the analysis of Australian rainfall data.

Across Australia there has been a significant increase in both the number of rainfall stations used in the estimation of the new IFDs compared to the AR&R87 IFDs and the length of record available. In particular, there is considerably more data from continuous rainfall stations with which to estimate the IFDs for durations of less than an hour, and therefore IFDs for these durations rely more on data and less on interpolation. This, coupled with the adoption of contemporary methods, has resulted in significant changes – both increases and decreases – between the new IFDs and the AR&R87 IFDs for various parts of Australia. Although the nature of the changes to the IFDs varies across the country and with duration and Annual Exceedance Probability (AEP), increases of greater than 30% and decreases of greater than 30% compared to the AR&R87 IFDs are seen for specific durations and AEPs.

This paper discusses the data and methods adopted in the derivation of the new IFDs; presents the differences between the new IFDs and the AR&R87 IFDs; and identifies the parts of Australia (with particular reference to Western Australia) where the changes are greatest. Comparisons between the quantiles derived from at-site rainfall frequency analysis and the gridded new IFDs and the AR&R87 IFDs are presented which show that, in the majority of cases, the new IFDs provide a more accurate estimate of the quantiles.

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1. INTRODUCTION

The Bureau of Meteorology (the Bureau) has recently completed a five year project undertaken as part of the Australian Rainfall and Runoff (AR&R) Revision to produce new Intensity-Frequency-Duration (IFD) design rainfall estimates for the whole of Australia. The new IFDs were released on 1 July 2013 via the Bureau's website and will replace the IFDs previously provided in AR&R87 (although until the revision of other design flood inputs such as temporal patterns, areal reduction factors, losses is completed the new IFDs can only be used in specific circumstances). Guidance on the use of the new IFDs can be found on both the Bureau website www.bom.gov.au and the AR&R Revision website www.arr.org.au

The new IFDs are based on a greatly expanded rainfall database and use contemporary methods for the analysis of the rainfall data. In addition, the length of record available for each station has been maximised through quality control processes and regionalisation methods. The new IFDs provide a better overall fit to the current rainfall database than the AR&R87 IFDs did to the database adopted in their derivation.

As with all statistical methods, there is always uncertainty in the derived results because of sampling variability. In the new IFDs this uncertainty has been reduced through the increased sample size afforded by the additional years of recorded data since the last IFDs were produced and the inclusion of significant amounts of rainfall data from water agencies around the country.

As is to be expected, there are differences between the AR&R87 and new IFDs, which vary across Australia and with duration and Annual Exceedance Probability (AEP). Some of the difference is due to increased data availability in locations that previously had limited data, and some is due to the different methods for statistical analysis and interpolation used for the new IFDs.

Both the AR&R87 IFDs and the new IFDs are estimates, but the new IFDs are the Bureau's best estimate of the design rainfalls for Australia based on the current rainfall database and the latest methods. They provide a clear, consistent point of reference for all hydraulic and hydrologic analysis in Australia. In the following sections the changes to estimation of the new IFDs will be discussed and the impact of these changes presented.

2. DATA AND METHODS ADOPTED FOR ESTIMATING IFDS

2.1. AR&R87 IFDs

The AR&R87 IFD estimates were developed by the Bureau of Meteorology (the Bureau) nearly 30 years ago using a database comprised primarily of information from the Bureau's network of daily read and continuous rainfall stations and adopting techniques for the statistical analysis of the data that were considered appropriate at the time. In particular, the methods used in the 1987 edition of Australian Rainfall and Runoff (AR&R 87) relied on subjective, manual interpolation to fill in areas with limited rainfall data.

2.2. New IFDs

In the intervening years since the publication of the previous IFDs, the Bureau's network of rainfall stations has been expanded and nearly 30 more years of additional data have been collected resulting in an increase in the number of stations with sufficient length of record to be included in the analyses. In addition, the Bureau now has ready access, under terms of the Water Regulations 2008, to daily read and continuous rainfall data collected by other organisations which supplements the Bureau's network, particularly in urban areas and areas of steep rainfall gradients. Figure 1 presents the additional sub-daily rainfall stations that were available for the estimation of the new IFDs while Figures 2 and 3 show the additional period of record that was available for both the daily read and sub-daily rainfall stations.

