HYDROLOGICAL MODELLING FOR TENTERFIELD CREEK DAM UPGRADE DESIGN

NSW Public Works
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For and on behalf of
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1 INTRODUCTION

1.1 OVERVIEW

The township of Tenterfield is located in northern New South Wales (NSW) about 150 km west of Ballina, close to the NSW-Queensland border (Figure 1.1). It is a major inland town serviced by three major highways i.e. the New England, Mt Lindsay and Bruxner Highways.

Tenterfield Creek Dam is located about 2 km upstream of Tenterfield town, on Tenterfield Creek. The Dam was constructed in 1931 and augmented by 1.8m in 1974 as a water supply dam for the town. The dam commands a catchment area of about 38 km^2 and has a capacity of 1,150 megalitres. Tenterfield Creek flows across the NSW-Queensland border into the Severn River.

Figure 1.2 shows the major tributaries of Tenterfield Creek upstream of the Dam namely Green Swamp and Hawkins Creeks. The major tributaries downstream of the Dam in the study area include Groombridges, Currys Gap, Pitkins Swamp, Bryans Gap, Ghost Gully and Washbrook Creeks.

NSW Public Works (NSWPW) is currently undertaking design studies to upgrade the Tenterfield Creek Dam. To assist with these studies, NSWPW requested WRM Water and Environment Pty Ltd (WRM) to estimate the Probable Maximum Flood (PMF) inflows into the Dam and also the residual PMF discharges into Tenterfield Creek at several locations downstream of the Dam. This report has been prepared in response to this request.

1.2 SCOPE OF WORK

The scope of work for this study was as follows:

- Collect, collate and review available historical rainfall, streamflow, dam storage level and storage-stage-surface area relationship data,
- Develop a RORB model of Tenterfield Creek catchment study area,
- Calibrate and validate the RORB model,
- Estimate Probable Maximum Precipitation (PMP) on the Tenterfield Creek Catchment, and
- Estimate PMF discharge hydrographs at specified locations along Tenterfield Creek using the calibrated RORB model.

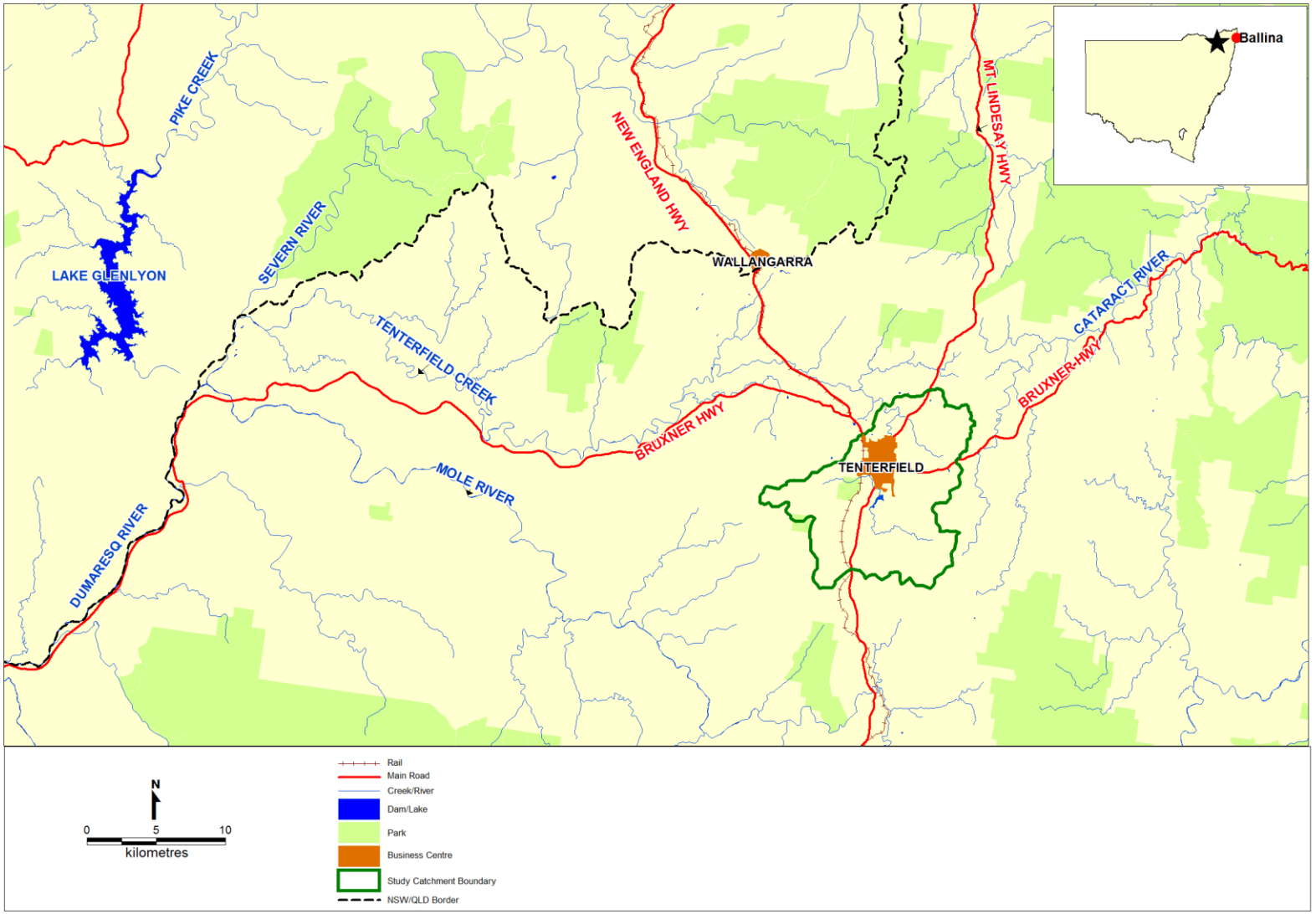

Figure 1.1 Tenterfield Creek Catchment Locality Map

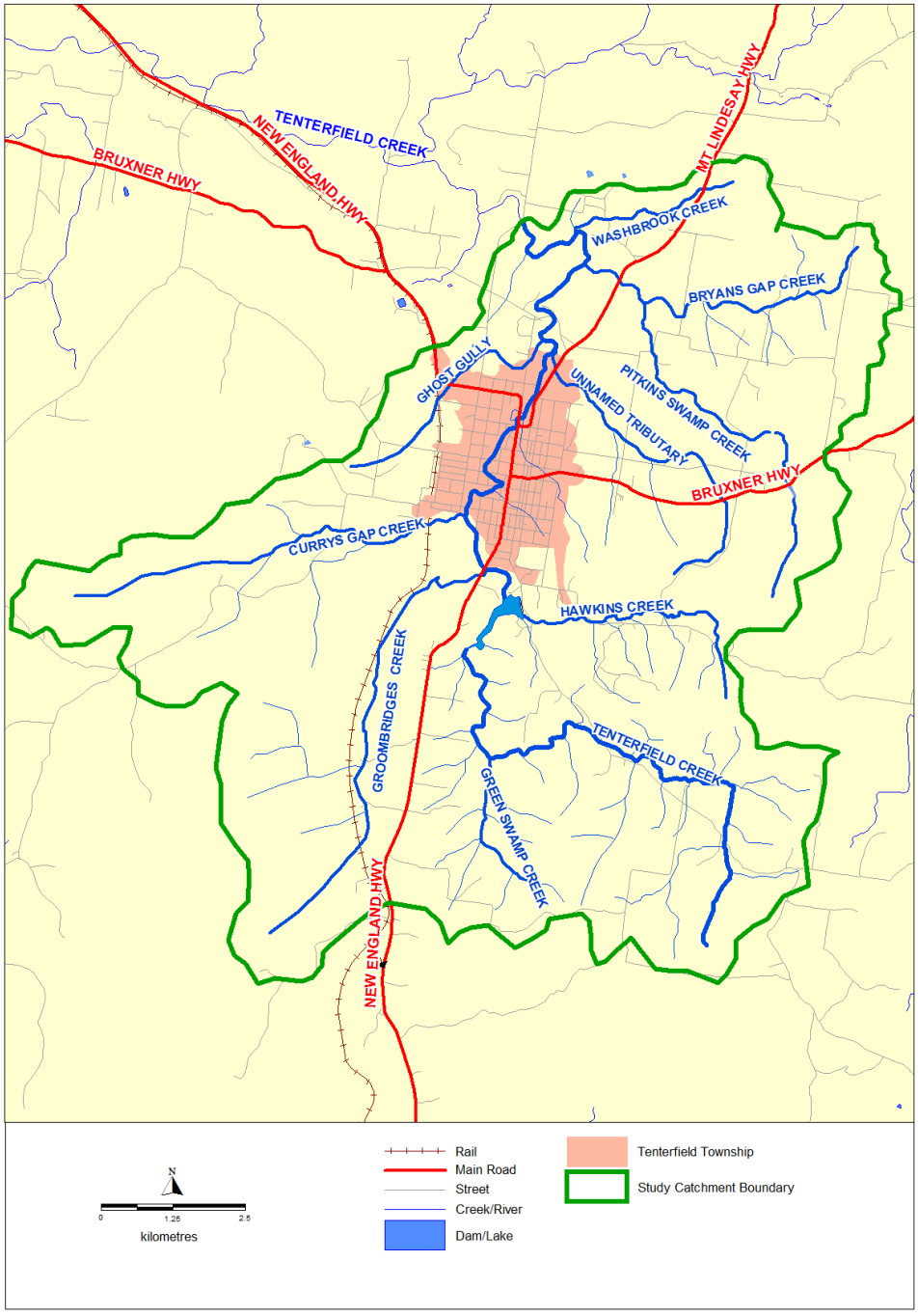

Figure 1.2 Major Creeks in the Tenterfield Creek Catchment Study Area

2 DATA AVAILABILITY

2.1 OVERVIEW

The most recent flood event in the Tenterfield Creek catchment occurred in January 2011. Prior to that the last reported flood event of any significance occurred in February 2001. Rainfall, water level and discharge data collected for the February 2001 and the January 2011 flood events were supplied by DHI Water and Environment (DHI). Table 2.1 summarises the available data from DHI for each event and Figure 2.1 shows the locations of the relevant gauging stations. Further information on the available data is provided in the following sections.

Table 2.1 Data Availability

Gauge	February 2001 Event			January 2011 Event		
	Rainfall	Water Level	Discharge	Rainfall	Water Level	Discharge
Black Swamp Rain Gauge	X					
Tenterfield Creek Rain Gauge				X		
Mt Mackenzie Rain Gauge				X		
Douglas St Stream Gauge		X			X	
Currys Gap Stream Gauge					X	X
Tenterfield Dam		X	X		X	X

Daily rainfalls recorded by the Bureau of Meteorology (BoM) at a number of their rainfall gauging stations in the vicinity of Tenterfield were also available for both February 2001 and January 2011 events. They include Tenterfield (Federation Park) and Tenterfield (Springside).

