OEH

ARR 2016 CASE STUDY - RURAL

REPORT ON SENSITIVITY TO ARR 2016 APPROACHES

DECEMBER 2018

Further Enquiries:

Office of Environment and Heritage
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: +61 2 9995 5000 (switchboard)
Phone: 131 555 (environment information and publications requests)
Phone: 1300 361 967 (national parks, general environmental enquiries, and publications requests)
Fax: +61 2 9995 5999
TTY users: phone 133 677, then ask for 131 555
Speak and listen users: phone 1300 555 727, then ask for 131 555
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au
Report pollution and environmental incidents
Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
See also www.environment.nsw.gov.au

Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: (02) 9299 2855
Fax: (02) 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

ARR 2016 CASE STUDY - RURAL

REPORT ON SENSITIVITY TO ARR 2016 APPROACHES

JANUARY 2019

Project ARR 2016 Case Study - Rural	**Project Number** 116030-02
Client OEH	**Client's Representative** Duncan McLuckie
Authors Mikayla Ward Monique Retallick Mark Babister Isabelle Testoni	**Prepared by** MER
Date 23 January 2019	**Verified by** MKB

Revision	Description	Distribution	Date
7	Final Report- Minor terminology change in losses	OEH	DEC 18
6	Final Report - updated	OEH	NOV 18
5	Final Report	OEH	MAY 18
4	Final Draft v3	OEH	DEC 17
3	Final Draft v2	OEH	NOV 17
2	Final Draft	OEH	SEP 17
1	Draft Report	OEH	AUG 17

ARR 2016 CASE STUDY - RURAL

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF DIAGRAMS

LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
CL	Continuing Loss
FFA	Flood Frequency Analysis
GIS	Geographic Information System
IFD	Intensity, Frequency and Duration (Rainfall)
IL	Initial Loss
mAHD	meters above Australian Height Datum
OEH	NSW Office of Environment and Heritage
PMF	Probable Maximum Flood
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

1. INTRODUCTION

In 2016, the 4th Edition of Australian Rainfall and Runoff (ARR 2016, Ball et al, 2016) was released. As part of the update design flood inputs have been revised including Intensity Frequency Duration (IFD) depths, Losses, Areal Reduction Factors and Temporal Patterns.

This report is one of two case studies developed for the NSW Office of Environment and Heritage (OEH) that support the Floodplain Risk Management Guide Considering Australian Rainfall and Runoff 2016 in studies (OEH ARR 2016 Guide). The guide and case studies aims to provide advice to floodplain managers in NSW on how to consider implementing and reporting on the changes to design flood practice relating to ARR 2016.

This case study focuses on the application of ARR 2016 to a large rural catchment and is presented in the form of a short report. It considers changes in losses, IFDs and approaches including flood frequency analysis, FFA.

Break out boxes, such as this one, assist the reader by providing advice on how the methods have been implemented and to detail steps that may not be included in a typical report.

This report provides an example only and the results should not be used beyond this purpose.

Council engaged a consultant to provide advice on the effect of the new ARR 2016 on design flood levels in a rural town in the upper reaches of a large river system in NSW.

In 2016, the 4th Edition of Australian Rainfall and Runoff (ARR 2016) was released. As part of the update, revised design flood inputs have been developed including Intensity Frequency Duration (IFD) depths, Losses, Areal Reduction Factors and Temporal Patterns. In addition, updates on recommended approaches to techniques such as flood frequency analysis (FFA) have changed.

The town of interest is located within a large river system. Due to hydraulic model run times an ensemble approach was chosen for the hydrological modelling only, with hydraulics concentrating on the mean event for each AEP.

This report details how sensitive the 1% AEP flood behaviour is to the ARR 2016 update of design inputs and approaches by comparing revised design flood estimates with estimates from the *Catchment Flood Study (2016)*.

2. BACKGROUND

2.1. Study Area

The focus of this study is a rural town located in the upper reaches of a large coastal river system on the north coast of NSW. The catchment area upstream of the town is approximately 340 km^2. There is little urban development in the catchment outside of the small townships. The upper reaches of the catchment are characterised by steep slopes and orographically enhanced rainfall.

2.2. Previous Studies

2.2.1. Catchment Flood Study (2016)

The *Catchment Flood Study (2016)* was undertaken to define the catchment area and flood behaviour for existing catchment conditions. This study used the Watershed Bounded Network Model (WBNM) for the hydrologic modelling of the catchment developed as part of the *Review of Catchment Hydrology (2011)*. This flood study adopted the inflows from the calibrated hydrologic model for the hydraulic model (TUFLOW) previously calibrated to several events including 1974, 1977, 2001 and 2009. Design flood levels were developed for a range of AEPs.

2.2.2. Review of Catchment Hydrology (2011)

The *Review of Catchment Hydrology (2011)* investigated known hydrologic issues in the catchment. Studies in this area of the NSW north coast present a range of challenges due to problems encountered matching rainfall runoff modelling with flood frequency results. As part of the study hydrologic models were developed and calibrated to historical events.

3. AVAILABLE DATA

The new design inputs (Intensity Frequency Duration (IFD) depths, losses, pre-burst, Areal Reduction Factors and Temporal Patterns) were available through the ARR Data Hub available at http://data.arr-software.org/ (*Babister et al, 2016b*), accessed in March 2017. The new IFD information was available from the BoM http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016 which can also be accessed via a link from the ARR Data Hub. The ARR Data Hub website allows sampling of the inputs by either a region shapefile or as latitude and longitude coordinates. Given the rainfall gradient over the catchment and the size of the catchment area of 340 km^2 which is significantly larger than a single grid size, data was sampled for individual sub-catchments to capture the spatial variability and as a total catchment to assess the catchment average. Appendix A contains the ARR Data Hub output for the catchment.

Given the catchment area is 340 km^2 and significantly more than the area of 1 grid cell in the design inputs (6.25km^2) and the rainfall gradient over the catchment, the spatial variability of inputs needs to be considered. The ARR Data Hub does allow for spatially averaged data to be extracted, for example for loss information across a catchment. To input a polygon into the ARR Data Hub the user must:

- Use latitude and longitude coordinates
- Select at least the: .dbf, .prj, .shp and .shx files

As shown in the Diagram 1 below.

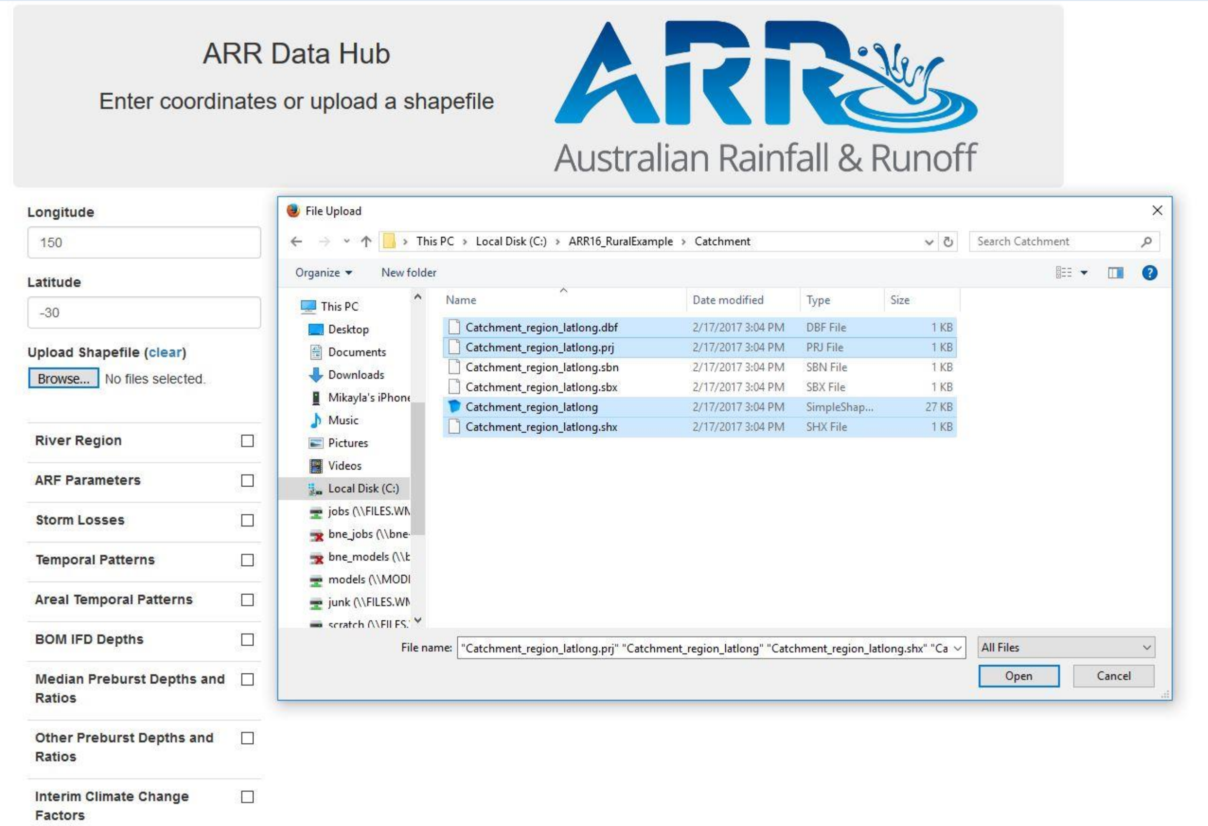


Diagram 1: ARR Data Hub shapefile input

Diagram 2 shows the catchment shape input into the ARR Data Hub. The map viewer on the left can be used to verify that the correct input shape has been used.