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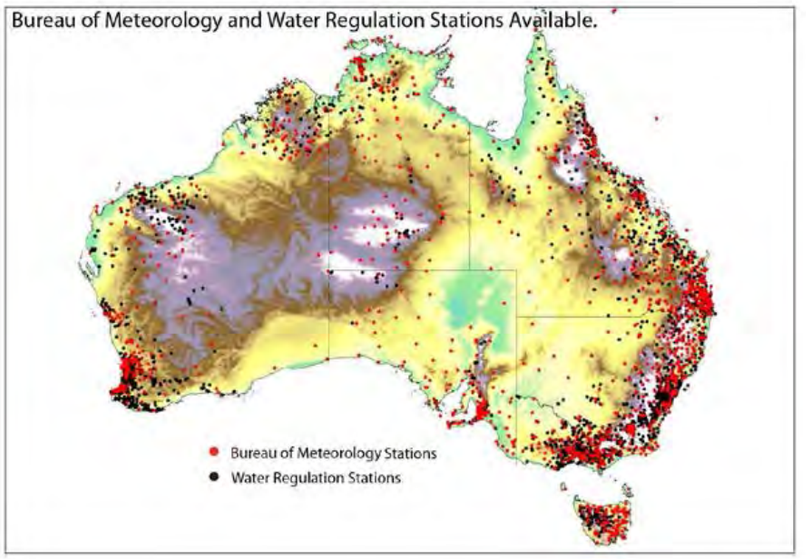

Figure 1 Location of Bureau and Water Regulations continuous rain gauges

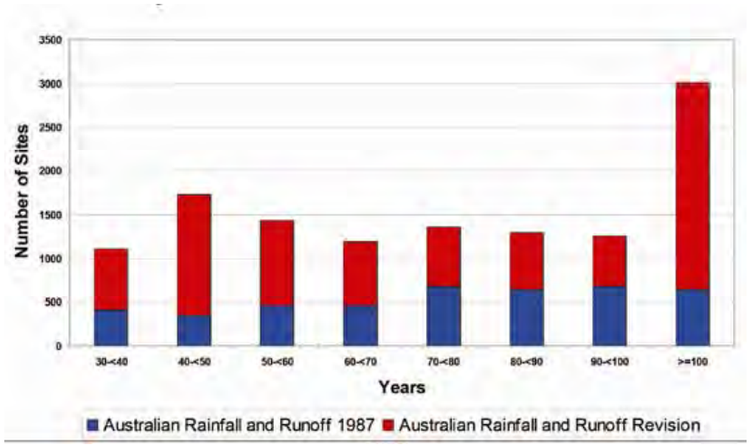

Figure 2 Available period of record for daily read rainfall stations

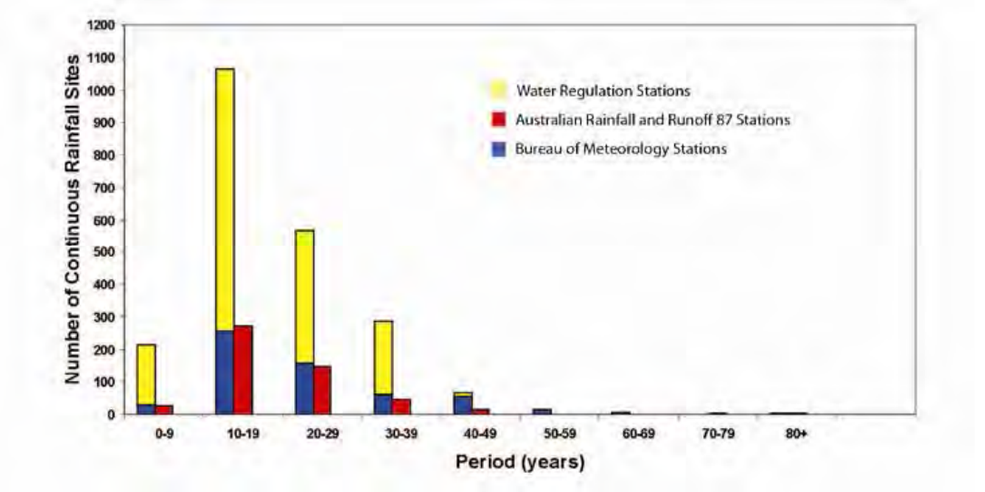

Figure 3 Available period of record for continuous rainfall stations

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In parallel with the expansion of the rainfall database, there have been developments in the statistical analysis of data since the estimation of the AR&R 87 IFDs. The new developments the Bureau has adopted for the new IFDs include:

1. The use of L-moments in fitting probability distributions to the data, which are considered to be more reliable than the previously adopted method of moments (Hosking and Wallace, 1997)
2. The fitting of a Generalised Extreme Value (GEV) distribution to the Annual Maximum Series (AMS) as this has been found to be the most appropriate distribution to be used with Australia rainfall data.
3. The regionalisation of the data using a Region of Influence (ROI) approach (Johnson et al, 2012a) in order to remove bias caused by stations with short periods of records.
4. The adoption of Bayesian Generalised Least Squares Regression (BGLSR) (Reis et al 2012) in order to infer sub-daily rainfall statistics from daily read rainfall data (Johnson et al, 2012b).