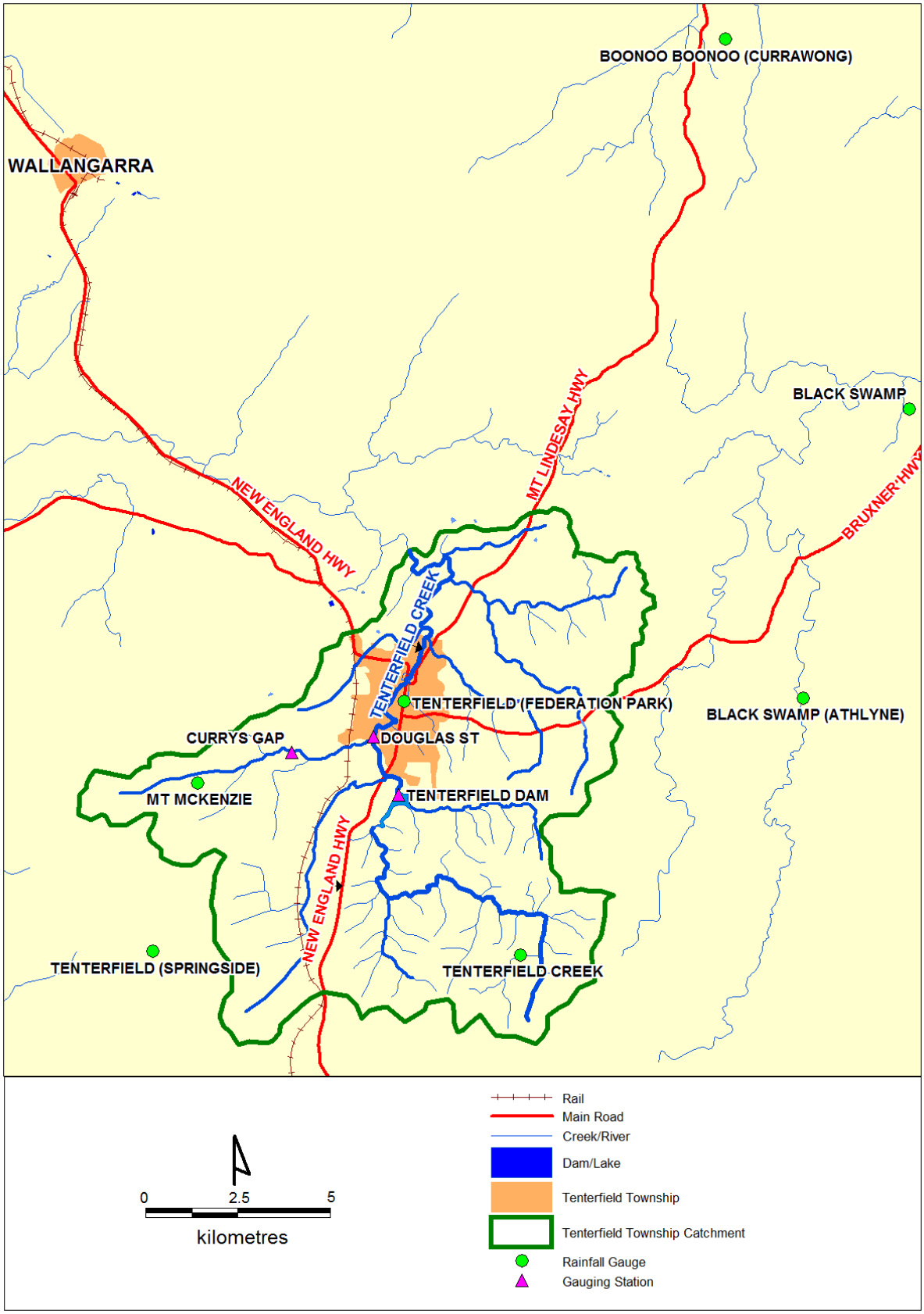

Figure 2.1 Gauging Station Locations

2.2 JANUARY 2011 EVENT

The rainfall and water level data available for the 2011 event is inconsistent and appears to contain some errors. These apparent inconsistencies and errors are discussed below.

Figure 2.2 shows the recorded 15-minute rainfall totals at the Tenterfield Creek and Mt McKenzie rain gauges for the January 2011 event. Daily rainfall totals are available for a number of Bureau of Meteorology rainfall stations in the Tenterfield vicinity. Table 2.2 provides a comparison of the accumulated totals at the sub-daily rainfall stations with the BoM daily rainfall station totals. It appears that the sub-daily rainfall stations are missing data on 10 and part of 11 (including possibly 12) January 2011, which is also consistent with BoM radar images showing storm cells moving over Tenterfield at the times when data appears to be missing. The daily totals at the Mt McKenzie sub-daily rainfall station for the 12 and 13 January 2011 appear comparable with the BoM daily station totals.

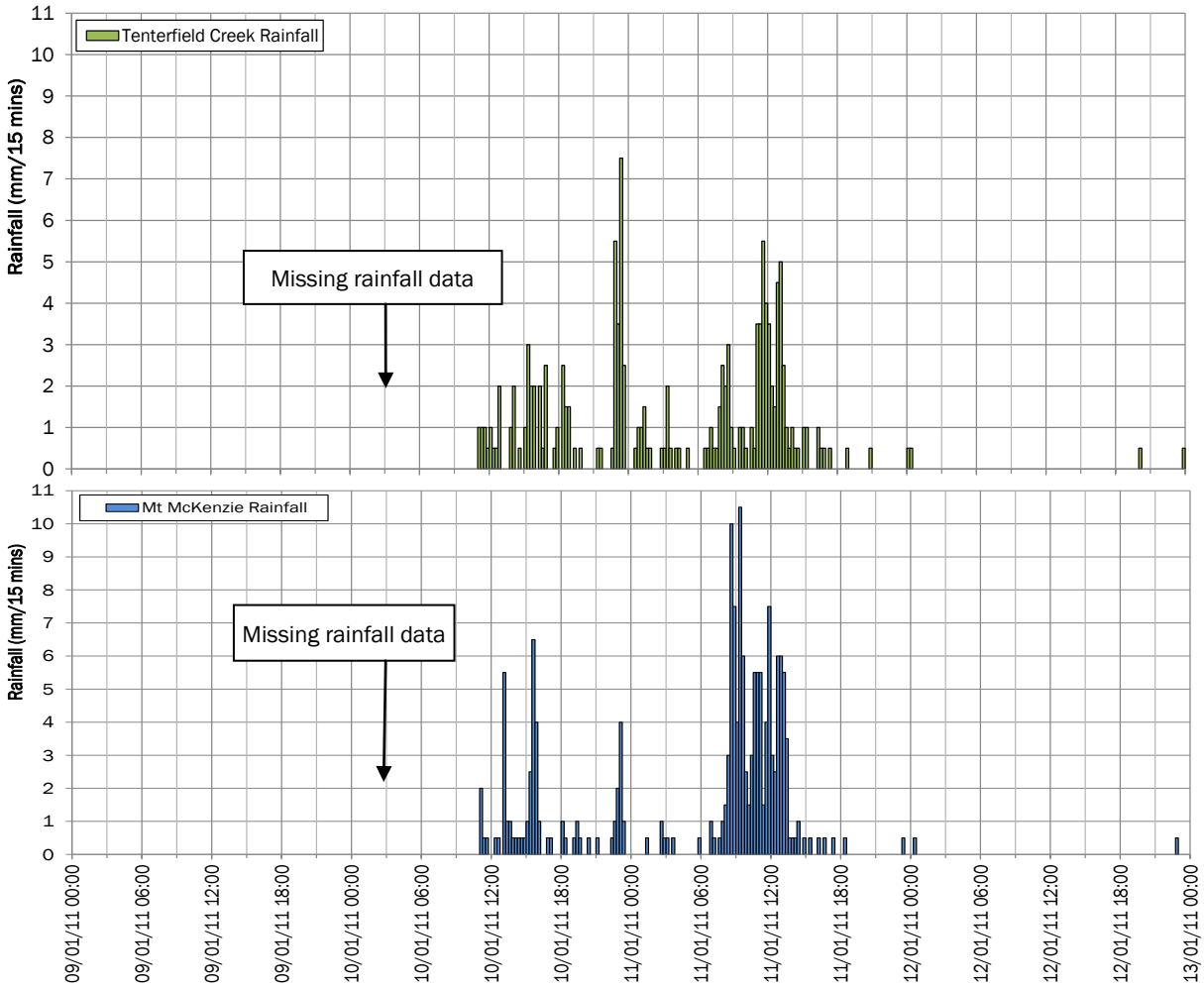

Figure 2.2 Rainfall at Tenterfield Creek and Mt McKenzie Gauges (9 Jan 2011 to 13 Jan 2011)

Table 2.2 Daily Rainfall Totals in the Tenterfield Vicinity (January 2011)

Station Name	Station No.	24-hour Rainfall Total (to 9am)				
		10th	11th	12th	13th	4-Day Total
Tenterfield Creek Rain Gauge	-	0.0 [a]	76.0 [a]	49.5 [a]	2.0	127.5
Mt McKenzie Rain Gauge	-	0.0 [a]	75.5 [a]	86.0	1.5	163.0
Black Swamp	56202	62.2	122.4	78.6	15.6	278.8
Tenterfield (Federation Park)	56032	18.0	144.0	88.6	4.0	254.6
Tenterfield (Springside)	56046	-	-	234.0 [b]	0.0	234.0

[a] Missing or incomplete data
[b] 3-day total

Figure 2.3 and Figure 2.4 show the available discharge and water level data, respectively, for the January 2011 event. Figure 2.3 and Figure 2.4 also show the 15-minute rainfall totals at the Mt McKenzie rainfall gauge. There appears to be an inconsistency between the timing of the rainfall and what should be the subsequent response in water level and discharge.

As mentioned above, there appears to be a period of missing data prior to about midday on 10 January 2011. However the recorded sub-daily rainfall station data on 12 January 2011 (especially at Mt McKenzie) appears consistent with the daily rainfall stations and BoM radar images of storm cells in the Tenterfield vicinity. All rainfall stations in the Tenterfield vicinity recorded a significant amount of rainfall in the 24 hours to 9am on the 12 January 2011. However, the water level and discharge data available do not appear to produce a response to this rainfall. This indicates that it is likely the time stamps of the water level and discharge data have been recorded incorrectly.

The discharge and water level time series were shifted 11 hours later to provide an expected match to the recorded sub-daily rainfall data, as shown in Figure 2.5 and Figure 2.6. This time shift of 11 hours is consistent with the time shift adjustment made by DHI in their Tenterfield Creek Flood Study (DHI, 2013). This shifted data set was used in the RORB model calibration.

2.3 FEBRUARY 2001 EVENT

Rainfall data at 6-minute intervals for the February 2001 event was available for the Black Swamp Rainfall Station (Figure 2.7). This pluviograph data was compared against the BoM daily rainfall stations available in the vicinity of Tenterfield (see Figure 2.1 for their locations). Table 2.3 shows that the daily rainfall totals at Black Swamp and Boonoo Boonoo (Currawong) are generally higher than at Black Swamp (Athlyne) and Tenterfield (Federation Park).

Figure 2.7 also show the Dam outflows provided by DHI based on their spillway rating curve (DHI, 2013).

Figure 2.8 shows the water levels recorded at Tenterfield Creek Dam and Douglas Street Gauging Stations. The water levels at Douglas Street Gauging Station could not be converted to reliable discharges due to the inaccurate and unreliable rating curve available (DHI, 2006 and DHI, 2013).