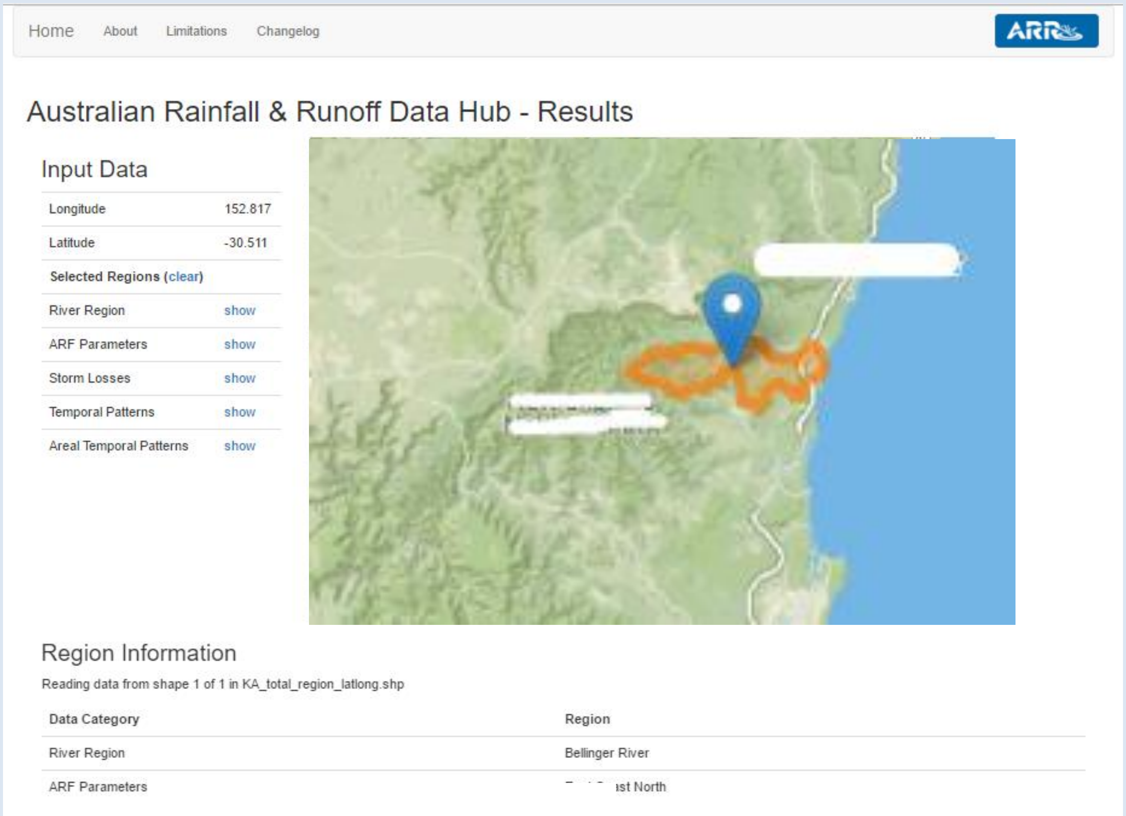


Diagram 2: ARR Data Hub Results

The ARR Data Hub website automatically produces a PDF file of the results which provides a record of the data used and shows a timestamp allowing for version tracking of inputs. This results file is to be included as an appendix to study reports to both efficiently verify inputs and improve the reproducibility of results in the future. Reports must clearly note where the data used have varied from the ARR Data Hub values and provide appropriate justification.

Appendix A is the output from the ARR Data Hub for the catchment input. The catchment was input as a polygon. It is noted that for each input polygon, the percentage of the area that intersects with the regions of the different design inputs is shown. The ARR Data Hub output will automatically show the region in which the majority of the catchment is located. If this percentage is not close to 100% then consideration should be given to carrying out sensitivity analyses on different region inputs.

3.1. Losses

Values for initial loss were taken from the ARR Data Hub. High pre-burst depths in the region highly influence initial losses in this catchment. Continuing loss from the ARR Data Hub was found to be 4.2mm/hr as an entire catchment average. The continuing losses in this area are considered very high. As discussed later in section 4.6 these losses were not applied as calibration FFA was available. As FFA is the most reliable form flood estimation available, losses from calibration to FFA are recommended over the ARR Data Hub losses in ARR 2016.

3.2. Design Rainfall

Intensity Frequency Duration (IFD) information was sourced from the Bureau of Meteorology website http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016. Due to the significant spatial variation of IFDs in the catchment the IFD information for each subcatchment was sourced.

The *Review of Catchment Hydrology (2011)* found that the 1987 IFDs overestimated the orographic effects of the steep-sloped upper reaches of the catchment and adopted locally derived IFDs in the region. Design flood levels from this assessment were available for comparison.

Catchments with a significant spatial variability (change in design rainfall by 5% - 10%) in rainfall should be spatially distributed. Catchment average rainfall should then be reported. The IFD is available as a gridded dataset for specific catchments if requested directly from BoM. In most cases the centroid for each sub-catchment can be downloaded from the BoM website.

3.3. Median Pre-burst

Appendix A includes the catchment average pre-burst information for the catchment from the ARR Data Hub. The pre-burst is found to be as high as 84.1 mm for the 18 hour 1% AEP event. In this location, the median pre-burst is often in excess of the storm initial loss.

3.4. Temporal Patterns

ARR 2016 Book 2 Chapter 5 (Babister et al, 2016a) recommends the use of areal temporal patterns for catchments greater than 75 km^2. The catchment is 340 km^2 and therefore the areal temporal patterns relevant to this location were downloaded from the ARR Data Hub.

Note that areal patterns are only provided in one bin for all AEPs due to data availability. Table 2.5.9 of ARR 2016 provides a table of what catchment area range to use the areal patterns for.

3.5. Baseflow

The ARR Data Hub provides baseflow factors around Australia. The catchment used in this case study does not have significant baseflow and therefore this was not included in the study.

Baseflow factors should be sourced from the ARR Data Hub for the outlet of the catchment and not the centroid. The PDF produced by the ARR Data Hub for baseflow factors should be attached in addition to the PDF for other design inputs, if it has been applied. As per the advice in ARR 2016 Book 5 Chapter 4 these factors are for a 10% AEP and should be converted for each AEP as per Table 5.4.1 of in *ARR 2016 Book 5 Chapter 4 (Hill et al, 2016)*.

In the ARR Data Hub baseflow is determined at the outlet of the catchment or tributary based upon generic regional approaches, therefore an at site baseflow analysis is preferable. On the NSW east coast baseflow is often a small component of the flow (1-2%) and is often ignored. Where baseflow is trivial it is acceptable to calibrate to total flow. In locations where baseflow is not trivial, baseflow should be removed and rainfall runoff models should be calibrated to the remaining quickflow with baseflow added back after calibration.

4. HYDROLOGY

The hydrologic model developed in the *Review of Catchment Hydrology (2011)* and used in the *Catchment Flood Study (2016), was* adopted for the current study. This was calibrated based on the 1974, 1977, 2001 and 2009 historical events and the Flood Frequency Analysis (FFA) undertaken using pre ARR 2016 methods. The previous study found that the critical storm duration was 36 hours. Filtering was undertaken to remove embedded bursts from the ARR 1987 temporal patterns in the previous study (Review of Catchment Hydrology, 2011). An ensemble in hydrology and mean in hydraulics approach was selected due to the long hydraulic model run times (15 hours).

Due to embedded burst for rarer AEP in ARR 1987 the following durations were typical critical in Zone 1 (NSW): 1.5, 2, 9, 36 hr. For locations where this was the case the critical duration and flows for ARR 2016 are likely to decrease relative to ARR 1987.

4.1. Design Rainfall

In this area the 1987 IFDs were known to overestimate rainfall which made calibration to FFA difficult. Therefore the earlier studies used locally derived IFDs based upon at-site data to calibrate the hydrological model to pre 2016 ARR IFD techniques.

To test sensitivity to ARR 2016 a comparison of the 1987, locally derived IFD and 2016 IFD for the 1% AEP is presented in Table 1. This shows that the 2016 IFDs are around 20% lower than the 1987 IFD for the 24 and 36 hour duration storms. The 2016 IFDs are 4-7% higher for the 24 hour and 11-13% lower for the 36 hours compared to the locally derived IFDs. Sub-catchment average IFD information was used in the hydrologic model for all three IFD estimates.

Table 1: Comparison of 1987, locally derived and 2016 IFD 1% AEP Rainfall Depths

Duration (minutes)	IFD Depths (mm)						Percentage change with 2016 IFD (%)			
	24 hour duration			36 hour duration			24 hour		36 hour	
	1987	**locally derived**	**2016**	**1987**	**locally derived**	**2016**	**1987**	**locally derived**	**1987**	**Locally derived**
Upper Catchment	551	433	451	674	623	540	-18%	4%	-20%	-13%
Lower Catchment	438	406	435	521	567	507	-1%	7%	-3%	-11%

Increases or decreases in the IFDs compared to 1987 and previously local derived IFDs based upon at-site data should be reported. As the new IFDs have been updated using a different methodology and 30 years more data it is expected there will be differences. Sub-daily design rainfall is especially likely to change due to the large increase in the number of pluviograph gauges included in the analysis.

An at-site IFD analysis should be carried out with nearby gauges where there is concern that the gridded BoM IFD data doesn't match local data. This does not mean that the at-site data is superior to the gridded BoM IFDs. The at-site data should be used as a check that no consistent bias is seen in the IFD results.

Appendix F in the OEH ARR 2016 Guide provides a map of changes in key IFD durations and AEP across NSW.

Some advice on doing an at-site analysis is given in Appendix D of the OEH ARR 2016 Guide.

4.2. Losses

The availability of a reliable gauge record meant that the continuing loss could be calibrated to FFA. The adopted continuing loss value varies with AEP and it shown in Table 3. Therefore the catchment average continuing loss (section 3.1) from the ARR Data Hub was not applied as calibration data was available.

This case study was undertaken prior to the WMAwater (2018) "Review of ARR Design Inputs for NSW" and has not been updated to reflect this latest work and the hierarchy of approaches to losses and pre-burst recommended in Section 3.7.1 of the OEH Flood Risk Management Guide: Incorporating 2016 Australian Rainfall and Runoff.

The use of calibration losses are the top tier in the losses hierarchy recommended in the guide therefore no change to the continuing loss steps in this case study would be required.

However, the guide recommends the use of probability neutral pre-burst rather than median pre-burst in estimation of burst loss. In addition, it recommends that the balance between pre-burst and initial loss should be reviewed to ensure that this is reasonable. This review is less critical as the catchment area is greater than 100km^2 and as such continuing losses are generally more critical to peak flood conditions.

4.3. Pre-burst Rainfall

The pre-burst has been sourced from the ARR Data Hub (see Appendix A). The median pre-burst value was taken. Burst initial loss (for rural catchments) was calculated from the ARR Data Hub values by applying the formula:

Burst Initial Loss = Storm Initial Loss – Pre-burst

This means that burst initial loss varied for each duration and AEP. As the pre-burst varies greatly across the catchment this was applied to each subcatchment individually (alternatively catchment average pre-burst could be used). Where the pre-burst gave a negative burst initial loss the burst initial loss was assumed to be zero. Table 2 summarises the losses used in the study which shows that large negative values were calculated when determining the burst initial loss. There is no method available to add this back into the temporal pattern and therefore 0mm initial loss (IL) was assumed. This is a conservative approach, therefore the catchment is assumed to be wet before the event.

