The Revised Intensity-Frequency-Duration (IFD) Design Rainfall Estimates – Evolving to Meet Changing User Needs and Emerging Science

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The Bureau of Meteorology is currently finalising a revision of the IFD estimates, with the revised IFDs on schedule to be finalised in November 2012. The revision uses a greatly expanded rainfall database in addition to adopting more statistically rigorous methods that are most appropriate to Australian Rainfall data. The revised IFD estimates will better meet the changing needs of users by providing estimates for the shorter durations and more frequent Annual Exceedance Probabilities (AEPs) that are required for urban design. The dissemination of the revised estimates will be undertaken electronically using the GIS capabilities that are now available.

1. INTRODUCTION

Design rainfall estimates are an essential component of the design of infrastructure including gutters, roofs, culverts, stormwater drains, flood mitigation levees and retarding basins. The current Intensity-Frequency-Duration (IFD) estimates were developed by the Bureau of Meteorology (the Bureau) over 20 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 deemed appropriate at the time. The IFDs were disseminated as hard copy maps in Volume 2 of Australian Rainfall and Runoff (AR&R) (IEAust, 1987) and either a graphical or an analytical process was used to derive IFDs for a specific site. The focus of the IFDs was the design of structures on relatively large rural catchments and therefore durations of less than one hour were not considered necessary. The approach adopted for the IFD estimates contained in the current edition of Australian Rainfall and Runoff (AR&R87) (IEAust, 1987) is summarised in Table 1. Figure 1 gives an example of the hard copy maps that were used to disseminate the current IFD
estimates and shows the design rainfall isopleths for the Melbourne environs for an ARI of 50 years and a duration of 72 hours.

In the intervening years, the Bureau’s network of rainfall stations has been expanded and almost 30 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 areas of steep rainfall gradients. In parallel with the expansion of the rainfall database, there have been significant advances in statistical methods, mapping procedures, and information dissemination techniques which make a revision of the IFD estimates long overdue. Further, the requirements of the end-users have changed with a significant shift in focus from flow estimation in large rural catchments to urban design on small catchments necessitating the provision of IFD estimates for durations as short as one minute. This has required an emphasis on providing sub-hourly IFDs and the need to develop methods that optimise the information available from the continuous rainfall stations.

Table 1 Summary of current IFD method

<table>
<thead>
<tr>
<th>Variable</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>Primarily Bureau stations</td>
</tr>
<tr>
<td>Record length</td>
<td>~ up to 1983; 7500 daily read &gt; 30 years; 600 pluviographs &gt; 6 years</td>
</tr>
<tr>
<td>Durations</td>
<td>5 minutes to 72 hours (3 days)</td>
</tr>
<tr>
<td>ARIs</td>
<td>1 year to 100 years</td>
</tr>
<tr>
<td>Frequency analysis</td>
<td>Annual maximum series; method of moments; Log-Pearson Type III</td>
</tr>
<tr>
<td>Seasonal estimates</td>
<td>No</td>
</tr>
<tr>
<td>Mapping</td>
<td>Manual with meteorological insight</td>
</tr>
<tr>
<td>Confidence Intervals</td>
<td>No</td>
</tr>
<tr>
<td>Climate Change</td>
<td>No; stationary climate assumed; climatic trends assumed to have negligible effect on IFDs</td>
</tr>
<tr>
<td>Delivery method</td>
<td>Maps; IFD tables &amp; charts calculated on-line</td>
</tr>
</tbody>
</table>
In the following sections a summary of the work that is currently being undertaken by the Bureau of Meteorology into revising the IFD estimates is presented. The updated database and proposed method utilise all the available data and adopt ‘state of the science’ techniques.

2. DATABASE

2.1. Sources of data

The current IFD estimates for Australia were based primarily on the Bureau’s network of daily read and continuous rainfall stations which consisted of approximately 7500 daily read rainfall stations with greater than 30 years of data and 600 continuous rainfall stations with greater than 6 years of data that were available in 1983.

In the intervening years, the Bureau’s network of rainfall stations has been expanded and almost 30 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 2011, the Bureau of Meteorology’s Australian Data Archive for Meteorology (ADAM) contained:

- approximately 20 000 daily read rainfall stations (both open and closed) from 1800
- nearly 1500 continuous rainfall stations – using both Dines tilting syphon pluviograph (DINES) and Tipping Bucket Rain Gauge (TBRG) instrumentation.
The location of these rain gauges and the period of record are shown in Figure 2 for the daily read stations and Figure 3 for the continuous rainfall stations.