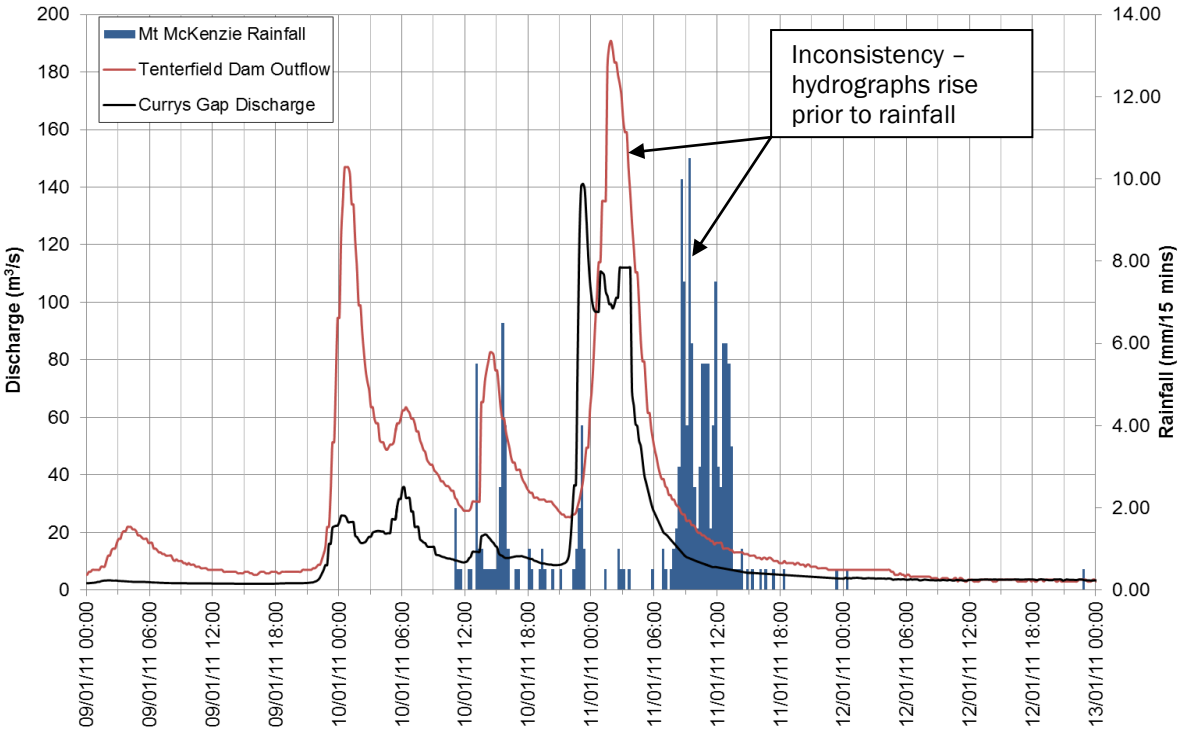

Figure 2.3 Discharge Data (9 Jan 2011 to 13 Jan 2011) – showing inconsistency with rainfall

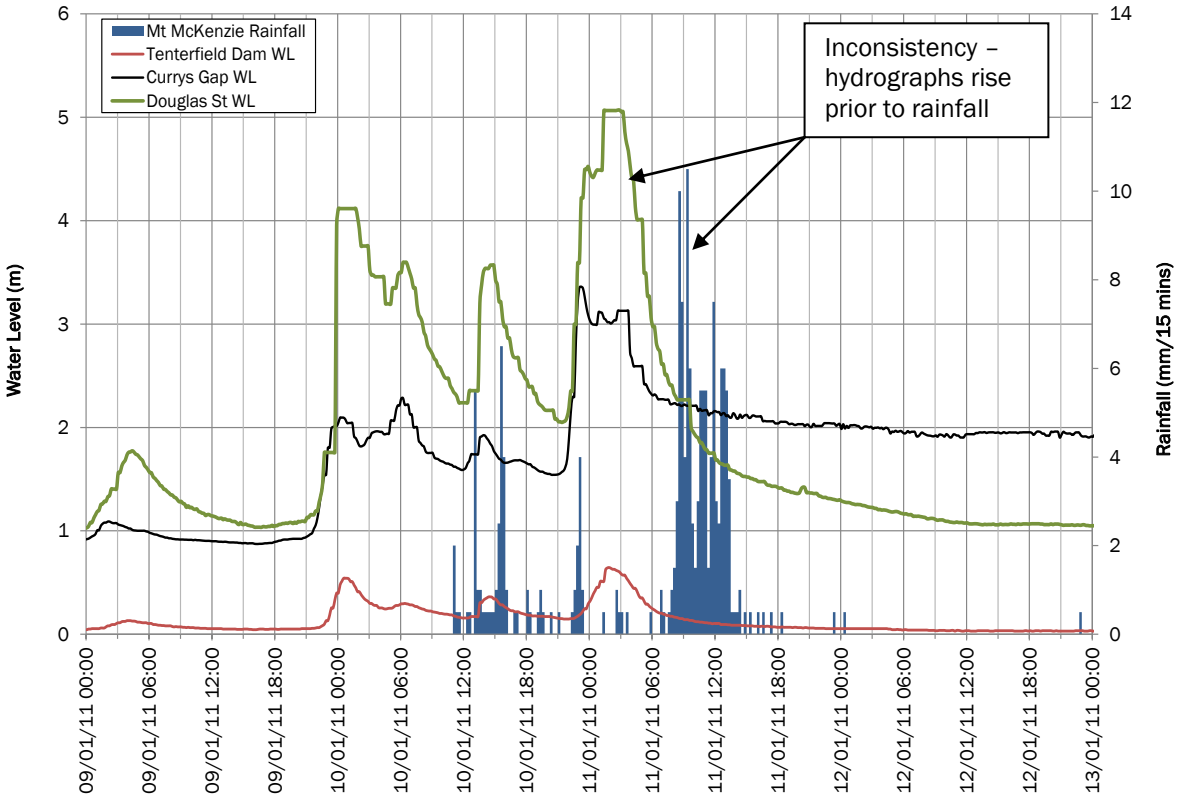

Figure 2.4 Water Level Data (9 Jan 2011 to 13 Jan 2011) – showing inconsistency with rainfall