Table 2: Losses

Subcatchment	Median Pre-burst 24 hour 1% AEP (mm)	Storm IL (mm)	Calculated Burst IL (mm)	Modelled Burst IL (mm)	CL (mm/hr)
K_SUB_A	67.9	16	-51.9	0	0
K_SUB_B	74.4	16	-58.4	0	0
K_SUB_C	94.2	24	-70.2	0	0
K_SUB_D1	94.2	28	-66.2	0	0
K_SUB_D2	95.4	29	-66.4	0	0
K_Sub_E	73.3	27	-46.3	0	0
K_SUB_F	95.4	29	-66.4	0	0
K_SUB_G	95.7	33	-62.7	0	0
K_SUB_H	95.7	34	-61.7	0	0
K_SUB_I	95.7	39	-56.7	0	0
K_SUB_J	73.5	40	-33.5	0	0
K_SUB_K	78.6	43	-35.6	0	0
K_SUB_L	69.2	43	-26.2	0	0
K_SUB_M	69.2	43	-26.2	0	0
K_SUB_N	84.7	43	-41.7	0	0
K_SUB_O	74.7	45	-29.7	0	0
K_SUB_P	74.7	44	-30.7	0	0

There are a number of approaches to the use of losses in rural catchments depending on the availability of data. Refer Section 3.7.1 of the OEH Flood Risk Management Guide: Incorporating 2016 Australian Rainfall and Runoff.

In this case FFA was available and the continuing loss could be calibrated to the FFA.

4.4. Temporal Patterns

Areal temporal patterns for the region were downloaded from the ARR Data Hub website. Ensembles of 10 temporal patterns were run for the 1% AEP with areal temporal patterns for standard durations between 12 hour (720 min) and 3 days (72 hour or 4230 min) as per recommendation in *ARR 2016 Book 2 Chapter 5 (Babister et al, 2016a)*.

ARR 2016 now provides ensembles of areal temporal patterns, i.e. 10 temporal patterns for each duration. Areal temporal patterns do not change for AEP. Areal temporal patterns have been derived for a number of different catchment areas. ARR2016 Table 2.5.9 provides a guide to applying the areal patterns. The column on the right is the designated pattern while the column on the left is the range of catchment areas it should be applied to. The patterns are selected based on the total catchment area to the point of interest but applied to each subcatchment area.

ARR 2016 Book 2 Chapter 5 (Babister et al, 2016a) Table 2.5.9. Areal Temporal Pattern Sets for Ranges of Catchment Areas

Range of Target Catchment Areas (km^2)	Catchment Area of Designated Areal Temporal Pattern Set (km^2)
75 – 140	100
140 – 300	200
300 – 700	500
700 – 1600	1000
1600 – 3500	2500
3500 – 7000	5000
7000 – 14,000	10,000
14,000 – 28,000	20,000
28,000 +	40,000

ARR 1987 temporal patterns should not be used for new flood studies utilising ARR 2016 IFDs or methods. Previous results based upon ARR 1987 methods or ARR 1987 methods may be used to test for sensitivity or to demonstrate the differences in the methods. Appendix A provides a map of the temporal pattern regions in NSW.

Note that even though the areal temporal patterns don't change with AEP some checks should be done to make sure the critical duration doesn't change with AEP.

4.5. Flood Frequency Analysis

The catchment has a gauge located on the main river upstream of the study area. Flood Frequency Analysis (FFA) was carried out as part of the *Review of Catchment Hydrology (2011)* with the 2011 FFA presented in Diagram 3. While there is a reasonable fit in the original FFA undertaken with an earlier version of FLIKE, there have been updates to the method in the intervening years. The original data was manually filtered, resulting in 33 records in the 60 years between 1950 and 2009.

ARR 2016 recommends the use of Bayesian flood frequency analysis techniques, such as presented in Flike.

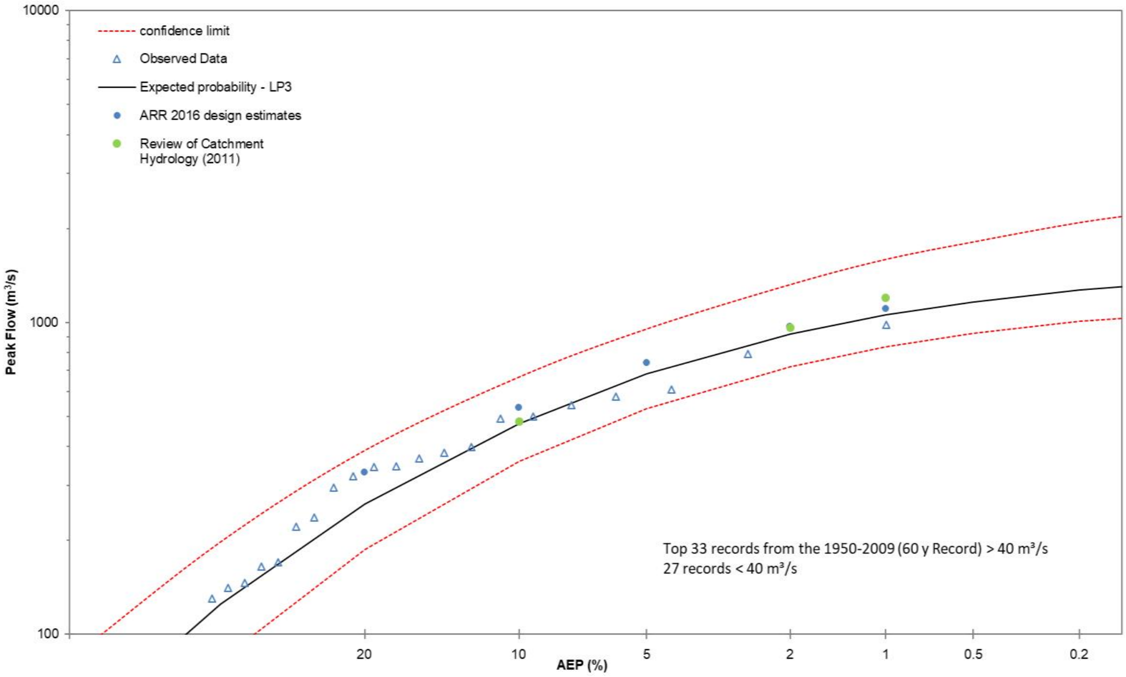


Diagram 3: FFA Source: (Review of Catchments Hydrology (2011))

The FFA was updated for this study using FLIKE and the Multiple Grubbs Beck test considering ARR 2016 advice and is presented in Diagram 4. The 60 years of stream flow data used in the *Review of Catchment Hydrology (2011)* was run through FLIKE. The application of the Multiple Grubbs Beck test removes some of the low flows that are unduly influencing the fit to the upper end of the curve. Diagram 4 and Table 3 show the updated FFA results, ARR 2016 design estimates for the temporal pattern closest to the mean, observed data and the *Review of Catchment Hydrology (2011)* design flood estimates. The new FFA results in a slightly higher estimated design flood quantiles.

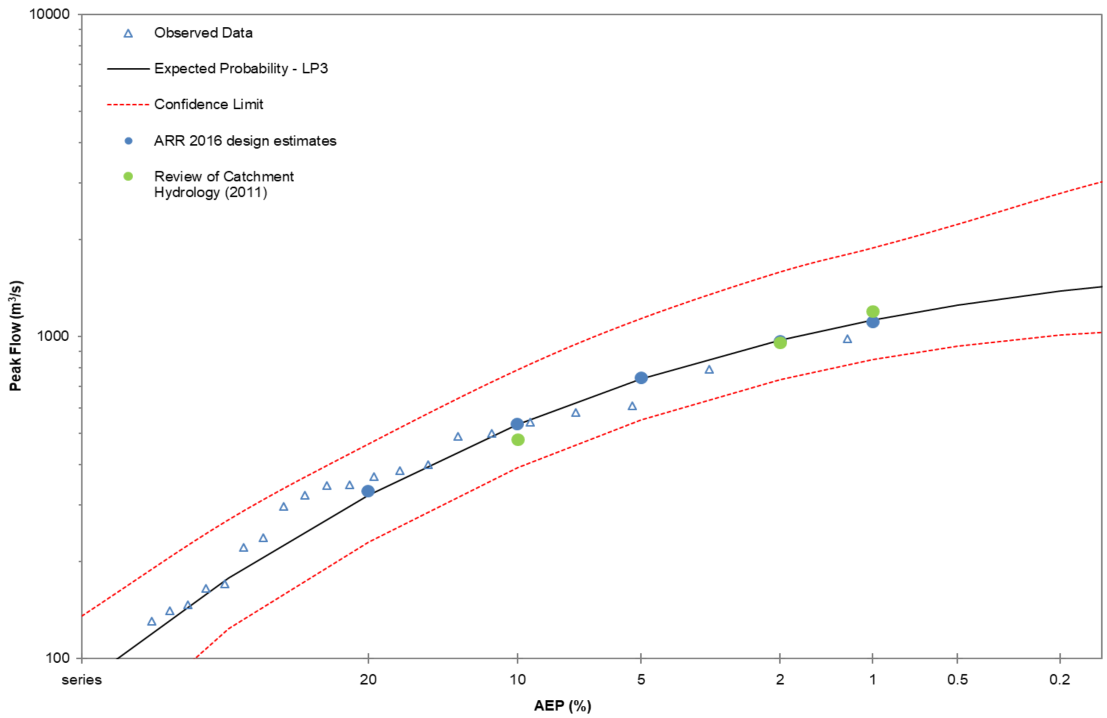


Diagram 4: FFA (FLIKE with Multiple Grubbs Beck applied)

4.6. Calibration

The hydrological model was calibrated to several historical events including the 2009 flood which was approximately a 1% AEP event in the catchment at the stream gauge upstream of the town. Continuing loss was varied from 0 to 4mm/hr to calibrate to the FFA given the long gauge record. Storm initial loss and pre-burst was sampled for each subcatchment from the ARR Data Hub. The resultant burst initial loss was negative for all events and AEPs and was therefore assumed to be 0 mm.

> If the burst initial loss is negative (i.e. pre-burst is greater than storm initial loss) then the initial loss for modelling is assumed to be zero. There is currently no way to add excess pre-burst compared to the storm initial loss into the design storm burst.

Table 3 presents the results from the areal temporal patterns (ATPs) closest to the mean of the 10 temporal patterns for each AEP. The highlighted cells represent which of the two patterns were selected for the design quantiles. In general, it was considered best practice to select the temporal pattern that gives the answer just above the mean. Diagram 5 shows how the ensemble for the critical duration for each AEP compare to the FFA.

Table 3: Peak Flood Flows at the stream gauge upstream of town for different AEPs

AEP	Peak Flow (m^3/s)			Continuing Loss (mm/hr)	ARR 2016 Peak Flow – Critical Duration 18hr (m^3/s)		
	Flood Study FFA	Updated FFA	Flood Study Hydrologic		ATP Below	Mean	ATP Above

			model				
20%	261	321		4	311	331	336
10%	474	532	480	2.5	507	533	544
5%	682	736		1	710	742	753
2%	917	975	960	0	930	968	977
1%	1055	1125	1200	0	1067	1107	1114

The previous flood study was also calibrated to the FFA. However, the adopted flow overestimated the 1% AEP peak flow compared to the FFA estimate (1200 vs 1055 m^3/s). As shown in Diagram 4 the ARR 2016 results produce a better calibration than the previous flood study to the revised FFA. However, the ARR 2016 1% AEP peak flow is less than the previous flood study and slightly less than the FFA. A continuing loss of zero has been used to achieve this flow.