Figure 2 Location of Bureau daily read rain gauges and period of record
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. These additional stations supplement the Bureau’s network particularly in areas of steep rainfall gradients and urban areas.

The Water Regulations 2008 identified approximately 260 ‘persons’ who are required to give to the Bureau, water information that they have in their possession, custody, or control. Of the 260 data custodians, 74 have indicated that they possess data from daily read rainfall stations and 45 that they have data from continuous rainfall stations. The following additional rainfall data have been received via the Water Regulations:

- ~ 350 daily read rainfall stations
- ~ 2175 continuous rainfall stations.

The effect of more than doubling the number of continuous rainfall stations upon which the IFD estimates are derived will make a significant improvement to the accuracy and representativeness of the IFD estimates, especially for sub-daily durations and in urban areas.

The location of these rain gauges and the period of record are shown in Figure 4 for the daily read stations and Figure 5 for the continuous rainfall stations.
Figure 4 Location of Water Regulations daily read rain gauges and period of record
2.2. Quality controlling of data

Although the rainfall from non-Bureau sources greatly increased the amount of available data, the various sources from which the data were provided meant that the data have been previously quality controlled to differing degrees using a range of quality control coding systems. The result of this was that it was difficult to establish a baseline of quality controlled data using existing procedures. In view of this, it was decided that the quality controlling of the rainfall data would be applied to all data, regardless of source, and would be predicated on the assumption that no checking or correcting of the data had been undertaken previously. Where quality controlling of the data had been undertaken in a systematic fashion, for example using the HYDSTRA Time Series Data Management tools developed by Kisters Pty Ltd and adopted by large water authorities, there would be efficiencies in terms of a reduction in the amount of suspect data identified and requiring checking and correction.

The scope of the quality controlling requirements and the volume of data needing to be quality controlled, necessitated the development of automated procedures for the identification of suspect data and, as far as possible, the correction of these data. The rainfall data have been Quality Controlled (QC’d) using the automated procedures that were developed as part of the IFD Revision Project. The QCing undertaken of both the daily read and continuous rainfall data is summarised below; detailed descriptions of these procedures can be found in Green et al. (2011).
2.2.1. Daily read rainfall data

For the daily read rainfall data the QCing of the data that has been undertaken includes:

- Infilling of missing data
- Disaggregation of flagged accumulated daily rainfall totals
- Detection of suspect data, identification and correction of:
  - Unflagged accumulated totals
  - Time shifts
  - Identification of gross errors
- Manual correction of gross errors identified as having a high probability of being incorrect

2.2.2. Continuous rainfall data

Automated procedures have also been developed and applied for the QCing of the continuous rainfall data. These procedures use comparisons with other data sources including the Australian Water Availability Project (AWAP) gridded data, daily read rainfall stations, automatic weather stations, and synoptic stations to identify spurious and missing data. Manual QCing of the data was undertaken to correct the spurious data.

In order to reduce the amount of continuous rainfall data that needed to be quality controlled to a manageable volume, only a subset of the largest rainfall events based on the Partial Duration Series (PDS) was QC’d. The PDS was created by extracting the highest rainfall records equal to three times the number of years of record at each site.

2.2.3. Meta data

The meta data associated with each of the Bureau’s rainfall stations were also checked. For each of the stations, the Bureau’s meta database, SitesDB, includes details of the station’s location in latitude and longitude, and elevation. A project was recently undertaken whereby, for all stations that are currently open, the co-ordinates and elevation of the gauge were checked when the routine inspections were made. If the co-ordinates in SitesDB were found to be incorrect, the meta data were corrected.

For stations that are no longer operational, gross error checks on station locations and elevations were performed by comparing DEM derived elevations to those recorded in the station metadata. Checks of latitude and location were also carried out by plotting the latitudes and longitudes in GIS. Revisions to station locations or elevations were carried out using Google Earth and information on the station provided in the Bureau’s station metadata catalogue.