In addition, the computing capacity now available allowed more objective gridding techniques to be used, which provide a consistent, repeatable interpolation method across Australia. In particular, this enabled the translation from point to gridded rainfall estimates to be carried out with thin plate smoothing splines which were implemented using ANUSPLIN (Hutchinson 2007; The et al, 2012).

A comparison of the data and methods used to derive the new IFDs and the AR&R87 IFDs is provided in Table 1.

Table 1. Comparison of Data and Methods used for New IFDs and AR&R87 IFDs

Step	New IFDs	AR&R87 IFDs
Number of rainfall stations	Daily read – 8074 Continuous – 2280	Daily read – 7500 Continuous – 600
Period of record	All available records up to 2012	All available records up to ~1983
Length of record used in analyses	Daily read > 30 years Continuous > 8 years	Daily read > 30 years Continuous > 6 years
Source of data	Bureau of Meteorology & other organisations collecting rainfall data	Primarily Bureau of Meteorology
Extreme value series	Annual Maximum Series (AMS)	Annual Maximum Series (AMS)
Frequency analysis	Generalised Extreme Value (GEV) distribution fitted using L-moments	Log-Pearson Type III (LPIII) distribution fitted using method of moments
Extension of sub-daily rainfall statistics to daily read stations	Bayesian Generalised Least Squares Regression (BGLSR)	Principal Component Analysis
Gridding	Regionalised at-site distribution parameters gridded using ANUSPLIN	Maps hand-drawn to at-site distribution parameters, digitised and gridded using an early version of ANUSPLIN

3. COMPARISON BETWEEN NEW IFDS AND AR&R87 IFDS

In light of the differences in data and methods used to derive the new IFDs and the AR&R87 IFDs which are summarized in Table 1, it is to be expected that there will be differences between the new IFDs and the AR&R87 IFDs. These differences vary across Australia, across durations and across AEPs. In the following sections examples of these differences are presented. However, it should be noted that, in order to be able to compare the new IFDs to the AR&R87 IFDs, the AR&R87 values have been converted from Average Recurrence Interval (ARI) to AEP. In addition, the durations and AEPs for which the comparisons are presented have been selected as they are the same as those in the 6 master charts contained in Volume 2 of the 1987 edition of Australian Rainfall and Runoff.

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3.1. Differences Across Australia

Figure 4 presents the differences between the new IFDs and the AR&R87 IFDs for one hour (60 minute) duration and 2% AEP. Figure 4a shows the new IFDs; Figure 4b the AR&R87 IFDs from the Computerised Design Intensity Rainfalls System (CDIRS) grids; and Figure 4c the percentage difference between the two sets of IFDs which has been calculated using the following equation:

Percentage difference = (New IFD – AR&R87 IFD) * 100 / AR&R87 IFD

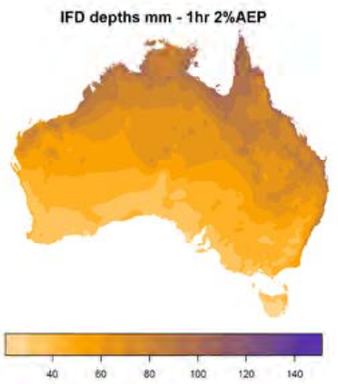

Figure 4a New IFDs

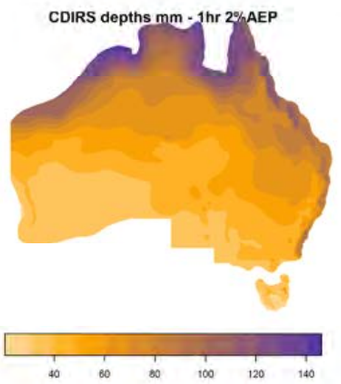

Figure 4b AR&R87 IFDs

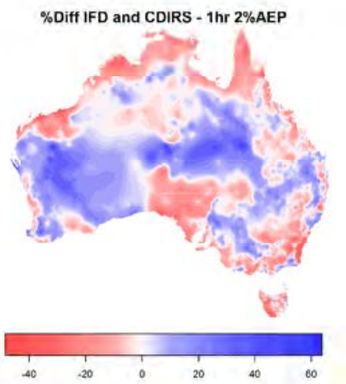

Figure 4c Percentage difference between new IFDs & AR&R87 IFDs

In Figure 4c the blue grid cells indicate areas where the new IFDs are greater than the AR&R87 IFDs and the red grid cells indicate areas where the new IFDs are less than the AR&R87 IFDs. An assessment was made of the comparisons, in the form of Figure 4c, that were undertaken for the complete range of durations and AEPs. Although comparisons for individual sets of duration and AEPs (such as shown in Figure 4c) show some trends, across all durations and AEPs there is no systematic trend in the differences between the new IFDs and the AR&R87 IFDs. This is not unexpected as the differences between the new IFDs and the AR&R87 IFDs not due either to changes in the methods adopted or to increases in the available data but to both factors and how they interact with each other.