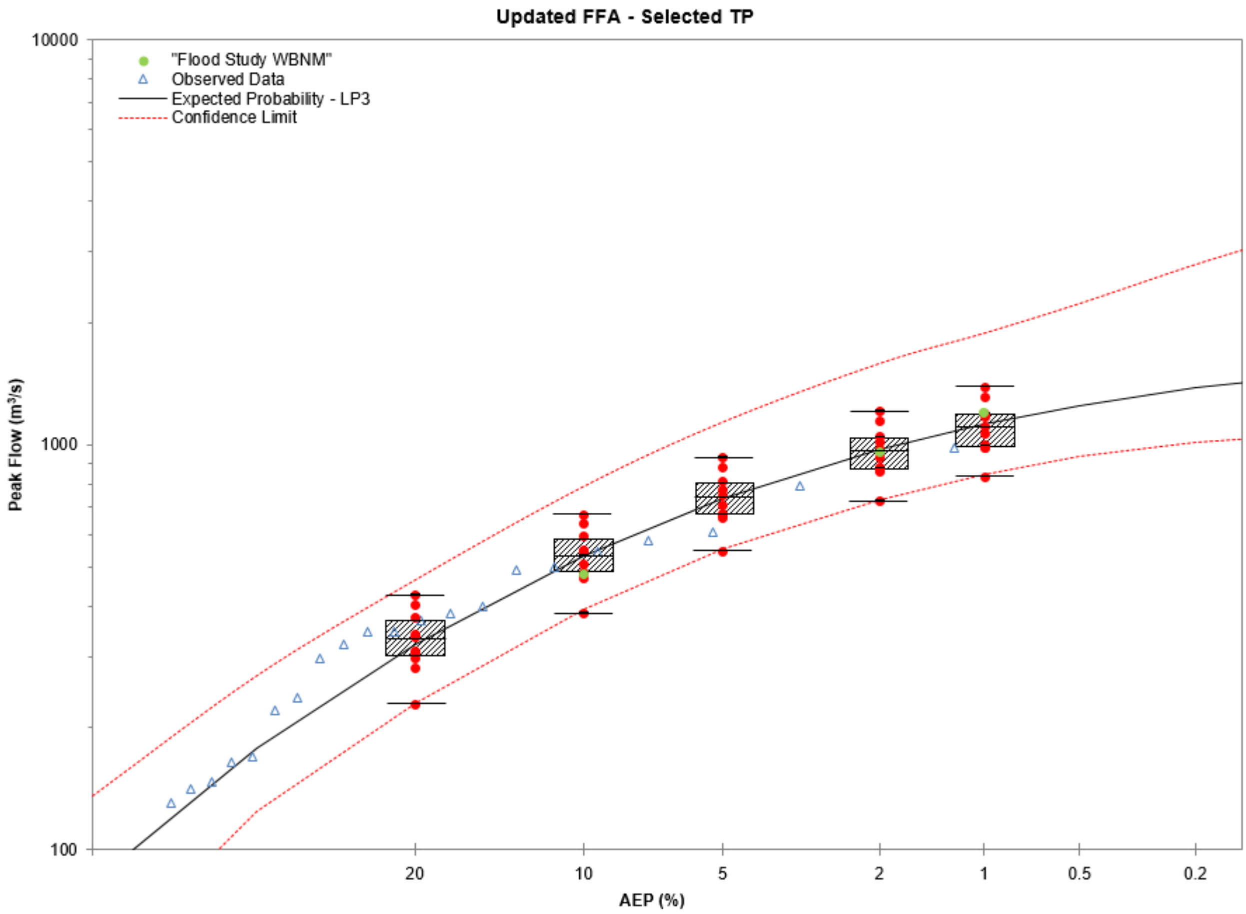
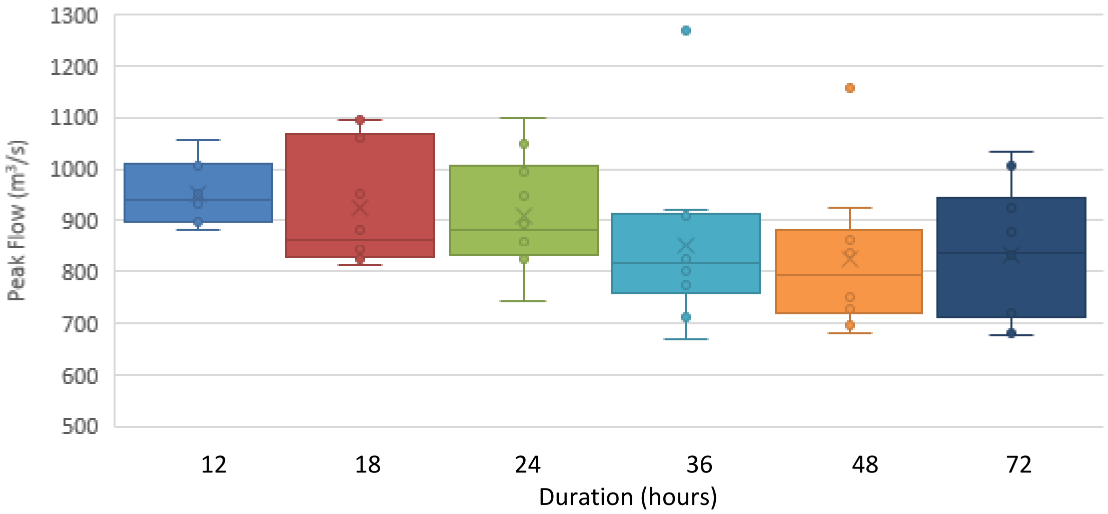


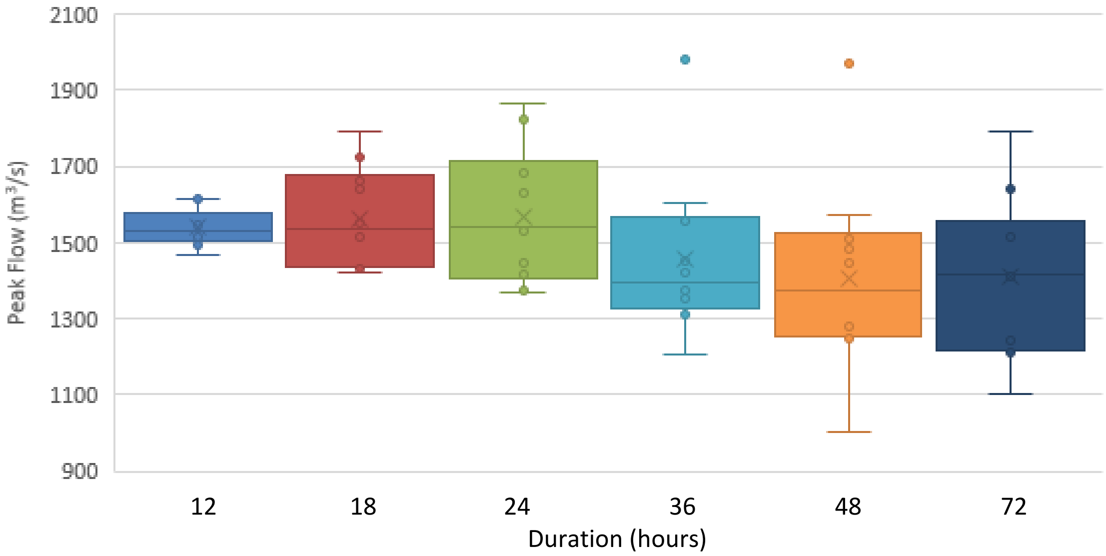
Diagram 5: Critical Duration Box plot on FFA

4.7. Critical Duration

Areal temporal patterns for the 12, 18, 24, 36, 48 and 72 hour durations were run through the hydrological model. The critical duration was identified using a box plot of the peak flow from the ensembles of all durations for the 10% and 1% AEP event (as recommended in ARR 2016 Book 2 Chapter 5 Section 5.9.2, Babister et al, 2016a). Two critical locations in the catchment; the stream gauge (a) and the town (b) are presented in the box plots (Diagram 6 and 7).