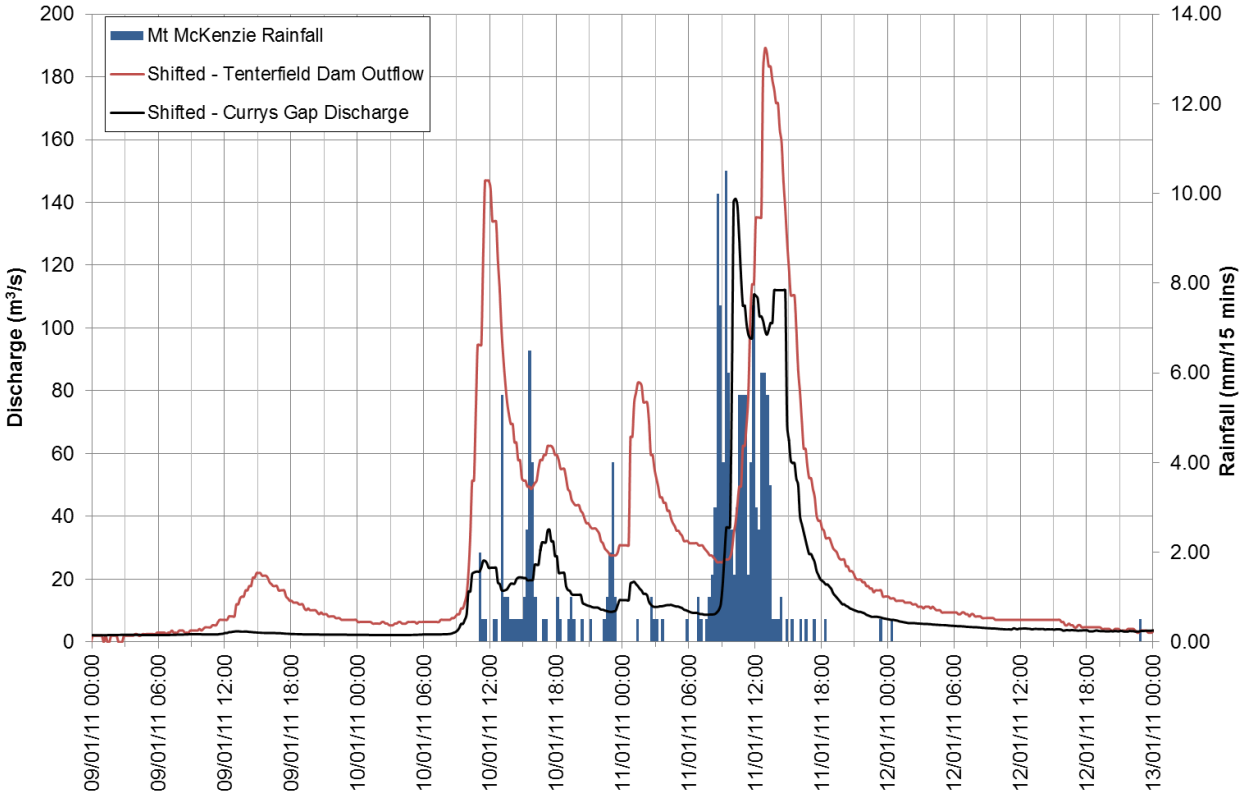

Figure 2.5 Shifted Discharge Data by 11 hours

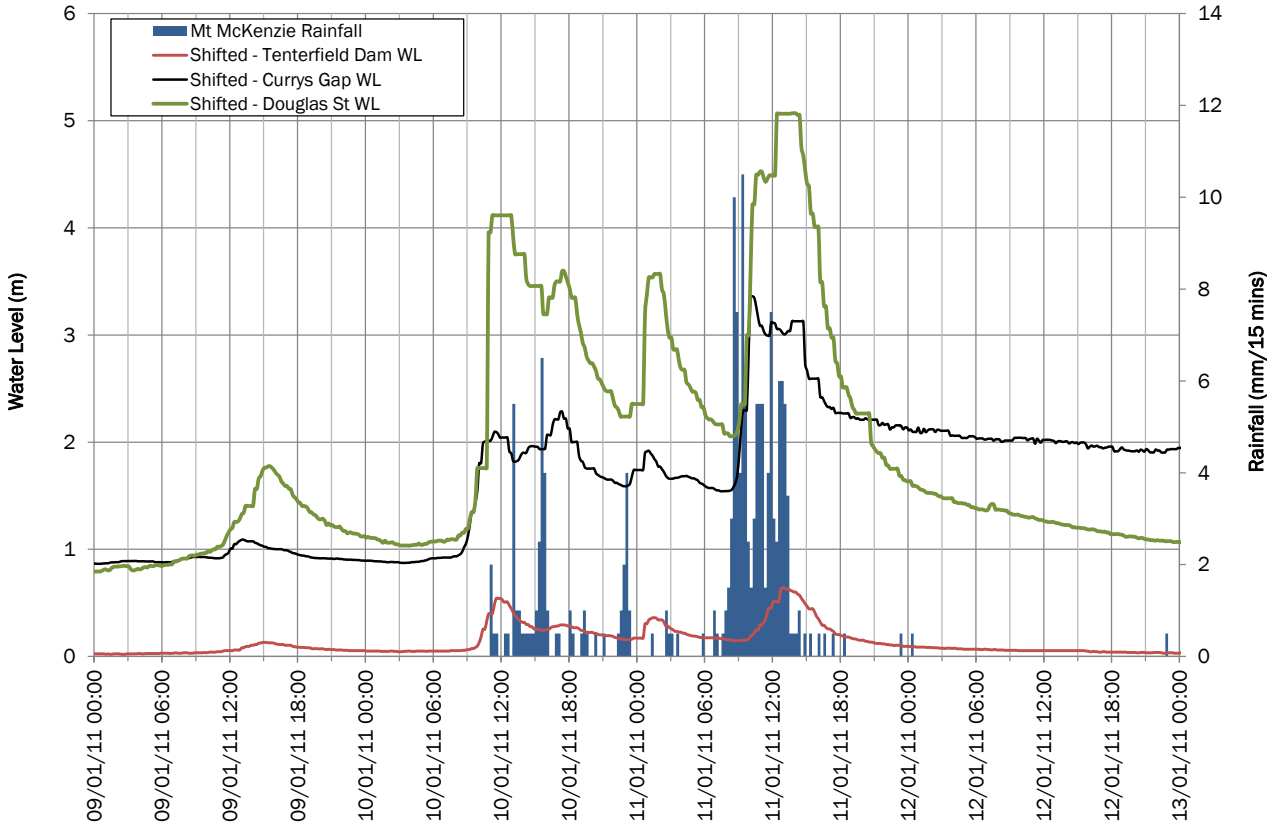

Figure 2.6 Shifted Water Level Data by 11 hours

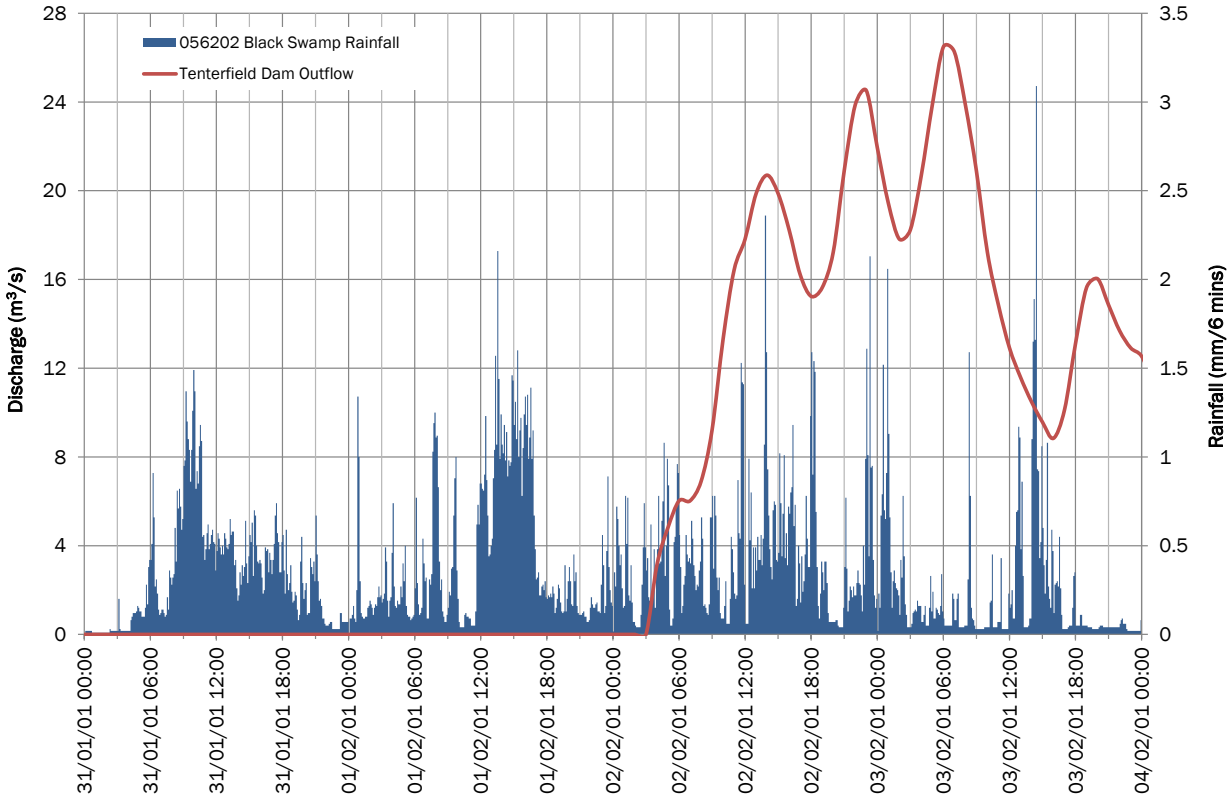

Figure 2.7 Tenterfield Creek Dam Outflows and Black Swamp Rainfall (31 January to 4 February 2001)

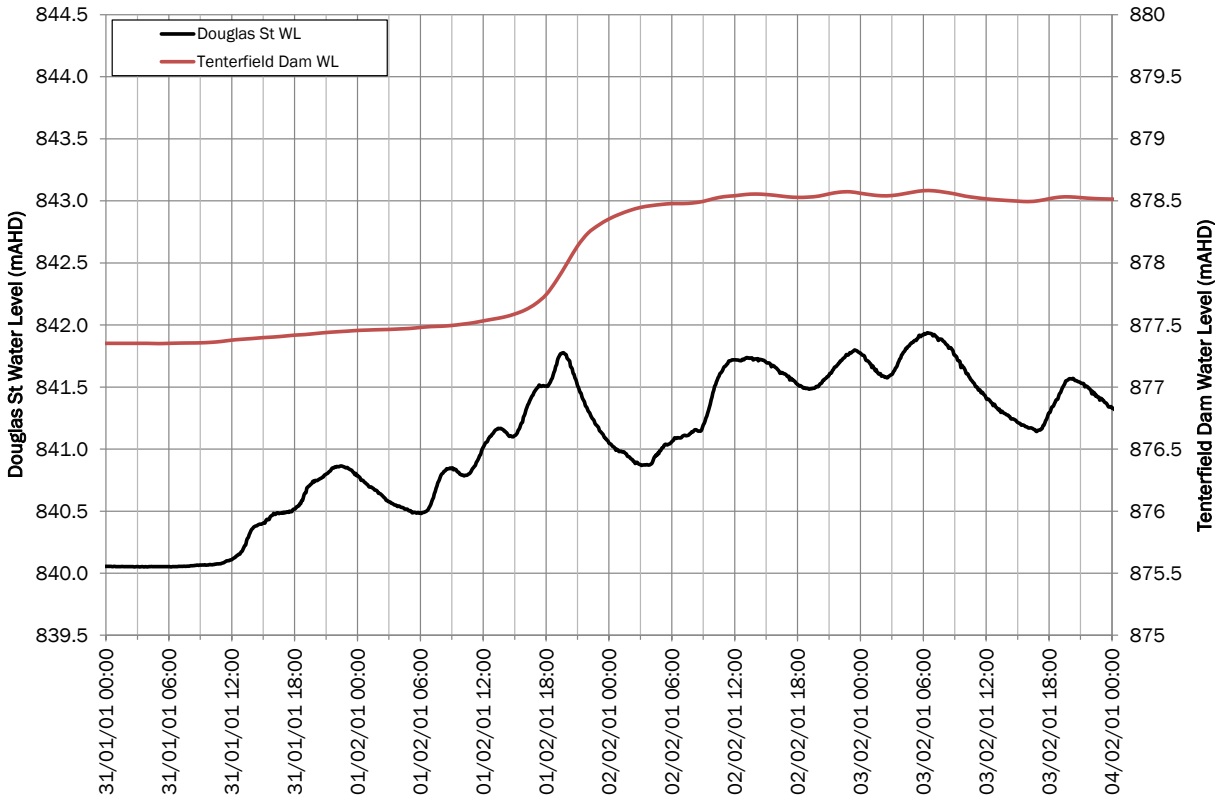

Figure 2.8 Water Levels Recorded at Tenterfield Creek Dam and Douglas Street Gauging Stations (31 January to 4 February 2001)

Table 2.3 Daily Rainfall Totals (to 9am) in the Tenterfield Vicinity, January and February 2001

Station Name	Station No.	24-hour Rainfall Total (to 9am)					
		31-Jan	1-Feb	2-Feb	3-Feb	4-Feb	5-Day Total
Tenterfield (Federation Park)	56032	22.4	85.6	71.6	37.2	15.5	232.3
Black Swamp (Athlyne)	56203	-	67	95	61	6.2	229.2*
Boonoo Boonoo (Currawong)	56141	85	19	120	104	15	343
Black Swamp	56202	40.8	89.9	112.4	96.1	36.6	375.8

*4-day total

2.4 STAGE-STORAGE CURVE FOR TENTERFIELD CREEK DAM

Figure 2.9 shows the stage-storage curve for the Tenterfield Creek Dam derived using the surface area versus elevation information obtained from NSWPW and Hydro Tasmania (2000). The adopted curve was adjusted to fit the full supply capacity of 1, 150 megalitres at 878.43m AHD.

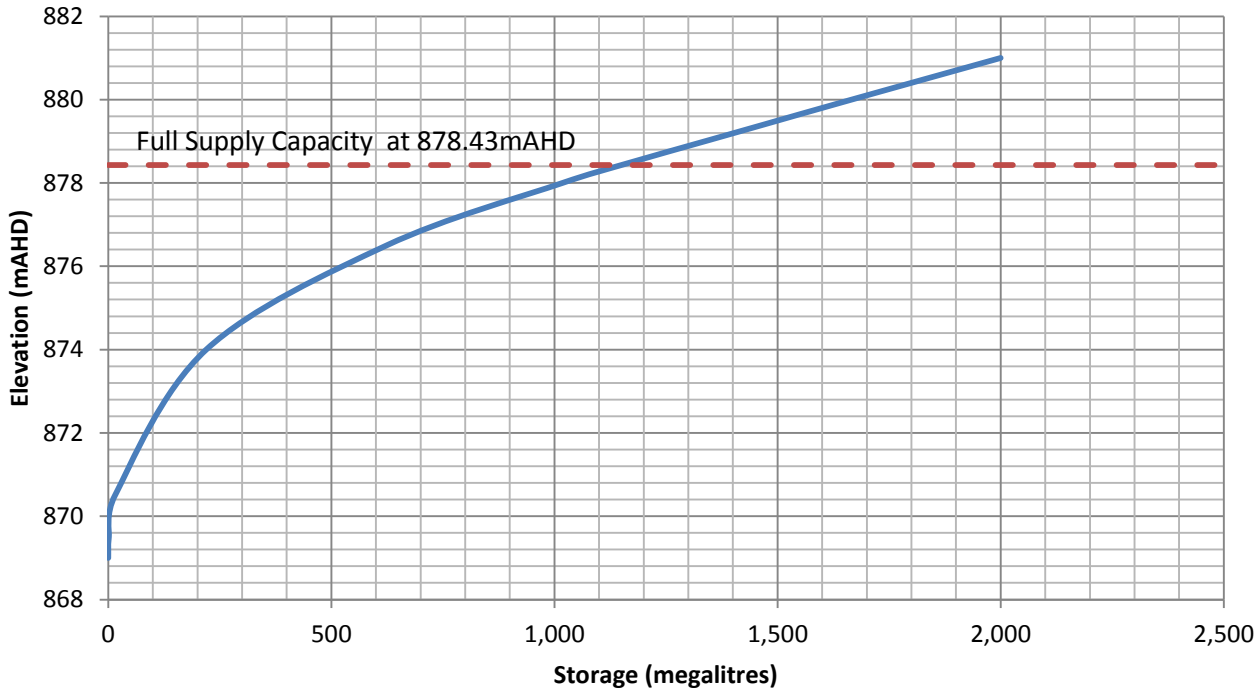

Figure 2.9 Stage-Storage Curve for Tenterfield Creek Dam

2.5 RATING CURVES

The rating curves derived for the Tenterfield Dam outflow (spillway) and the Currys Gap Gauging Station by DHI (2013) were adopted in this study. Figure 2.10 and Figure 2.11 show the rating curves adopted in the study for the Dam and Currys Gap Gauging Stations respectively.

The rating curve for the Douglas Street Gauging Station is considered inaccurate and unreliable for the discharges to be estimated from the water level measurements (DHI, 2006 and DHI, 2013). This is discussed in Section 3.3.