For the limited number of closed stations for which an elevation was not included in SitesDB, the station elevation was extracted from the Geoscience Australia 9 second DEM based on the latitude and longitude.
3. METHOD TO ESTIMATE IFDS

3.1. Overview

The method required to estimate IFDs involves the following broad steps:

- Establishment of a rainfall database
- Extraction of a series of extreme values
- Undertaking of at-site frequency analysis
- Undertaking of regional frequency analysis
- Regionalisation
- Gridding of the data

The first step pertaining to data is discussed in the previous section; the remaining steps are discussed in the following sections.

3.2. Extreme value series

The extreme value series – both the Annual Maxima Series (AMS) and the Partial Duration Series (PDS) – have been extracted from the QC’d database for all stations with more than eight years of record for continuous stations and thirty years of data for daily rainfall stations.

3.2.1. Restricted to unrestricted conversion factors

In order to convert the restricted daily read rainfall depths to unrestricted depths, conversion factors of 1.15 for 1 day, 1.11 for 2 days, 1.07 for 3 days, 1.05 for 4 days, and 1.04 for 5 days were adopted, based on Jakob et al. (2005).

3.2.2. AMS to PDS conversion

Due to the different values selected for analysis in the AMS and the PDS, fitted distributions for the two series will lead to different estimates of the rainfall quantiles. For frequent events, the PDS is considered to be more reliable as it will include many rainfall events around the exceedance probability of interest. A conversion factor therefore needed to be applied to the AMS rainfall estimates for events more frequent than the 1 in 10 AEP to account for the lower estimates than those obtained if the PDS had been used. The adopted conversion factors were 1.11 for the 1 in 2 AEP and 1.02 for the 1 in 5 AEP. These conversion factors were based on the ratio of the 1 in 2 and 1 in 5 AEP estimates of the 24 hour rainfall depth from the AMS and PDS respectively, averaged across Australia.

3.3. At-site frequency analysis

As shown in Table 1, the current IFD estimates were derived using statistical techniques that were deemed appropriate at the time. A Log-Pearson Type III distribution was fitted to the annual maximum series of rainfall data using the method of moments.
However, in recent years analyses undertaken as part of the development and application of the CRC-FORGE in the estimation of design rainfalls for Annual Exceedance Probabilities (AEPs) from 1 in 100 to 1 in 2000 (Nandakumar et al, 1997) found that a Generalised Extreme Variable distribution fitted using L-moments (Hosking and Wallis, 1997) was the most appropriate approach for Australian rainfall data.

In order to assess the most appropriate distribution to adopt across Australia for both the AMS and the PDS for the IFD revision project, a range of distributions was trialled using single site analysis. Five distributions – GLO, GEV, GNO, PE3 and GPA – were fitted to both the AMS and PDS extracted from the available long-terms continuous rainfall stations for durations of 6, 12, 18, and 30 minutes and 1, 2, 3, 6, and 12 hours. The goodness of fit of each distribution was assessed using the approach recommended by Hosking and Wallis (1997) which uses a goodness of fit measure $Z_{\text{Dist}}$ with a threshold $|Z_{\text{Dist}}| \leq 1.64$. The following distributions found to produce the best fit on an at-site analysis:

- Annual Maximum Series – Generalised Extreme Value (GEV)
- Partial Duration Series – Generalised Pareto (GPA)

The comparison of distributions was subsequently repeated for regional estimates with the same results.

On the basis of the results of the above comparison, the GEV distribution was fitted to the previously extracted AMS and the GPA was fitted to the PDS for all stations which met the record length criteria of thirty years for daily read rainfall stations and nine years for continuous rainfall stations.

3.4. Regional frequency analysis

Regional frequency analysis was undertaken using the L-moments which were extracted from each of the frequency distributions. While for durations of 1 day and longer this was a fairly straightforward approach, for sub-daily durations the scarcity of long term continuous rainfall records meant that an alternative approach was needed to supplement the available data. For the IFD revision project, a Bayesian Generalised Least Squares Regression (BGLSR) approach was adopted. More details of this are provided below.

3.4.1. Daily durations (24 hours to 168 hours)

The L-moments of mean, L-CV and L-skewness were used to summarise the statistical properties of the extreme value series data at each station location. L-moments are commonly used in rainfall and flood frequency analysis (Hosking and Wallis, 1997) due to their efficiency in fitting the data and lack of bias in the sample estimates, particularly in the higher order moments, when compared to ordinary moments.