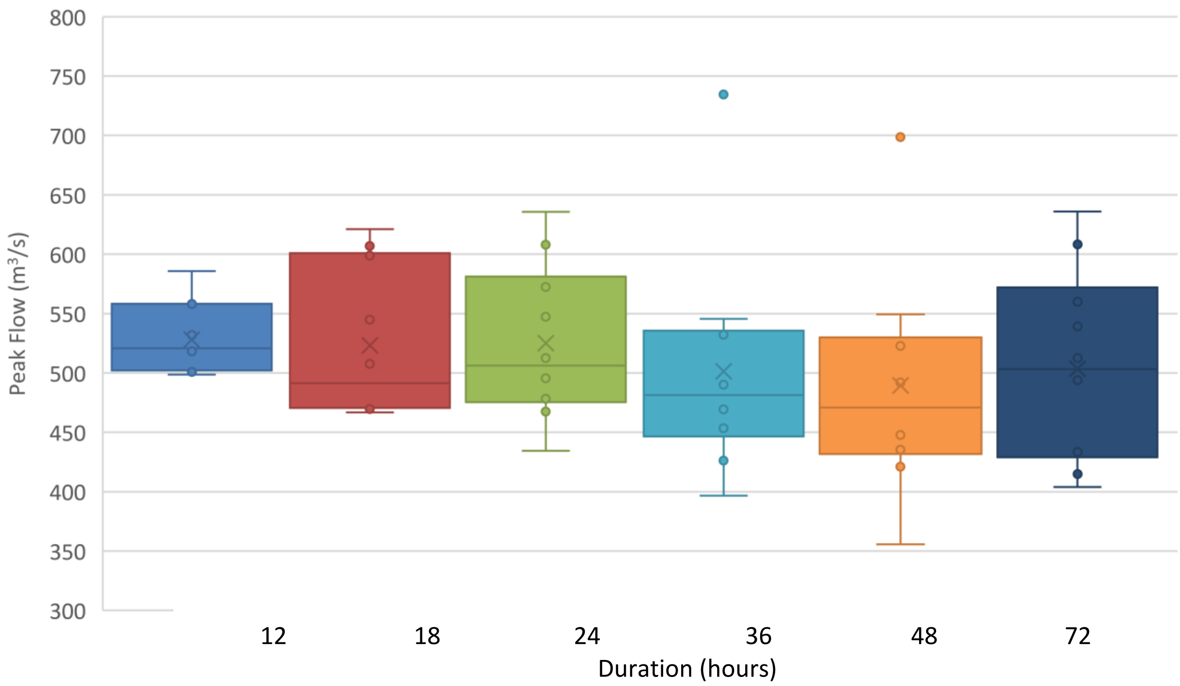


a) Stream Gauge

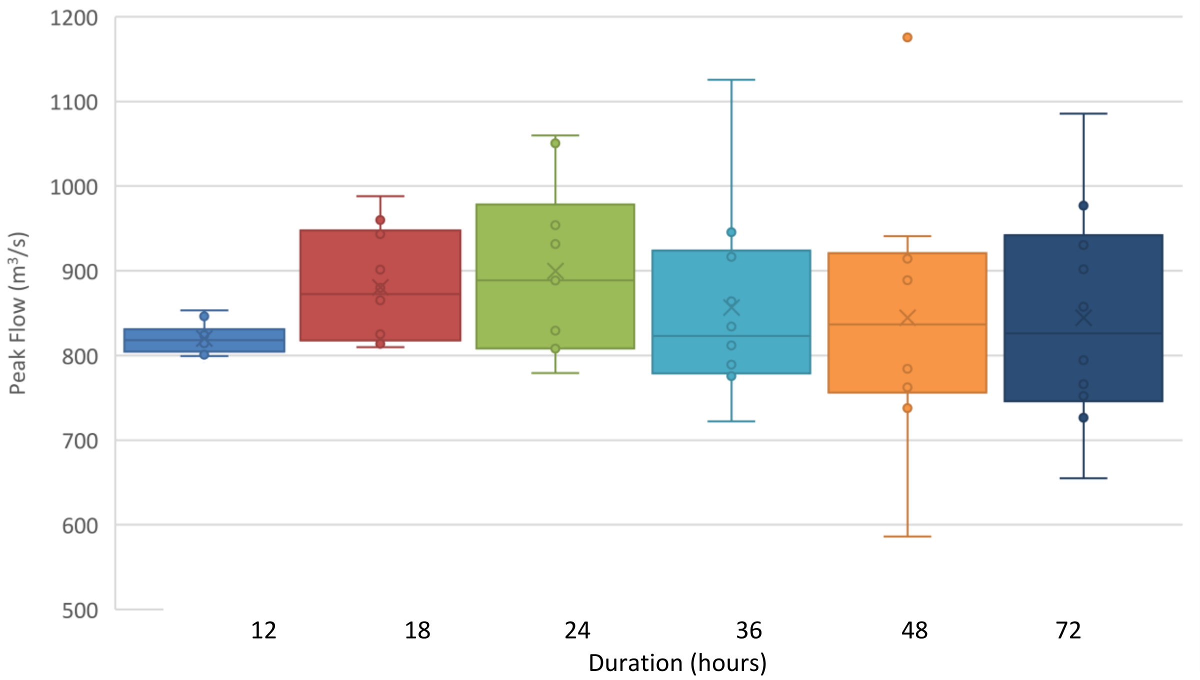


b) Town

Diagram 6: Areal Temporal patterns box plot of 1% AEP peak flows at a) Stream gauge and b) Town



a) Stream Gauge



b) Town

Diagram 7: Areal Temporal patterns box plot of 10% AEP peak flows at a) Stream gauge and b) Town

The area of interest for this study is the town. This is downstream of the stream gauge (critical duration of 18 hours) and the critical duration at the town is taken as 24 hours. Diagram 8 shows the 10 (ten) temporal pattern hydrographs and the ARR 1987 temporal pattern using the 2016 IFD (to show sensitivity to changing pattern). Temporal pattern 9 was chosen as the representative mean pattern to run in the hydraulic model. Temporal pattern 9 is relatively slow rising. Due to the long run time of the hydraulic model (approximately 15 hours) only the selected mean temporal pattern was run in the hydraulic model.

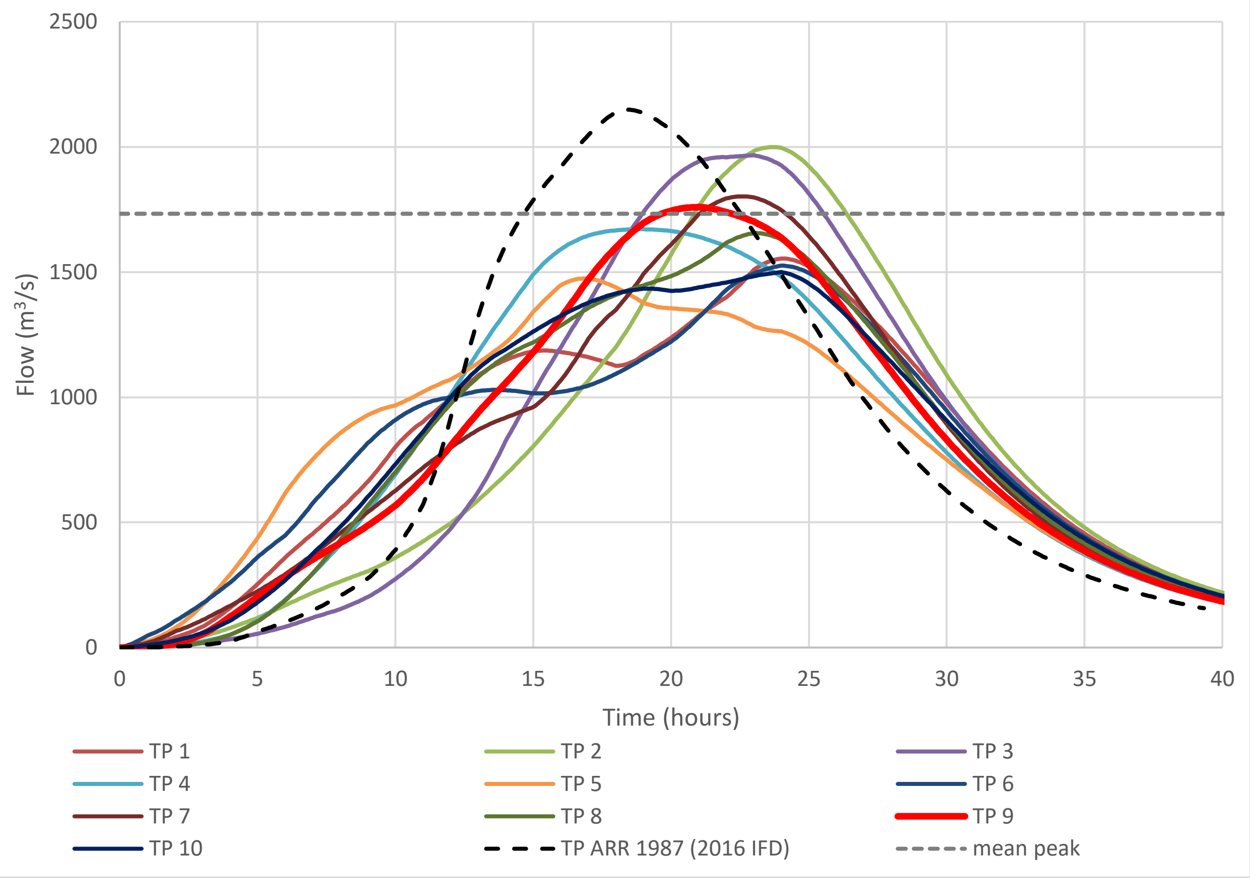


Diagram 8: Variation in the shape of ensemble temporal patterns

Assessing the critical duration based solely on the peak flow can overlook other key metrics which may be critical in management. These may include flood volume or rate of rise or time to reach a critical level. Therefore selection of a representative mean temporal pattern can also consider other aspects. Rate of rise or volume could also be used to select a mean temporal pattern to examine these aspects, if critical. For example, if a key management issue was evacuation then the rate of rise should also be considered in choosing the mean pattern. To demonstrate this the 3 (three) hydrographs closest to the mean (12, 18 and 24 hour durations) using the areal temporal patterns are presented in Diagram 9.

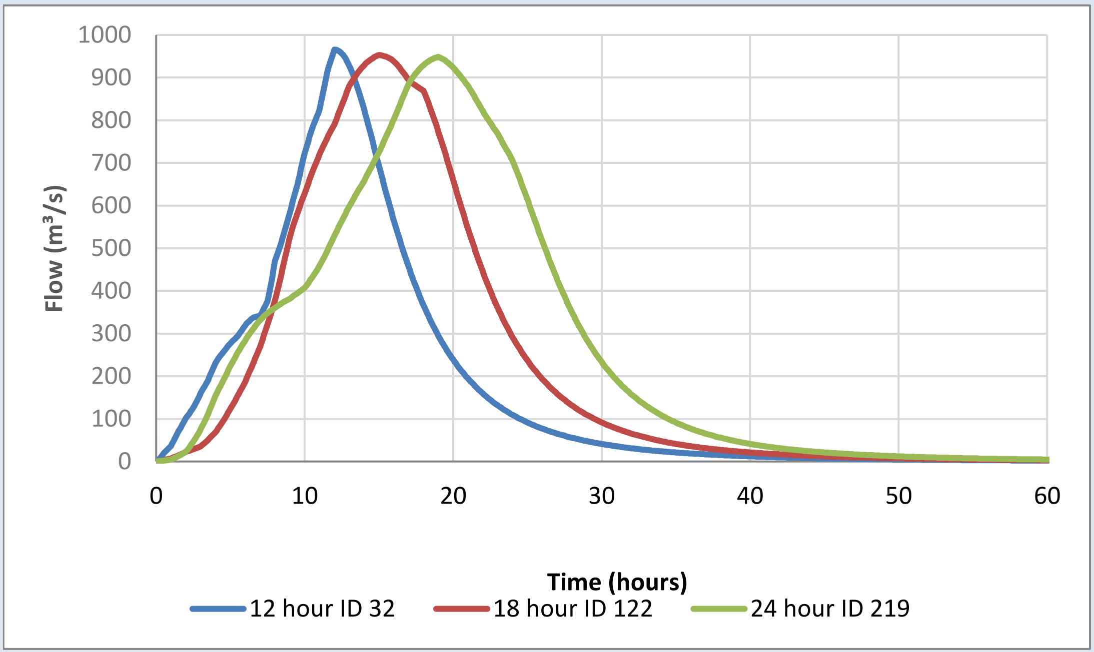


Diagram 9: 1% AEP hydrographs of different durations

Examining the hydrographs, the peak is very similar for all three hydrographs, though the rate of rise is significantly different. Diagram 10 presents a box plot of the rate of rise to 90% of the peak flow. The same methodology used for temporal pattern selection on peak flow can be applied to rate of rise, if that is what is critical in the study. Based on Diagram 10 the 12hr pattern would be chosen. Note fast rising events should only be used to assess options relating to evacuation limitations.