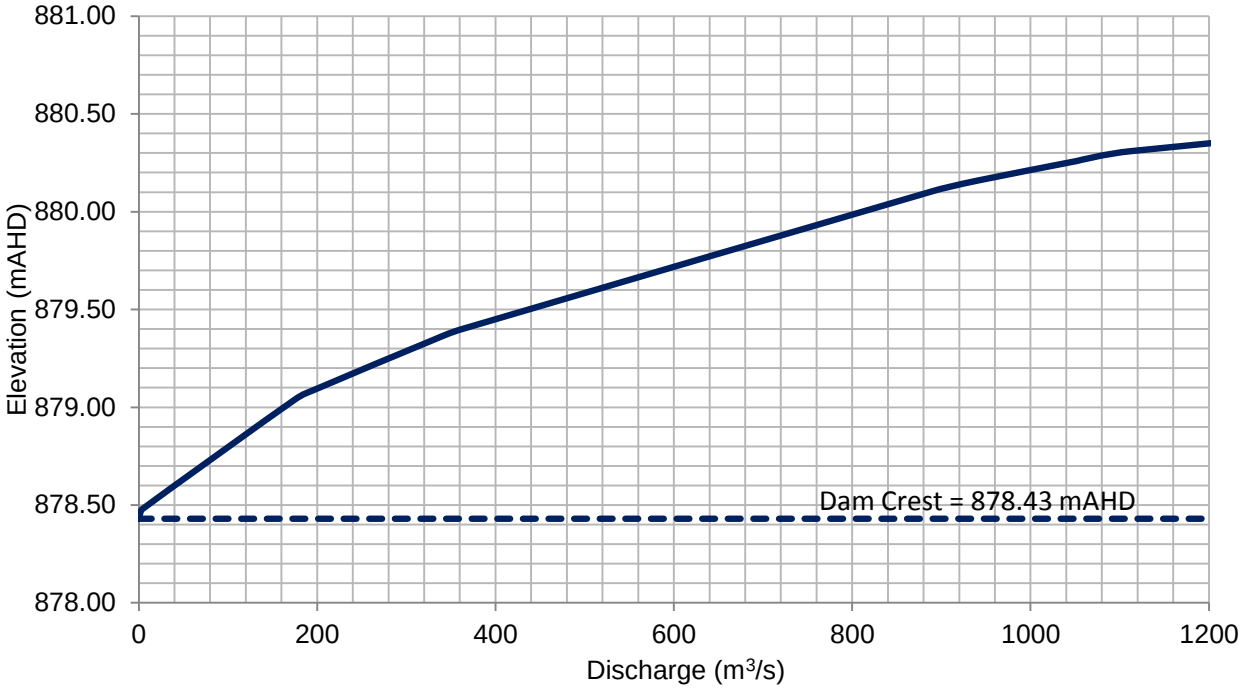

Figure 2.10 Rating Curve for Tenterfield Creek Dam Outflow (Spillway)

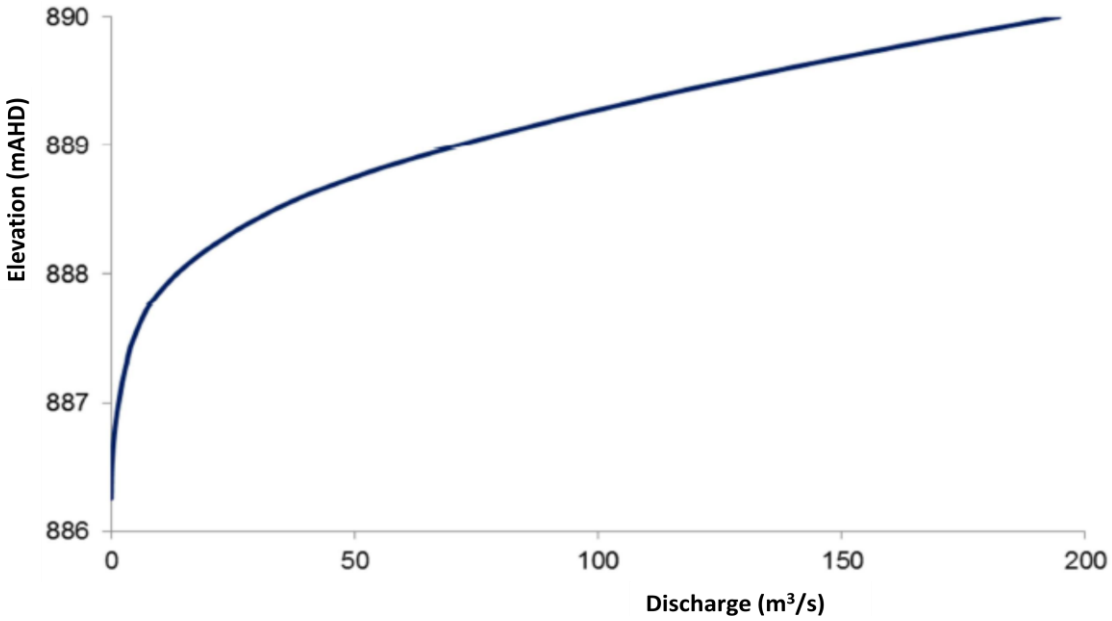

Figure 2.11 Rating Curve for Currys Gap Gauging Station

3 RORB MODEL CONFIGURATION

3.1 MODEL CONFIGURATION

A RORB model of the Tenterfield Creek catchment of the study area was set up with 20 sub-catchments, A to T as shown in Figure 3.1. Sub-catchments A to I drain into the Dam. The total catchment area modelled is 124 km^2, of which 38 km^2 drains into Tenterfield Creek Dam.

In addition to the Dam inflows and the catchment outflows, the NSWPW design studies also require local (residual) inflow hydrographs downstream of the Dam at locations INF1 to INF4 as defined in Table 3.1 and shown in Figure 3.1. The RORB model was configured to provide these residual downstream inflows.

Table 3.1 Hydrograph Reporting Locations

Reporting Location	Description	Contributing RORB Sub-catchments
Dam Inflow	Combined Inflows into Tenterfield Dam	A to I
INF1	Combined Inflows - Groombridges (INF1a) and Currys Gap Creeks (INF1b)	J, K, L, M and N
INF2	Combined Inflows – local inflows into Tenterfield town (INF2a) and Un-named Tributary (INF2b)	O and P
INF3	Combined Inflows – Ghost Gully (INF3a) and Pitkins Swamp and Bryans Gap Creeks (INF3b)	Q, R and S
INF4	Washbrook Creek	T
Outflow	Downstream Boundary of Model	A to T

3.2 MODEL CALIBRATION

The RORB model was calibrated against the January 2011 rainfall event using the available data (described in Section 2.2). The calibration was attempted with sub-daily rainfall data for both Tenterfield Creek and Mt McKenzie Rainfall Stations. The best results for the calibration were obtained using the sub-daily rainfall at the Mount McKenzie Rainfall Station. This is consistent with the observation that the Tenterfield Creek rainfall data on 12 January 2011 may be incomplete as discussed in Section 2.2. For reasons provided in Section 2.5, the calibration was undertaken against the recorded discharge hydrograph at Currys Gap Gauging Station and the outflow hydrograph at the Dam provided in DHI (2013).

Figure 3.2 shows the calibration results using the RORB model routing parameters, k_c = 16 and m = 0.8. The initial and proportional loss model was used with an initial loss of 30 mm. The initial water level at the Dam was set at full supply capacity at the start of the simulation. The calibration is considered acceptable given the uncertainties in the available data.