3.4.2. Sub-daily durations (1 hour to 12 hours)

At sites at which there was a continuous rainfall station with more than eight years of record, the mean, L-CV and L-skewness, were determined from the at-site extreme value series for each
duration.

The continuous rainfall stations were also used to derive prediction equations between site characteristics and the sub-daily L-moments. This was done in order to be able to estimate sub-daily rainfall parameters based on site characteristics and daily rainfall statistics to improve the spatial coverage of sub-daily data.

As can be seen from Figures 2(b) and 3(b) the spatial coverage of sub-daily rainfall stations is considerably less than that of the daily read stations. Therefore, a method is needed to improve the spatial coverage of the sub-daily data. This is most commonly done using information from the daily read stations with statistics of sub-daily data being inferred from those of the daily data.

Techniques that have been adopted previously to do this include:

- Factoring of the 24 hour IFDs
- Principal component analysis
- Partial least squares regression

However, a major weakness of the previously adopted approaches is their inability to account for variation in record lengths from site to site and inter-station correlation.

An approach that avoids these problems is Bayesian Generalised Least Squares Regression (BGLSR) because it accounts for possible cross-validation and unequal variance by constructing an error covariance matrix and can explicitly account for sampling uncertainty and intersite dependence.

A further advantage of the BGLSR is that the Bayesian formulation allows for the separation of sampling and modelling errors. This is important because it was found that the sampling errors dominate the total error in the model. The BGLSR produces estimates of the standard error in:

- the regression coefficients β
- the predictions at-site used in establishing the regression equations
- the predictions at daily rainfall stations (i.e. ungauged sites not used in deriving the regression)

The error variances for the predictions are comprised of the regional model error and the sampling variance (Reis et al 2005).

Therefore, for the IFD revision, the prediction equations were derived BGLSR approach. Further details on the Bayesian GLSR approach can be found in Reis et al (2005) and Madsen et al (2002, 2005).

The following predictors were used in the BGLSR:

- Location (latitude and longitude)
- Elevation
- Slope
- Aspect
- Distance from the coast
- Mean annual rainfall
- Rainfall statistics for 24 hour, 48 hour and 72 hour durations - mean, L-CV and L-skewness.

The regression equations derived from the BGLSR were then applied to the daily read stations to predict the sub-daily L-moments at the daily station locations. This allowed for a greater density of sub-daily data to be used in gridding across Australia: this is described in Section 3.5 below.

3.5. Regionalisation

Regionalisation recognises that for stations with short records, there is considerable uncertainty when estimating the parameters of probability distributions and short records can bias estimates of rainfall statistics. To overcome this, it is assumed that information can be combined from multiple stations to give more accurate estimates of the parameters of the extreme value probability distributions.

For the revision of the IFDs, regionalisation has been used to estimate the L-CV and L-Skewness with more confidence. The regionalisation approach adopted is generally called the “index flood procedure” (Hosking and Wallis, 1997). This approach assumes that sites can be grouped into homogenous regions, such that all sites in the region have the same probability distribution, other than a scaling factor. The scaling factor is then normally termed the index flood or in this case, since the regionalisation is of rainfall data, the “index rainfall”. The index rainfall is the mean (i.e. first L-moment) of the extreme value series data at the station location.

For the IFD revision project, the station point estimates have been regionalised using a Region of Influence Approach (ROI). The ROI approach assumes that all the stations in the region of the station of interest have a common probability distribution which only needs to be scaled by a site specific factor. The assumptions of the approach are, firstly, that the specified probability distribution (GEV in the case of the AMS) is appropriate; that the region is truly homogenous; and, finally, that sites are independent or that their dependence is quantified.

After trialling of various approaches, ROIs defined a circle which is expanded until it includes 500 station years of record.