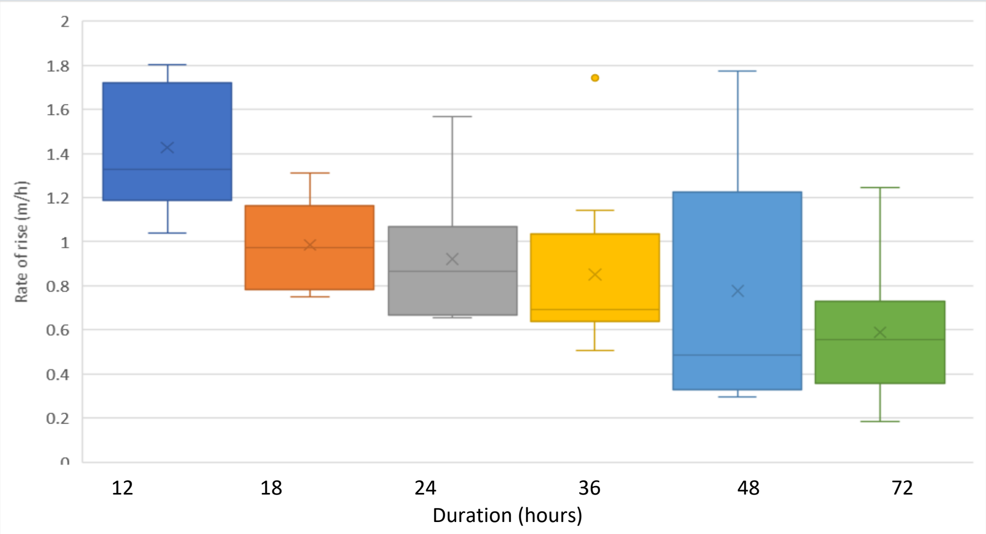


Diagram 10: Rate of Rise to 90% of peak flow

5. HYDRAULIC MODEL

This study used the 1D/2D hydrodynamic model of the study area developed using TUFLOW as part of the previous study. The calibrated model from the *Catchment Flood Study (2016)* was used for this assessment.

6. RESULTS

6.1. Design Flood Levels

Figure 3 presents the peak flood depths for the 1% AEP. Figure 4 presents the impact of the ARR 2016 changes on 1% AEP flood levels. Table 4 presents a comparison of the 1% AEP results from the *Catchment Flood Study (2016)* and the values estimated in this assessment considering ARR 2016 at key locations in the study area. A negative value shows where the flood level of the ARR update has decreased from the levels estimated in the *Catchment Flood Study (2016)* report.

Flood levels at all key locations have decreased in the order of 0.07m to 0.25m. The decreases are due to a combination of IFD changes, temporal pattern (the 36 hour was previously critical, now the 24 hour is critical) and changes in calibration to FFA.

Table 4: Peak Flood Level Comparison for 1% AEP

Location	Catchment Flood Study 2016 (mAHD)	Adjusted figures considering ARR 2016 update (mAHD)	Difference (m)
1	6.21	5.95	-0.25
2	5.89	5.76	-0.23
3	5.82	5.58	-0.23
4	5.61	5.40	-0.21
5	4.74	4.67	-0.07

7. CONCLUSIONS

This report examines the impacts of ARR 2016 on the 1% AEP flood level as a sensitivity analysis.

A comparison of pre 2016 ARR Flood Frequency Analysis (FFA) and design flows in the 2011 Review of Catchment Hydrology found that 1987 ARR IFDs were too high in this area. This resulted in a local analysis of at-site IFD data being undertaken and used in modelling. Hydrological modelling was calibrated against pre 2016 ARR FFA techniques and used in flood estimation for the *Catchment Flood Study 2016*.

Examining ARR 2016 techniques involved both an updated FFA analysis using recommended techniques in ARR 2016 as well as an assessment of the results of changes in IFDs in 2016.

Within this catchment the 2016 IFDs significantly reduced compared to the ARR 1987 IFD. The 1% AEP based upon the 2016 IFD is a 20% catchment average reduction in IFD depth compared to the ARR 1987 IFD. The 1% AEP based upon the 2016 IFD is a 4% increase on the locally derived IFD, used in the *Review of Catchment Hydrology (2011)* and the *Catchment Flood Study (2016).*

The changing techniques, temporal patterns and IFDs when calibrated against the FFA have a relatively minor impact on peak flood levels, within the range of -0.07m at the downstream end and up to -0.25m upstream of the Town. This result is expected due to the decrease in IFD and change in methodologies (such as the critical temporal pattern duration).

Given that this study is limited to a sensitivity analysis relating to ARR 2016 IFDs and techniques it is recommended that current flood levels based upon the *Catchment Flood Study (2016)* continue to be used until a more detailed assessment of flood levels based upon ARR 2016 techniques is undertaken as part of the next stage of the floodplain risk management process, the floodplain risk management study.

This report documents the sensitivity to ARR 2016 for the 1% AEP. If flood levels are sensitive to ARR 2016 methods and IFDs then consideration should be given to addressing ARR 2016 in more detail in the next stage of the floodplain risk management process, or in a subsequent review of this study. The priority of the next stage of the process or a study review should consider councils other priorities for flood risk management studies and actions and the relative scale of change resulting from ARR 2016.

8. REFERENCES

1. Hill P, Brown R, Nathan R and Graszkiewicz Z
Book 5 Chapter 4: Baseflow Models, Australian Rainfall and Runoff: A Guide to Flood Estimation
© Commonwealth of Australia (Geoscience Australia), 2016

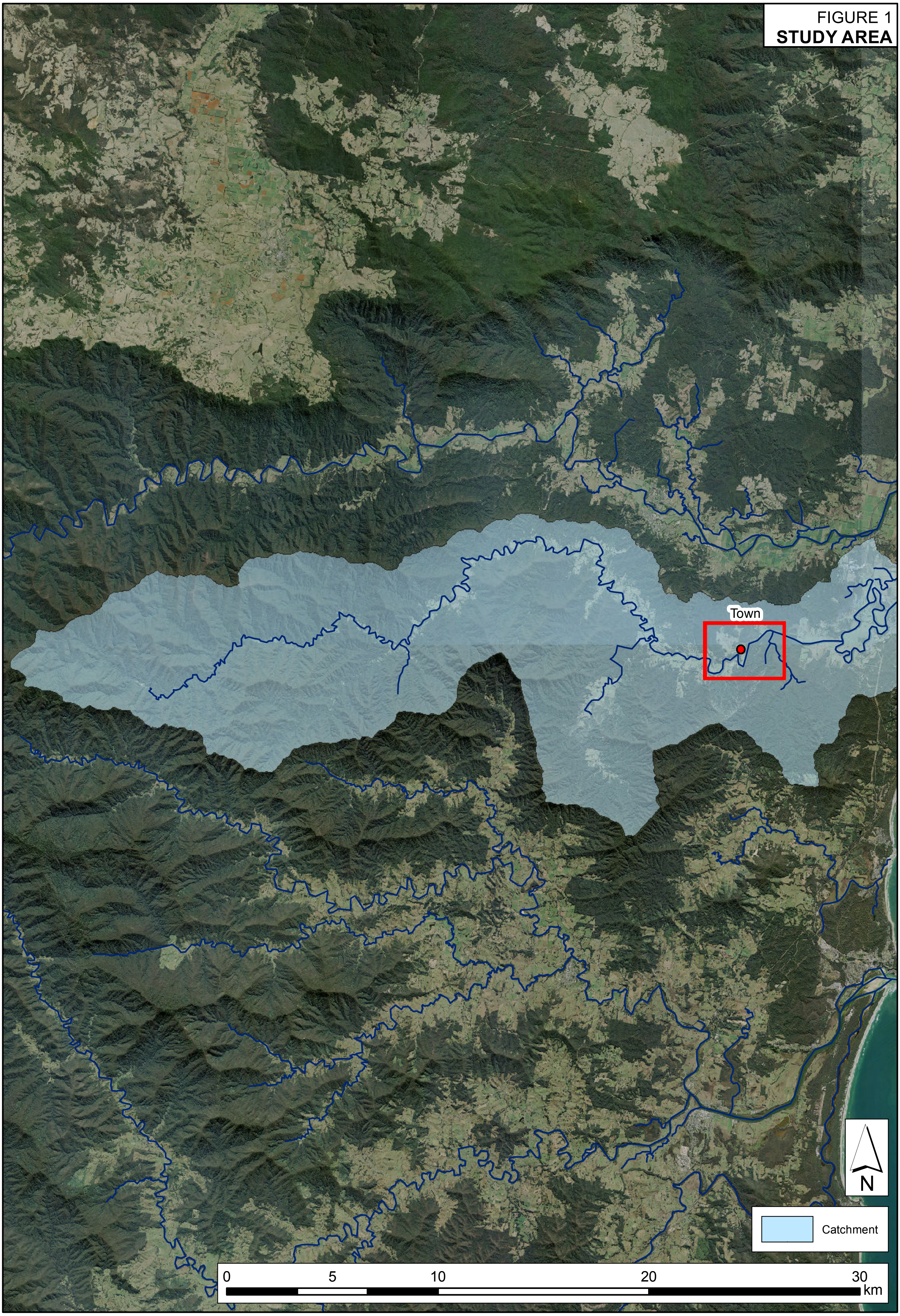
2. Babister M, Retallick R, Loveridge M, Testoni I and Podger S
Book 2 Chapter 5: Temporal Patterns, Australian Rainfall and Runoff: A Guide to Flood Estimation
© Commonwealth of Australia (Geoscience Australia), 2016

3. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors)
Australian Rainfall and Runoff: A Guide to Flood Estimation
© Commonwealth of Australia (Geoscience Australia), 2016

4. Babister M, Trim A, Testoni, I and Retallick M
The Australian Rainfall & Runoff Datahub,
37th Hydrology and Water Resources Symposium Queenstown NZ 2016.