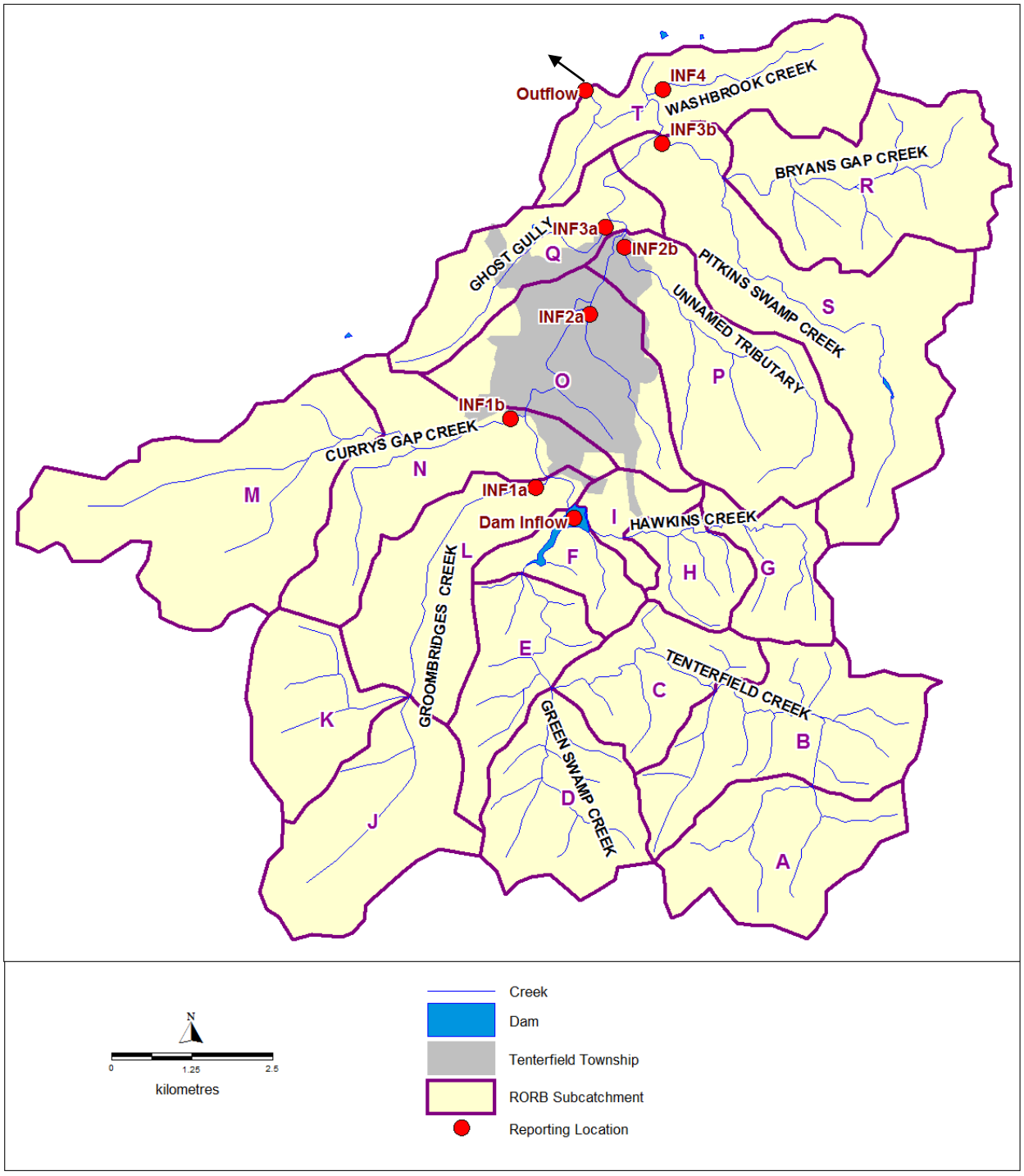

Figure 3.1 RORB Model Configuration

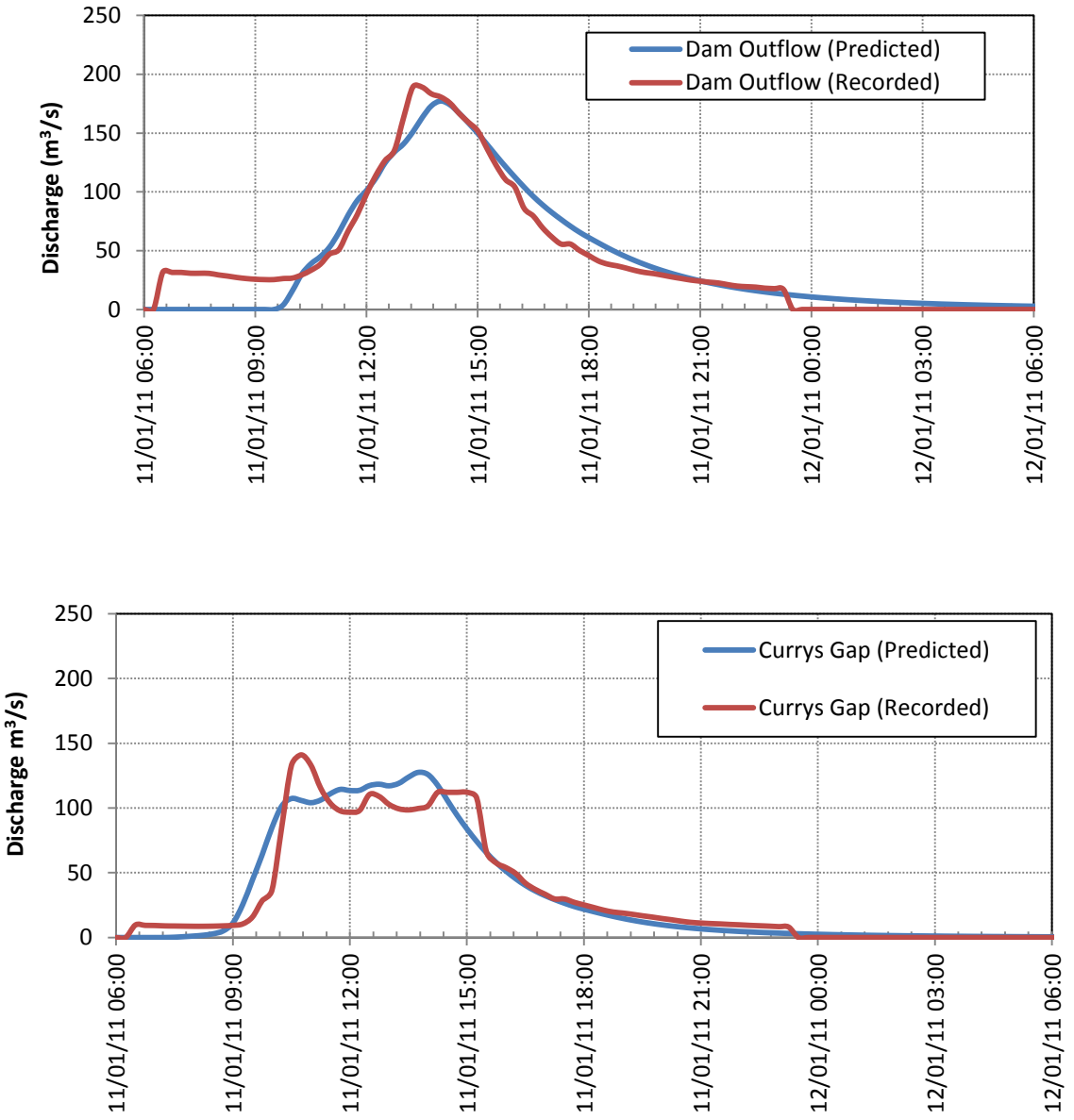

Figure 3.2 Calibration Plots at Dam Outflow and Currys Gap Gauging Stations for January 2011 Event

3.3 MODEL VERIFICATION

The RORB model was verified using the calibrated routing parameters, k_c = 16 and m = 0.8, against the February 2001 rainfall event, and using the recorded rainfall at Black Swamp Creek. The initial and proportional loss model was used with an initial loss of 10 mm. The initial water level at the Tenterfield Creek Dam was based on the recorded water level of 877.35 mAHD (at 0:00 hours, 31 January 2001) which is equivalent to 330 megalitres below full supply capacity.

Although recorded water levels at the Douglas Street Gauging Station were available for this event, the rating curve for this site is considered inaccurate and unreliable (DHI, 2006 and DHI, 2013). Therefore, the available data could only be used as a check to ensure the timing and shape of the predicted and recorded hydrographs are in agreement. As shown in Figure 3.3, the model predicted the timing and shape of the discharge hydrograph at Douglas Street to be reasonably consistent with the recorded water level hydrograph.

The model prediction of Tenterfield Creek Dam outflows were also compared with the recorded Dam outflows (Figure 3.4). The peak outflow is well predicted but the timing of the rising limb is not so well matched.

It should be noted that the 2001 event is only a small flood with a peak outflow of about 26 m^3/s. Given the uncertainties in the rainfall, water level and discharge data available, the validation shown is considered reasonable for the purpose of the study.

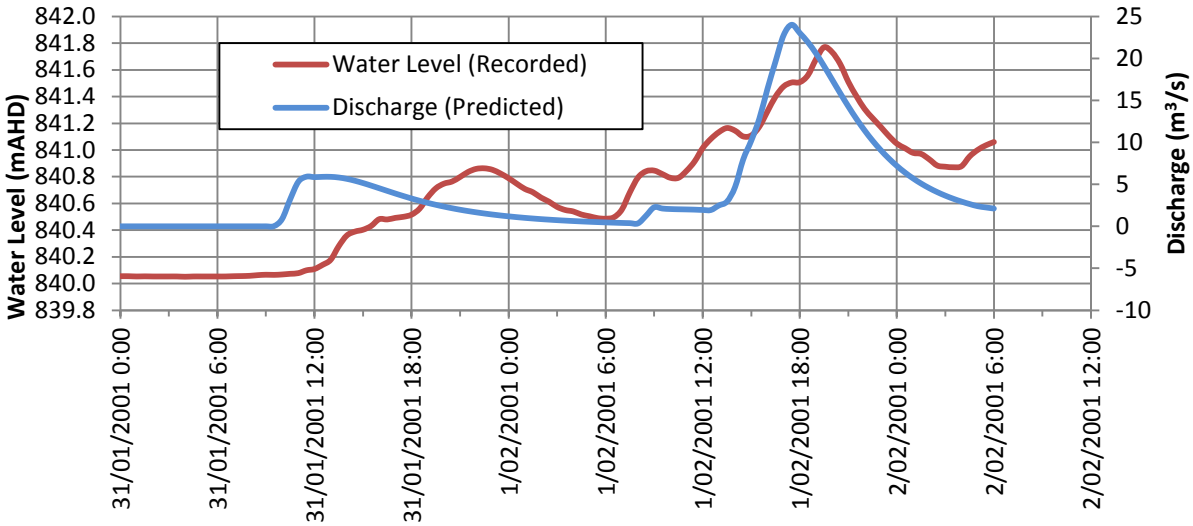

Figure 3.3 Verification Plots at Douglas Street Gauging Station for February 2001 Event

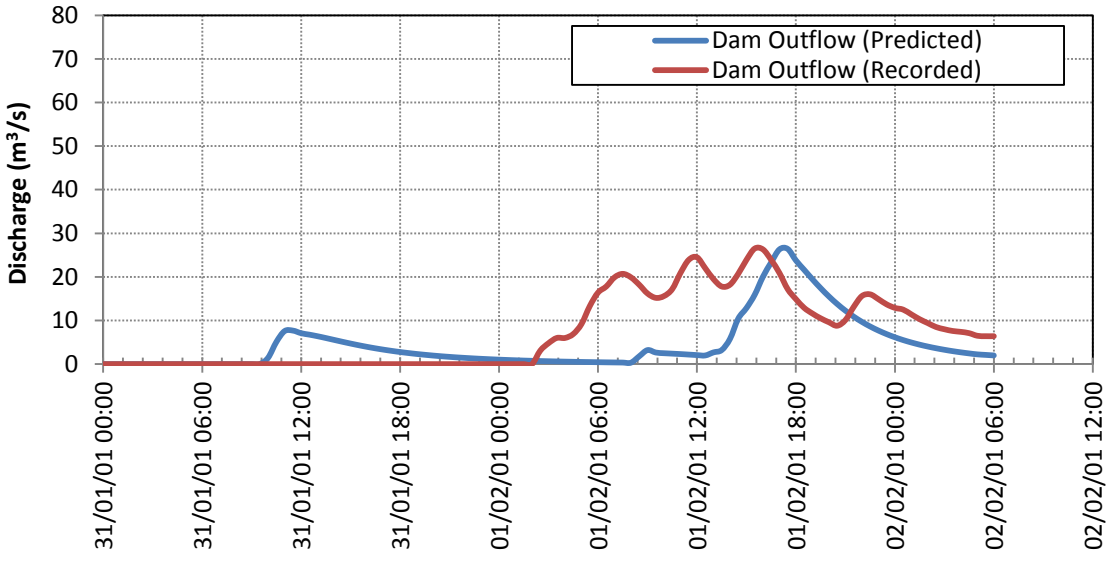

Figure 3.4 Verification Plots at Tenterfield Creek Dam for February 2001 Event

4 PROBABLE MAXIMUM PRECIPITATION

4.1 OVERVIEW

For the estimation of Probable Maximum Precipitation (PMP), the catchment of the Tenterfield Creek Dam is located in the Generalised Tropical Storm Method (GTSMR) Coastal Zone as defined in ARR (1998).

For storm durations of 6 hours or less, the spatial and temporal patterns were derived using the Generalised Short Duration Method (GSDM) (BoM, 2003a).

For storm durations of 24 hours or more, the spatial and temporal patterns were derived using the Generalised Tropical Storm Method- Revised (GTSMR) Method (BoM, 2003b).

Both GSDM and GTSMR methods were tested for the 12 hour storm duration. The GTSMR resulted in a slightly higher peak discharge at all reporting locations and was therefore adopted for this duration.

4.2 PMP ESTIMATES

The PMP estimates for the Tenterfield Creek catchment study area for storm durations ranging from 0.75 to 72 hours are presented in Table 4.1.

Table 4.1 PMP Estimates for Various Storm Durations

Duration (hours)	PMP (mm)
0.75	240
1	290
1.5	330
2	370
2.5	400
3	430
5	510
6	550
12	660
24	870
36	1,060
48	1,240
72	1,550

5 PROBABLE MAXIMUM FLOOD ESTIMATION

The Probable Maximum Flood (PMF) discharges along Tenterfield Creek and its tributaries were estimated using the RORB model that was calibrated and verified against the January 2011 and February 2001 flood events respectively. The calibrated RORB routing parameters (k_c =16 and m=0.8) were used for the PMF discharge estimation.

A zero initial loss and a continuing loss rate of 2.5 mm per hour were assumed for the PMF estimation. Sensitivity analysis was also carried out using a continuing loss rate of 1 mm per hour but the results were not sensitive to the adopted continuing loss rate (less than 1 per cent difference in the peak discharges for storm durations of less than 12 hours, and less than 3 per cent difference for storm durations equal or greater than 12 hours).

Depending on the location of interest along Tenterfield Creek, the critical storm durations for the PMF discharges vary between 1 and 5 hours as shown in Table 5.1. For example the peak inflow of 1,199 m^3/s into Tenterfield Creek Dam is for a 2 hour critical duration storm, whereas the peak catchment outflow of 2,823 m^3/s to the modelled catchment outlet is for a critical storm duration of 5 hours. The critical storm durations for residual inflows downstream of the Dam vary between 1 and 2.5 hours.

Appendices A to G show the predicted design discharge hydrographs for selected storm durations at the different locations defined in Section 3.1, for the PMF event.

Table 5.1 Critical Storm Duration for PMF Discharges at Various Locations

Location	Peak PMF (m^3/s)	Critical Duration (hours)
Dam Inflow	1,199	2.0
INF 1	1,100	2.5
INF 2	999	1.0
INF 3	867	2.0
INF 4	253	1.5
Outflow	2,823	5.0

6 REFERENCES

ARR (1998) Australian Rainfall and Runoff, A Guide to Flood Estimation, Volume 1, the Institution of Engineers Australia, 1998.

BoM (2003a) *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method*, Prepared by the Hydrometeorological Advisory Service, Australian Government Bureau of Meteorology, June 2003.

BoM (2003b) *Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method*, Prepared by the Hydrometeorological Advisory Service, Australian Government Bureau of Meteorology, November 2003.