3.2. Differences Across Duration – Perth Region

Differences for the Perth region between the new IFDs and the AR&R87 IFDs for the 2% AEP for the durations of 12 hours and 72 hours (3 days) are presented in Figures 5(a) and 5(b) respectively.

As can be seen,

- For the 12 hour duration, the new IFDs are predominantly greater than the AR&R87 IFDs, as shown by the predominance of blue, with differences of greater 50% being seen in the Yanchep Beach area (although much of the area to the north and east of the city of Perth show little difference.)
- However, for the 72 hour duration, the new IFDs are predominantly less than the AR&R87 IFDs, as shown by the predominance of red, with percentage changes ranging from -20% to -50%. It is also of interest to note that for the 72 hour duration the Yanchep Beach area shows little difference.

Differences between durations are to be expected, especially between IFDs which are based on sub-daily rainfall data (12 hour) and those based on daily read rainfall data (72 hour). This is due to the increase in the number of sub-daily rainfall stations that have been used to estimate the new IFDs. As can be seen from Figure 1, this is especially the case around the Perth region.

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Figure 5a Percentage difference across Perth region between new IFDs & AR&R87 IFDs for 2% AEP and 12 hour duration

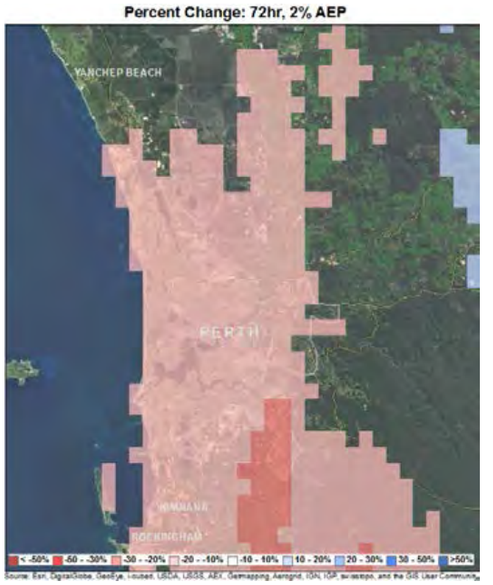

Figure 5b Percentage difference across Perth region between new IFDs & AR&R87 IFDs for 2% AEP and 72 hour duration

3.3. Differences Across AEP

In addition to difference across duration, differences can also be seen between AEPs. This is in part due to the longer periods of record that are now available which can result in the same rainfall depth for a given duration being assigned a different AEP. In Figure 6 differences across AEP between the new IFDs and the AR&R87 IFDs are presented for the Pilbara-Gascoyne region for the 1 hour (60 minute) duration for AEPs of 50% and 2%.

Figure 6a Percentage difference across Pilbara-Gascoyne region between new IFDs & AR&R87 IFDs for 1 hour (60 minute) duration and 50% AEP

Figure 6b Percentage difference across Pilbara-Gascoyne region between new IFDs & AR&R87 IFDs for 1 hour (60 minute) duration and 2% AEP

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As can be seen from Figure 6 (a) and (b),

- For the 50% AEP, the new IFDs are either equal to or greater than the AR&R87 IFDs with only small areas, mainly around Exmouth and Dampier showing the new IFDs being less than the AR&R87 IFDs.
- However, for the 2% AEP, although there are still areas in the south of the region where the new IFDs are greater than the AR&R87 IFDs, there are large areas in the north of the region where the new IFDs are less than the AR&R87 IFDs with percentage changes ranging from -30% to > -50%. It is of interest to note that the greatest changes for the 2%AEP are around Exmouth and Dampier which showed the new IFDs being less than the AR&R87 IFDs for the 50% AEP.

These differences between AEPs are not unexpected given the longer period of record now available for more accurately estimating the less frequent IFDs. In addition, as can be seen from Figure 1, significantly more sub-daily rainfall gauges were available for estimate the IFDs in the Pilbara-Gascoyne region than were available for the AR&R87 IFDs. This means the new IFDs for this region are based on the statistical analysis of observed rainfall data rather than the subjective, manual interpolation that was used for the AR&R87 IFDs in areas where there was insufficient or no data.