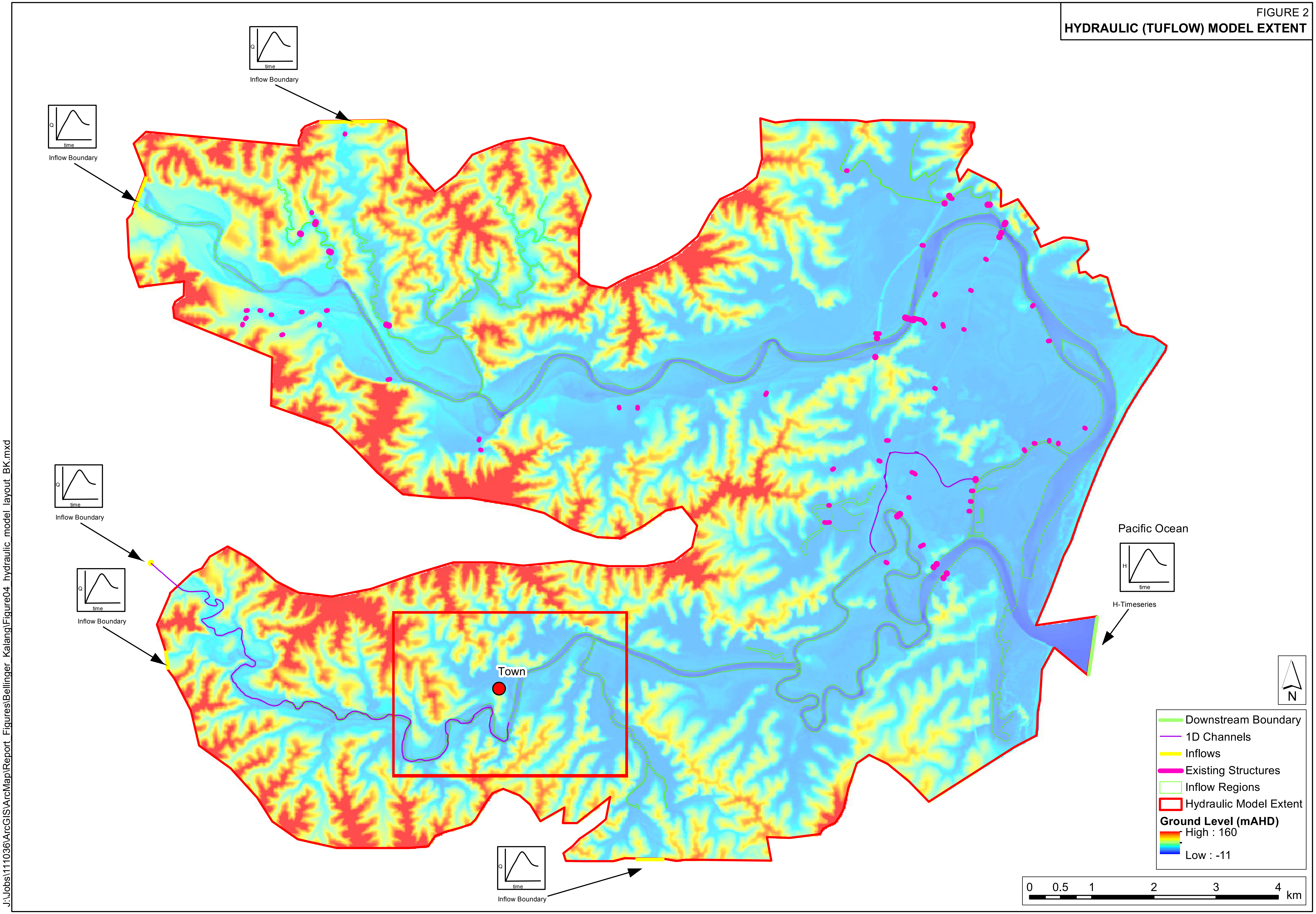
Figures

FIGURE 1
STUDY AREA



J:\Jobs\110050\Arcview\ArcMaps\Report_Figures\Figure01_StudyArea.mxd

FIGURE 2
HYDRAULIC (TUFLOW) MODEL EXTENT



J:\Jobs\111036\ArcGIS\ArcMap\Report_Figures\Bellinger_Kalang\Figure04_hydraulic_model_layout_BK.mxd

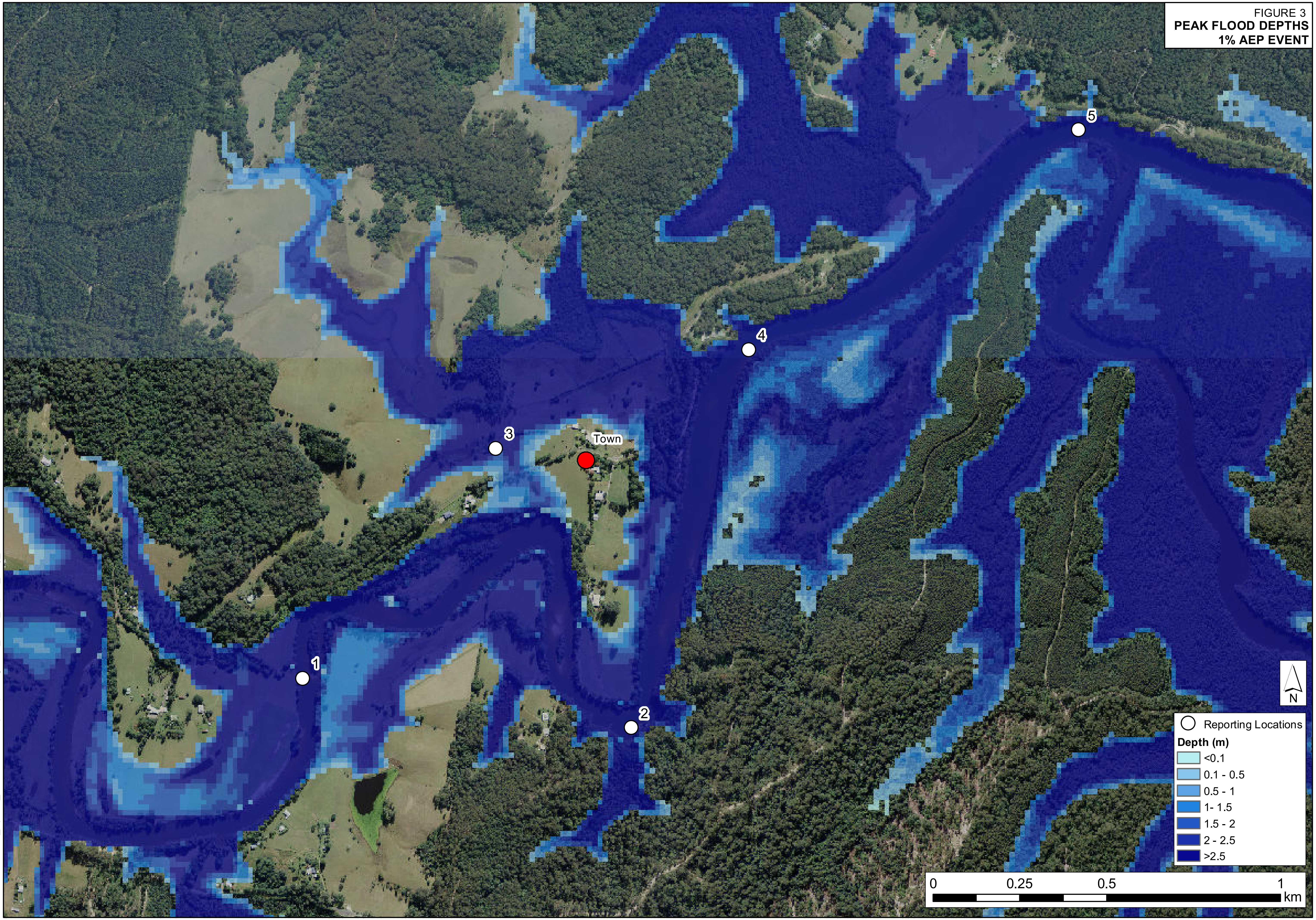
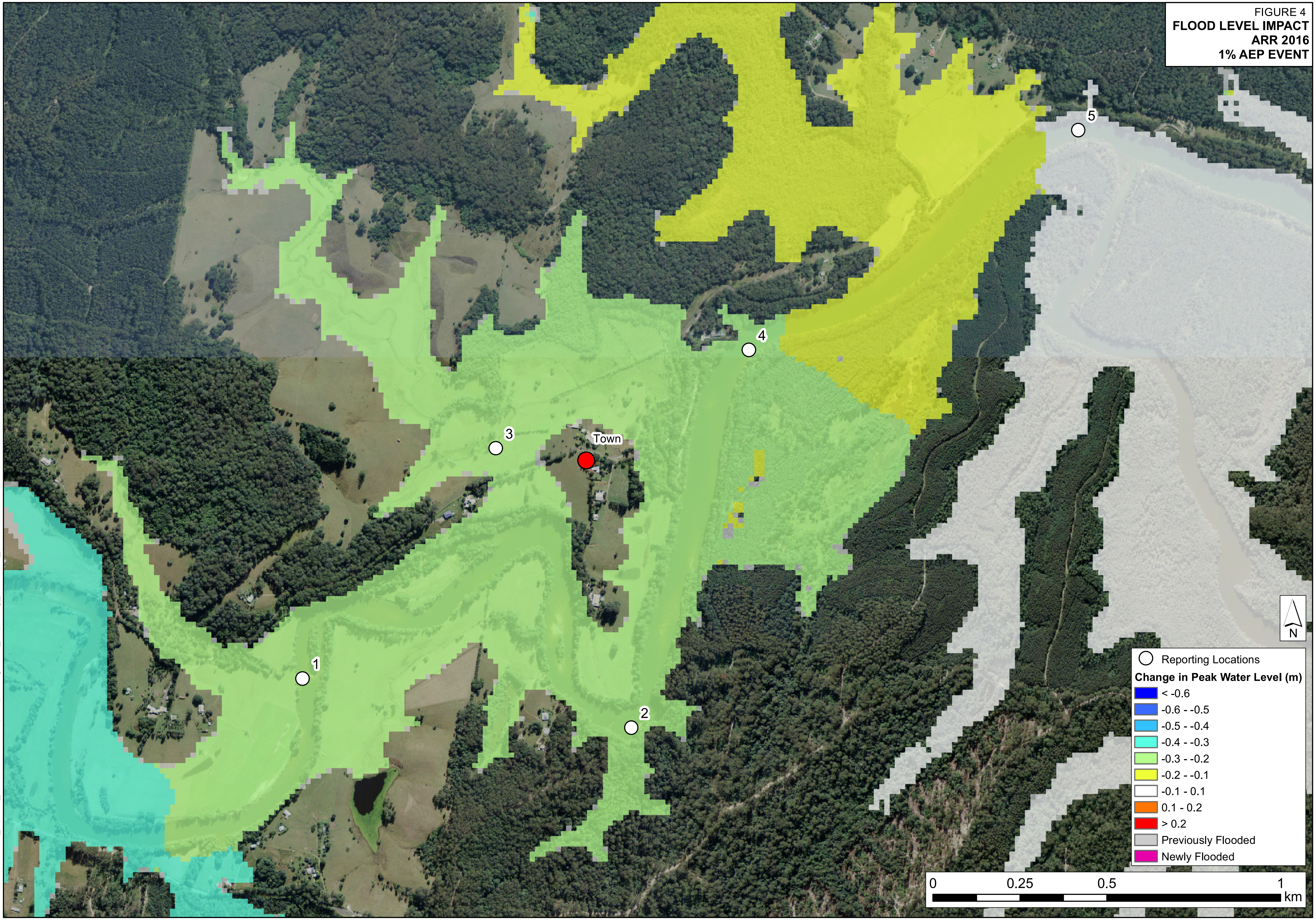