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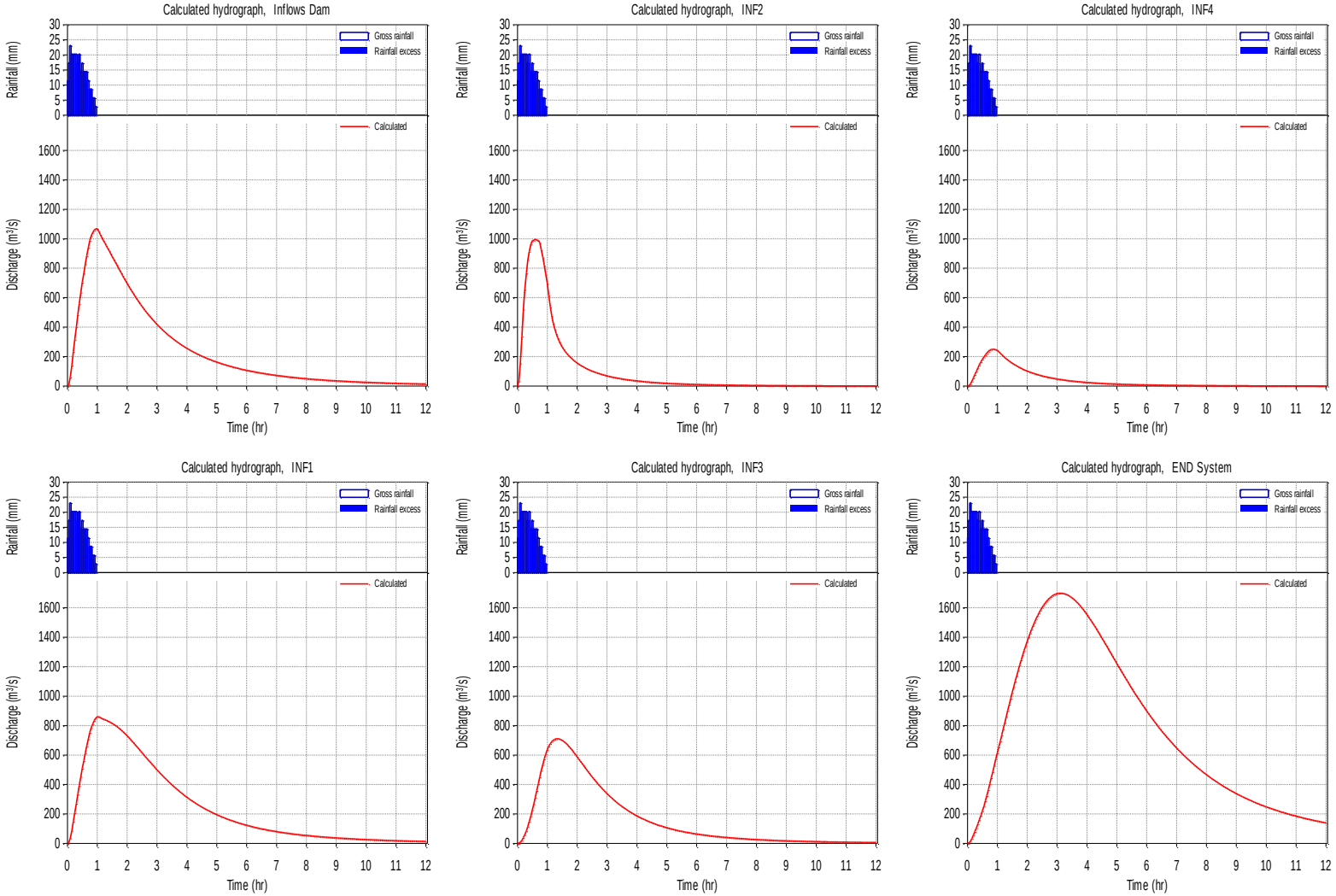
APPENDIX A