4. COMPARISON BETWEEN NEW IFDS AND AT-SITE FREQUENCY ANALYSIS

Both the new IFDs and the AR&R87 IFDs represent gridded, regionalized rainfall quantiles. As such, a direct comparison with quantiles derived from at-site frequency analysis will not necessarily produce the same results, especially for sites with only limited length of record. However, there is still value in comparing the at-site quantiles with the gridded IFD quantlies for both the new IFDs and the AR&R87 IFDs. Figures 7 and 8 show such a comparison with each plot showing for the AR&R87 IFDs (blue) and the new IFDs (red) the available AMS; the fitted distribution; and the gridded IFD quantiles

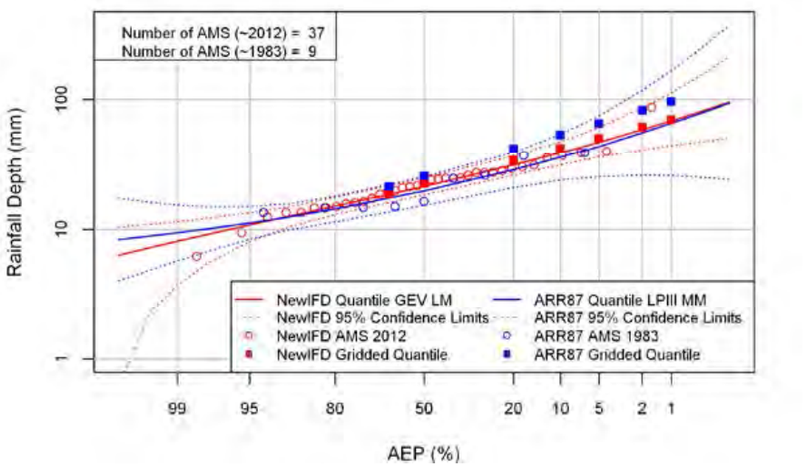

Figure 7 At-site comparison rainfall station no: 005007 – 1 hour duration

Figure 7 shows, for the continuous rainfall station No 005007 Learmonth Airport and a one-hour duration, that the use of 37 AMS values for the fitting of the GEV distribution using L-moments for the new IFDs, compared to the 9 AMS values used to fit the LPIII distribution using the method of moments for the AR&R87 IFDs, has resulted in gridded new IFD quantiles that better match the at-site quantiles. Similarly, Figure 8 shows for the daily read rainfall station No 006010 Carey Downs that the use of 27 additional AMS values for the new IFDs, provides more accurate estimates of the 2% and 1% AEP IFDs.

Similar comparisons were undertaken for numerous other stations across Australia. Although the results of these comparisons varied, in general the comparisons between the new IFDs and the at-site data showed an improvement.

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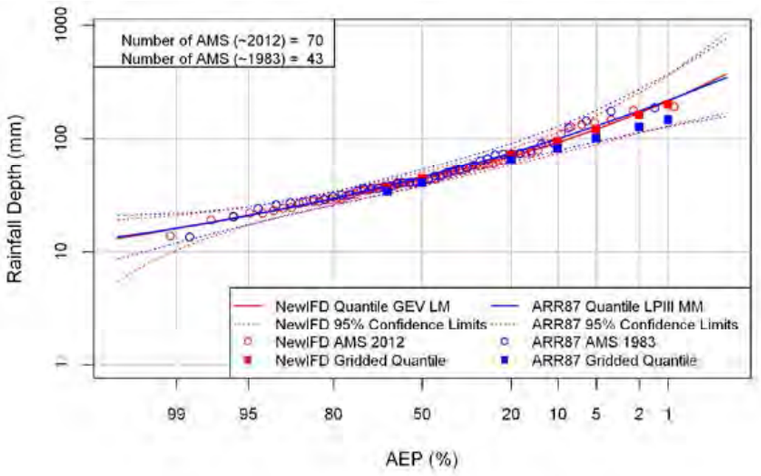

Figure 8 At-site comparison rainfall station no: 006010

5. CONCLUSIONS

The Bureau of Meteorology has released new Intensity–Frequency–Duration (IFD) Design Rainfall estimates that are based on a more extensive dataset, with nearly 30 years' additional rainfall data and data from 2300 extra rainfall stations.

Although, as to be expected there are differences between the new IFDs and the AR&R87 IFDs – with the new IFDs being both greater than and less than the AR&R87 IFDs – the new IFDs are more accurate estimates, combining contemporary statistical analyses and techniques with an expanded rainfall database.

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