FIGURE 3
PEAK FLOOD DEPTHS
1% AEP EVENT

J:\Jobs\111036\ARR_Update_BK\ArcGIS\ArcMaps\report\Figure03_Flood_Depths_100y_USextent.mxd



J:\Jobs\111036\ARR_Update_BK\ArcGIS\ArcMaps\report\Figure04_Reporting_Locations_USextent.mxd

Appendix A

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	152.817
Latitude	-30.511
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show

Region Information

Data Category	Region
River Region	Bellinger River
ARF Parameters	East Coast North

Data

River Region

Division	South East Coast (NSW)
RivRegNum	5
River Region	Bellinger River
Polygon Intersection Percentage	99.98

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1

ARF Parameters

Long Duration ARF

$$Areal\ reduction\ factor = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	East Coast North
a	0.327
b	0.241
c	0.448
d	0.36
e	0.00096
f	0.48
g	-0.21
h	0.012
i	-0.0013
Polygon Intersection Percentage	99.91

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1

Storm Losses

Storm Initial Losses (mm)	33.0
Storm Continuing Losses (mm/h)	3.7

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1

Temporal Patterns | Download (.zip)

CODE	ECsouth
LABEL	East Coast South
Polygon Intersection Percentage	100.0

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1

Areal Temporal Patterns | Download (.zip)

CODE	ECsouth
LABEL	East Coast South
Polygon Intersection Percentage	100.0

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1

BOM IFD Depths

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-30.5107564611&longitude=152.817101565&sdmin=true&sdhr=t
to obtain the IFD depths for catchment centroid from the BoM website

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h) \AEP(%)	50	20	10	5	2	1
60 (1.0)	3.0 (0.081)	5.5 (0.109)	7.1 (0.119)	8.7 (0.125)	7.1 (0.085)	5.9 (0.062)
90 (1.5)	5.4 (0.126)	9.8 (0.167)	12.7 (0.181)	15.5 (0.189)	14.9 (0.15)	14.4 (0.127)
120 (2.0)	7.8 (0.164)	16.2 (0.247)	21.7 (0.276)	27.1 (0.291)	23.8 (0.21)	21.3 (0.164)
180 (3.0)	6.3 (0.114)	24.1 (0.311)	35.9 (0.382)	47.2 (0.424)	43.6 (0.32)	41.0 (0.26)
360 (6.0)	15.5 (0.205)	36.0 (0.336)	49.6 (0.378)	62.6 (0.4)	77.3 (0.402)	88.3 (0.398)
720 (12.0)	21.8 (0.203)	40.3 (0.26)	52.5 (0.276)	64.3 (0.283)	71.1 (0.257)	76.2 (0.241)
1080 (18.0)	17.7 (0.132)	33.5 (0.173)	44.0 (0.185)	54.0 (0.191)	66.7 (0.196)	76.1 (0.197)
1440 (24.0)	15.5 (0.1)	24.8 (0.11)	31.0 (0.112)	36.9 (0.113)	55.0 (0.14)	68.5 (0.155)
2160 (36.0)	8.3 (0.044)	17.0 (0.061)	22.8 (0.067)	28.3 (0.071)	47.5 (0.1)	61.9 (0.117)
2880 (48.0)	1.6 (0.007)	7.0 (0.022)	10.6 (0.028)	14.1 (0.031)	31.9 (0.06)	45.3 (0.077)
4320 (72.0)	0.0 (0.0)	2.1 (0.006)	3.4 (0.008)	4.7 (0.009)	7.8 (0.013)	10.1 (0.015)

Layer Info

Time Accessed	02 March 2017 04:17PM

10% Preburst Depths

min (h)\AEP (%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
90 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
120 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
180 (3.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
360 (6.0)	0.0 (0.0)	0.1 (0.001)	0.2 (0.002)	0.3 (0.002)	0.1 (0.001)	0.0 (0.0)
720 (12.0)	0.0 (0.0)	0.2 (0.001)	0.3 (0.002)	0.5 (0.002)	0.2 (0.001)	0.0 (0.0)
1080 (18.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)
1440 (24.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.6 (0.002)	1.1 (0.002)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1

25% Preburst Depths

min (h) \AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.001)	0.2 (0.004)	0.3 (0.005)	0.4 (0.006)	0.2 (0.002)	0.0 (0.0)
90 (1.5)	0.0 (0.0)	0.4 (0.007)	0.7 (0.009)	0.9 (0.011)	0.8 (0.008)	0.7 (0.006)
120 (2.0)	0.0 (0.001)	1.0 (0.015)	1.6 (0.02)	2.2 (0.024)	1.3 (0.011)	0.6 (0.005)
180 (3.0)	0.1 (0.002)	2.6 (0.033)	4.2 (0.045)	5.8 (0.052)	3.3 (0.024)	1.5 (0.009)
360 (6.0)	0.5 (0.007)	5.1 (0.047)	8.1 (0.062)	11.0 (0.07)	6.4 (0.033)	2.9 (0.013)
720 (12.0)	1.0 (0.009)	6.4 (0.041)	10.0 (0.052)	13.4 (0.059)	8.7 (0.031)	5.2 (0.016)
1080 (18.0)	0.2 (0.002)	3.9 (0.02)	6.3 (0.027)	8.6 (0.031)	12.5 (0.037)	15.3 (0.04)
1440 (24.0)	0.8 (0.005)	3.4 (0.015)	5.1 (0.018)	6.7 (0.02)	17.9 (0.045)	26.2 (0.059)
2160 (36.0)	0.0 (0.0)	0.2 (0.001)	0.3 (0.001)	0.4 (0.001)	6.6 (0.014)	11.2 (0.021)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	1.9 (0.004)	3.3 (0.006)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1

75% Preburst Depths

min (h) \AEP(%)	50	20	10	5	2	1
60 (1.0)	35.0 (0.936)	39.0 (0.772)	41.7 (0.694)	44.3 (0.634)	40.2 (0.481)	37.2 (0.392)
90 (1.5)	27.9 (0.652)	46.9 (0.799)	59.4 (0.846)	71.4 (0.868)	82.4 (0.828)	90.7 (0.797)
120 (2.0)	41.9 (0.882)	62.8 (0.958)	76.6 (0.971)	89.9 (0.968)	114.7 (1.015)	133.4 (1.027)
180 (3.0)	49.6 (0.894)	80.1 (1.034)	100.3 (1.068)	119.6 (1.076)	145.9 (1.07)	165.6 (1.052)
360 (6.0)	65.3 (0.867)	100.6 (0.938)	124.0 (0.945)	146.4 (0.936)	172.0 (0.894)	191.2 (0.861)
720 (12.0)	61.9 (0.576)	93.2 (0.601)	114.0 (0.599)	133.8 (0.59)	160.7 (0.582)	180.8 (0.572)
1080 (18.0)	54.7 (0.409)	95.4 (0.491)	122.3 (0.515)	148.2 (0.525)	167.0 (0.49)	181.1 (0.468)
1440 (24.0)	39.6 (0.254)	70.9 (0.313)	91.6 (0.331)	111.5 (0.34)	127.2 (0.324)	139.0 (0.314)
2160 (36.0)	32.6 (0.171)	58.1 (0.209)	75.0 (0.222)	91.2 (0.229)	116.9 (0.247)	136.1 (0.258)
2880 (48.0)	21.4 (0.098)	43.9 (0.139)	58.8 (0.154)	73.1 (0.163)	110.4 (0.208)	138.3 (0.234)
4320 (72.0)	9.8 (0.039)	28.0 (0.077)	40.0 (0.091)	51.6 (0.1)	68.5 (0.113)	81.2 (0.121)

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1

90% Preburst Depths

min (h) \AEP(%)	50	20	10	5	2	1
60 (1.0)	134.2 (3.593)	137.8 (2.724)	140.1 (2.333)	142.4 (2.04)	169.5 (2.029)	189.9 (2.005)
90 (1.5)	126.4 (2.947)	140.7 (2.397)	150.1 (2.137)	159.2 (1.936)	194.8 (1.957)	221.5 (1.947)
120 (2.0)	132.9 (2.798)	171.9 (2.624)	197.8 (2.508)	222.6 (2.398)	247.0 (2.184)	265.3 (2.042)
180 (3.0)	133.0 (2.398)	180.6 (2.332)	212.1 (2.26)	242.4 (2.18)	263.8 (1.934)	279.9 (1.777)
360 (6.0)	133.1 (1.765)	174.3 (1.624)	201.5 (1.536)	227.7 (1.456)	286.9 (1.492)	331.3 (1.492)
720 (12.0)	124.0 (1.153)	178.6 (1.151)	214.8 (1.129)	249.5 (1.1)	301.9 (1.093)	341.1 (1.079)
1080 (18.0)	92.0 (0.687)	150.9 (0.778)	189.9 (0.8)	227.4 (0.806)	290.3 (0.852)	337.5 (0.873)
1440 (24.0)	106.7 (0.684)	145.3 (0.642)	170.9 (0.618)	195.5 (0.597)	257.7 (0.656)	304.2 (0.687)
2160 (36.0)	75.1 (0.393)	115.5 (0.416)	142.3 (0.421)	167.9 (0.422)	246.1 (0.521)	304.7 (0.576)
2880 (48.0)	64.2 (0.296)	97.8 (0.31)	120.0 (0.314)	141.4 (0.315)	204.2 (0.385)	251.2 (0.426)
4320 (72.0)	44.7 (0.177)	69.7 (0.191)	86.2 (0.195)	102.0 (0.198)	123.2 (0.203)	139.0 (0.207)

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1

Interim Climate Change Factors

Values are of the format temperature increase in degrees Celcius (% increase in rainfall)

	RCP 4.5	**RCP6**	RCP 8.5
2030	0.892 (4.5%)	**0.775 (3.9%)**	0.979 (4.9%)
2040	1.121 (5.6%)	**1.002 (5.0%)**	1.351 (6.8%)
2050	1.334 (6.7%)	**1.28 (6.4%)**	1.765 (8.8%)
2060	1.522 (7.6%)	**1.527 (7.6%)**	2.23 (11.2%)
2070	1.659 (8.3%)	**1.745 (8.7%)**	2.741 (13.7%)
2080	1.78 (8.9%)	**1.999 (10.0%)**	3.249 (16.2%)
2090	1.825 (9.1%)	**2.271 (11.4%)**	3.727 (18.6%)

Layer Info

Time Accessed	02 March 2017 04:17PM
Version	2016_v1
Note	ARR recommends the use of RCP6 values

Download TXT

Download PDF