3.6. Gridding of GEV parameters

The regionalisation process resulted in estimates of the GEV parameters at all station locations, which could be combined with the mean of the extreme value series at that site to estimate rainfall quantiles for any required exceedance probability. However IFD estimates are required across Australia, not just at station locations. Therefore the results of the analyses needed to be extended in some way to ungauged locations. ANUSPLIN (Hutchinson 2007) was chosen to grid the GEV parameters so that IFD estimates are available for any point in Australia.
The GEV parameters are being gridded in ANUSPLIN, as earlier testing has shown little difference in the resulting quantile estimates if the point parameter or point rainfall depths are gridded. Gridding rainfall parameters gives more flexibility in the choice of exceedance probabilities that can be extracted and requires fewer grids to be processed in ANUSPLIN.

ANUSPLIN applies thin plate smoothing splines to interpolate and smooth multi-variate data. The degree of smoothing of the fitted functions was determined through generalised cross validation. The splines are fitted using three independent variables; latitude, longitude and elevation. The elevation scale was exaggerated by a factor of 100 to represent the importance that elevation has on precipitation patterns (Hutchinson 1995).

3.7. Calculation of growth factors and rainfall depths

The outputs of the ANUSPLIN analysis were grids across Australia for each duration of index rainfall and the GEV shape (alpha) and scale (kappa) parameters. These were then processed to firstly estimate the growth factors for each grid location and then the rainfall depths for each exceedance probability, according to the following equations:

\[ \xi = 1 - \alpha \left( 1 - \Gamma(1 + \kappa) \right) / \kappa \]  \hspace{1cm} \text{Equation 1}

where \( \xi \) is the location parameter for the regionalised growth curve.

\[ q(F) = \xi + \alpha \left( 1 - (-\log(F))^{\kappa} \right) / \kappa \]  \hspace{1cm} \text{Equation 2}

where \( q(F) \) is the quantile function of the growth curve.

\[ Q(F) = \mu q(F) \]  \hspace{1cm} \text{Equation 3}

where \( Q(F) \) is the quantile function of the scaled growth curve, which is multiplied by the index rainfall \( \mu \).

Following this, the AMS to PDS conversion factors described in Section 2.3.1 above were applied to the 1 in 2 and 1 in 5 AEP estimates.

Figure 6 gives an example of the output from the gridding process undertaken using ANUSPLIN.
3.8. Sub-hourly values

To derive IFDs for durations between one hour and one minute the ‘simple scaling’ model developed by Menabde et al (1999) was adopted. The model was calibrated using the extreme value series from the database of continuous rainfall stations with more than eight years of data. For each continuous rainfall station the scaling factor, $\eta$, was determined and the at-site $\eta$ values gridded. The model was then applied to the 1 hour duration rainfall depth grids to estimate the rainfall depths for the 1 minute to 30 minute rainfall events according to the following equation:

$$I_d = \left(\frac{d}{D}\right)^\eta I_D$$  

Equation 4

Where $I_d$ is the sub-hourly rainfall intensity for duration $d$, $I_D$ is the 60 minute rainfall intensity (i.e. duration $D$ is 60 minutes).

3.9. Smoothing across durations

In order to reduce inconsistencies across durations and smooth over discontinuities in the gridded data (unevenly spaced differences in design rainfall estimates at neighbouring durations) arising from application of the method, a smoothing process was undertaken. This was done by applying a polynomial to each grid point to all the standard durations from 1 minute up to 10,080 minutes.

Figure 6 Example output from ANUSPLIN
The polynomial was of the form:

\[ y(x) = a_0 + a_1x + a_2x^2 + a_3x^3 + \ldots + a_nx^n. \]  

\[ \ldots \ldots \ldots \ldots \text{Equation 5} \]

where \( n \) is the degree (or order) of the polynomial and \( a_0, a_1, \ldots, a_n \) are coefficients to be determined.

Inconsistencies with respect to duration (rainfall depths at lower durations exceeding those at higher durations) were also found and were addressed in the manner described below.

Inconsistencies were detected by subtracting each grid from a longer duration grid at the same average recurrence interval (ARI) and checking for negative values. Inconsistencies were addressed by adjusting the longer duration rainfall upwards so that the ratio of shorter duration rainfall to the longer duration rainfall equals 0.99, or

\[ \text{Rainfall depth at the shorter duration} = 0.99 \]  

\[ \ldots \ldots \ldots \ldots \text{Equation 6} \]

Rainfall depth at the longer duration

The smoothing procedure was applied first to the original grids and the smoothed grids adjusted for inconsistencies. The grids were smoothed once again and a final adjustment for inconsistencies across durations was performed. The final grids were also checked for inconsistencies across AEP.

4. OUTPUTS

The outputs from the revision of the IFD estimates will reflect the change in the needs of the end-users for IFD information and the technology available for dissemination of the information. For AR&R87, the focus of the IFD estimates was primarily for the design of structures on relatively large rural catchments; however, the requirements of the end-users have changed with a significant shift in focus to urban design on small catchments.

4.1. Durations

The extent of durations considered in the current IFD relationships (outlined in Table 1), is 5 minutes to 72 hours. In response to changes in user requirements, the revised IFD estimates will be provided for durations from 1 minute to 7 days inclusive. In addition advice on how to extrapolate to durations of less than one minute and greater than 7 days will also be provided.

4.2. AEPs

The revised IFD information will be provided for AEPs to 1%. The revised IFD information will be blended with the CRCFORGE estimates, derived by each state, for AEPs from 1% to 0.05% to enable a smooth rainfall frequency curve to be derived to an AEP of 0.05%. 
4.3. Dissemination

The series of six master maps contained in Volume 2 of AR&R87 represented a significant advancement in the dissemination of IFD information at the time. However, with the capability to provide this information on-line, for example, via the Bureau’s Computerised Design IFD Rainfall System (CDIRS), the hard copy maps are used less frequently by practitioners.

The revised IFD estimates will be disseminated in an electronic format via a web interface which will enable users to derive both point and areal IFDs.

4.4. Implications of the revised IFDs

A detailed comparison on a national and regional basis between the revised IFDs and the AR&R87 IFDs is currently being undertaken; although, at the time of writing the results of these comparisons were not available. However, information on the differences between the revised IFDs and the AR&R87 IFDs will be provided on the new web-page at the same time as the revised points IFDs are released. This information will be provided both as maps and as tables of percentage changes.

4.5. Climate change advice

The revised IFDs will be for the current climatic regime. As part of the overall AR&R revision a climate change research strategy paper has been prepared to enhance understanding of how projected climate change may alter the behaviour of factors that influence the estimation of the design floods that are used in policy decisions involving infrastructure, town planning, floodplain management and flood warning and emergency management.

The AR&R Revision Climate Change Research Strategy identifies priorities for research direction to be undertaken over both the short term (Stage 1 – one year) and the longer term (Stage 2 – four years). The Strategy identifies five research themes:

1. Rainfall intensity-frequency-duration relationships
2. Rainfall temporal patterns
3. Continuous rainfall sequences
4. Antecedent conditions (including baseflow)
5. Simultaneous extremes

At the time of writing, funding has been provided for Stage 1 of Themes 1 and 2. In the interim, advice will be provided on how to consider the impact of climate change in projects that use design rainfalls and have life spans of long enough duration such that climate change may affect the project.

5. CONCLUSIONS

The Bureau of Meteorology is currently revising the IFD estimates that are used by practitioners for the design of infrastructure ranging from gutters to dams, with the revised IFDs to be released in November 2012.

The revision uses a greatly expanded rainfall database incorporating not only the almost 30 years of
additional data collected at the Bureau’s gauges but also data from the rain gauge networks operated by other organizations. All the data have been subject to rigorous quality controlling procedures.

In addition, the revision is adopting more statistically rigorous techniques such as the Generalised Extreme Variable distribution and L-moment for rainfall frequency analysis, Bayesian Generalised Least Squares Regression for deriving sub-daily rainfall statistics, GIS based methods for gridding and an “index rainfall procedure” for regionalisation.

The revised IFD estimates will be provided for durations from 1 minute to 7 days inclusive. The AEPs for which the revised IFDs will be provided will be from 50% to 1% inclusive. The revised IFD information will be blended with the existing CRCFORGE estimates for each state for AEPs from 1% to 0.05% to enable a smooth rainfall frequency curve to be derived to an AEP of 0.05%. The dissemination of the revised IFD estimates will be undertaken in an electronic format via a web interface which will enable users to derive both point and areal IFDs.

6. REFERENCES


Madsen, H., Arnbjerg-Nielsen, K. and Mikkelsen, P.S. (2009), Update of regional intensity-duration-frequency curves in Denmark: Tendency towards increased storm intensities. Atmospheric Research, 92, 343-349