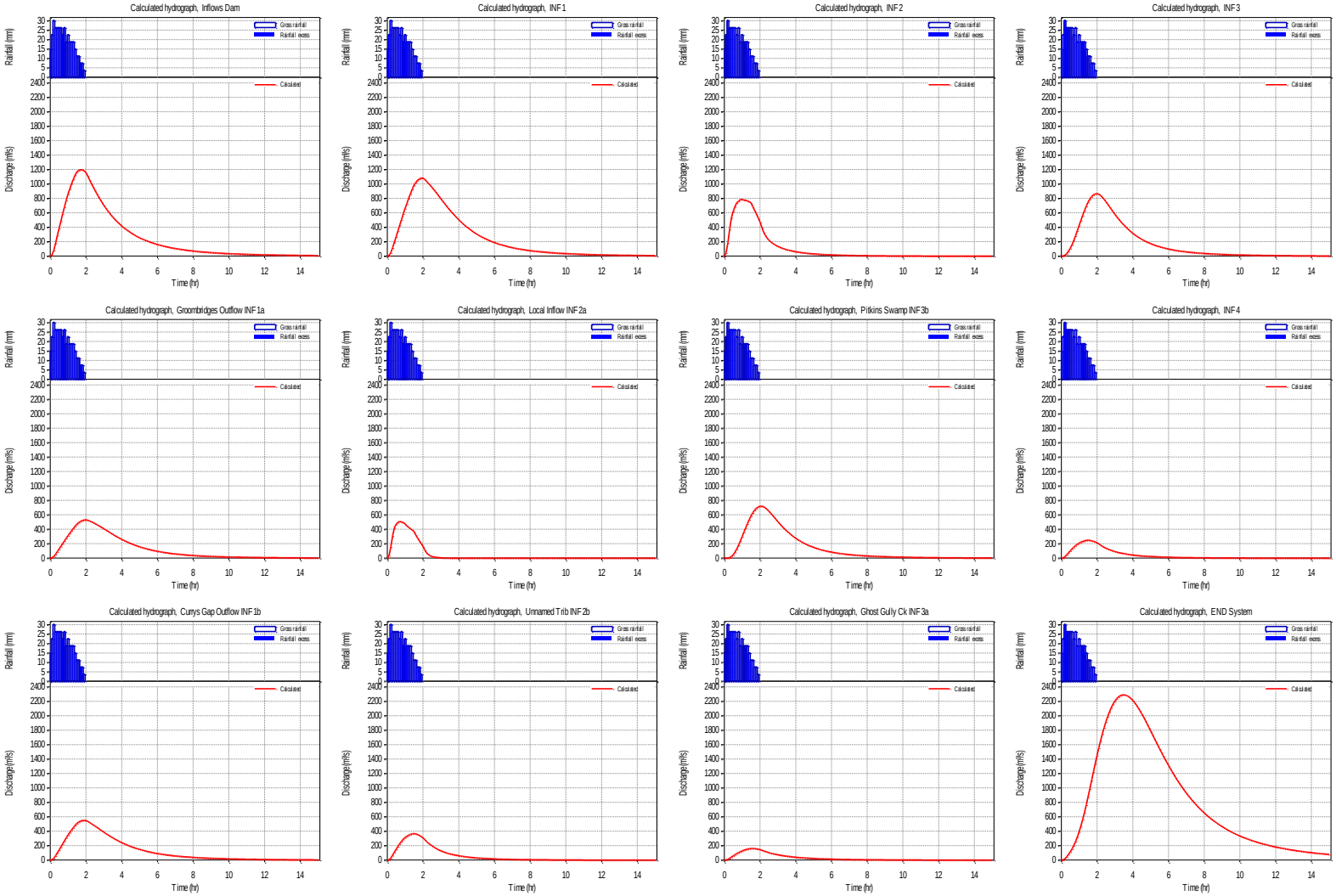
PMF HYDROGRAPHS – 1 HOUR STORM DURATION



PMF Design Hydrographs at Various Locations –1 hour storm duration

APPENDIX B

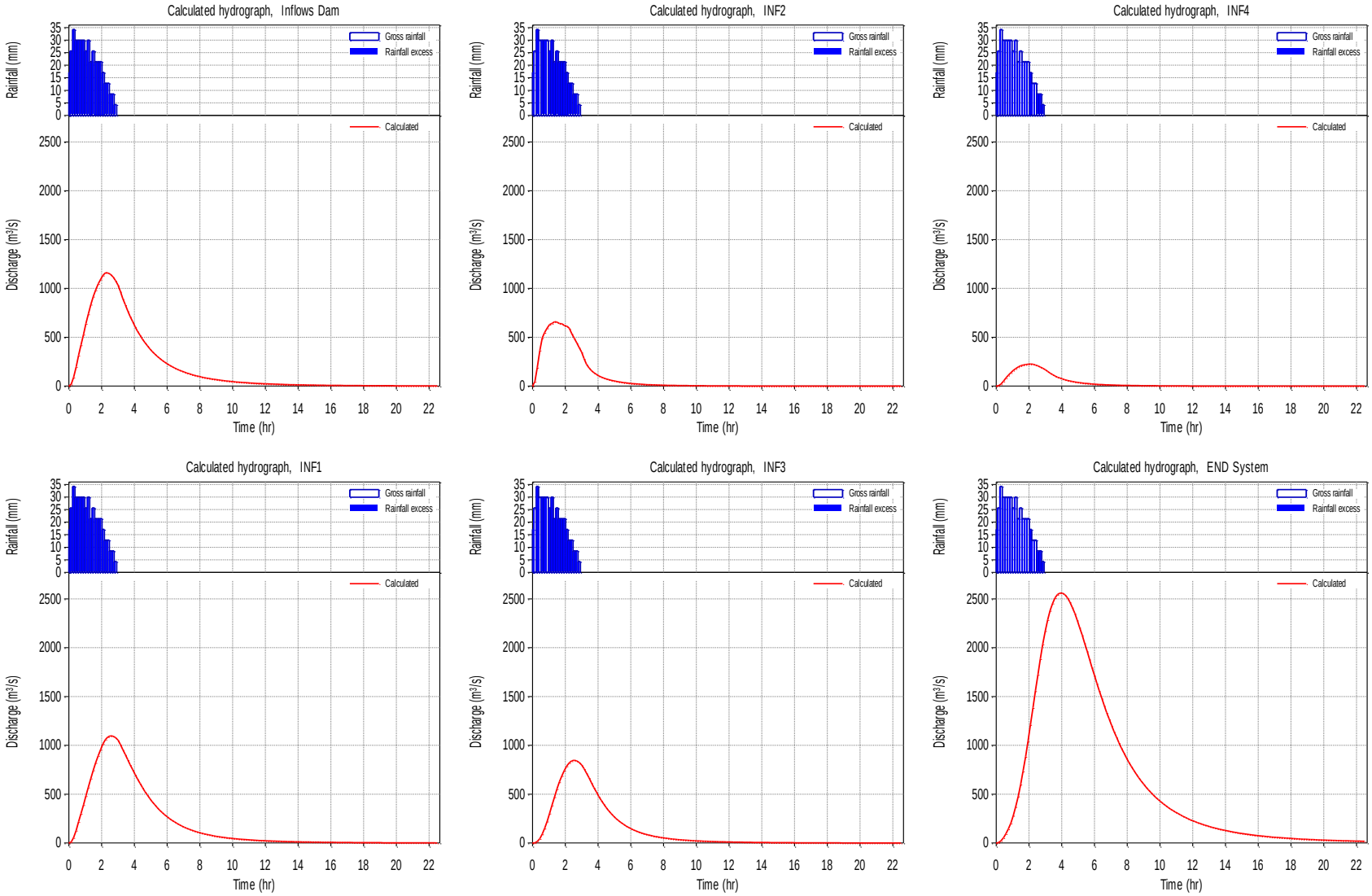
PMF HYDROGRAPHS – 2 HOUR STORM DURATION



PMF Design Hydrographs at Various Locations –2 hour storm duration

APPENDIX C

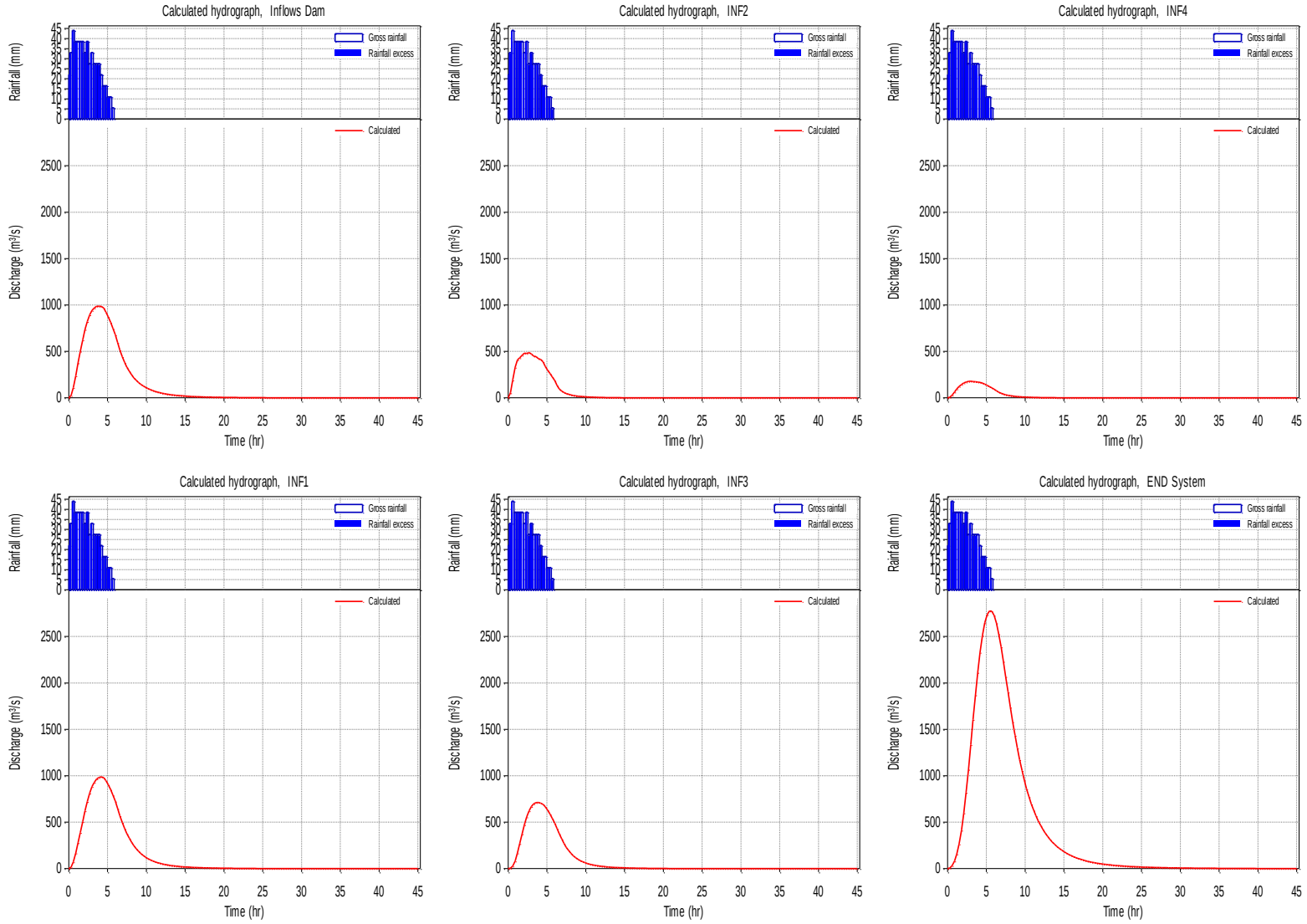
PMF HYDROGRAPHS – 3 HOUR STORM DURATION



PMF Design Hydrographs at Various Locations – 3 hour storm duration

APPENDIX D

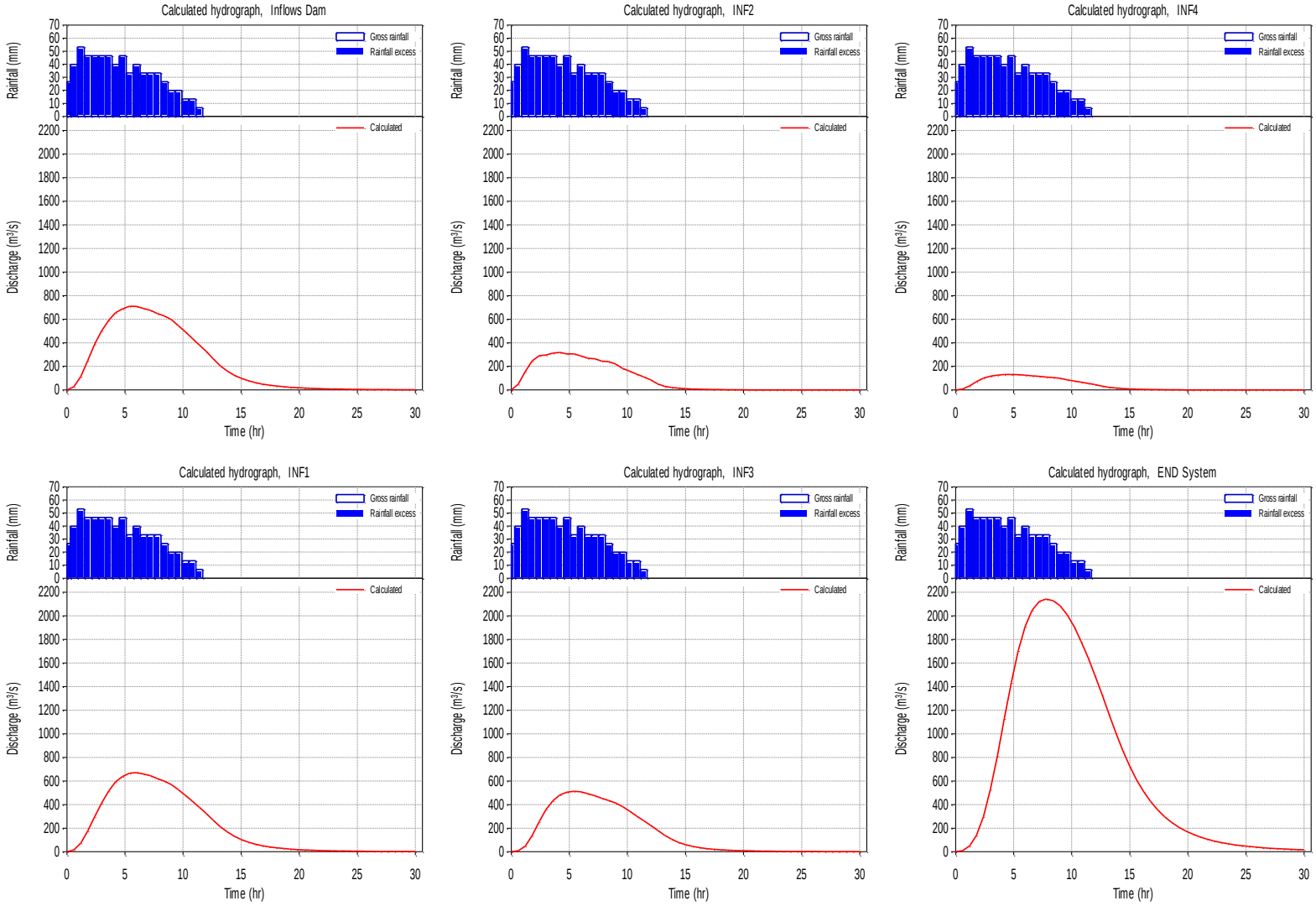
PMF HYDROGRAPHS – 6 HOUR STORM DURATION



PMF Design Hydrographs at Various Locations –6 hour storm duration

APPENDIX E

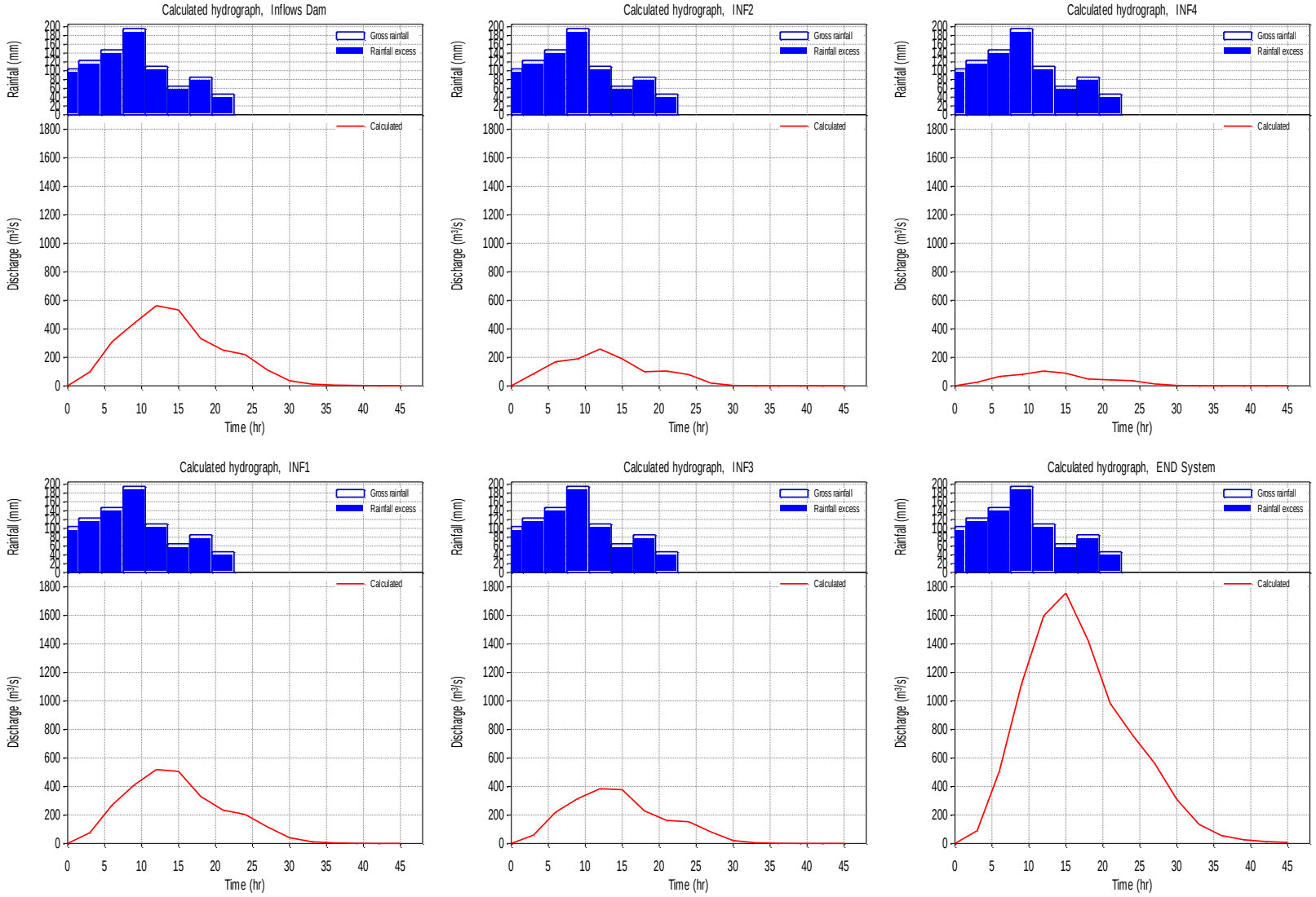
PMF HYDROGRAPHS – 12 HOUR STORM DURATION



PMF Design Hydrographs at Various Locations – 12 hour storm duration

APPENDIX F

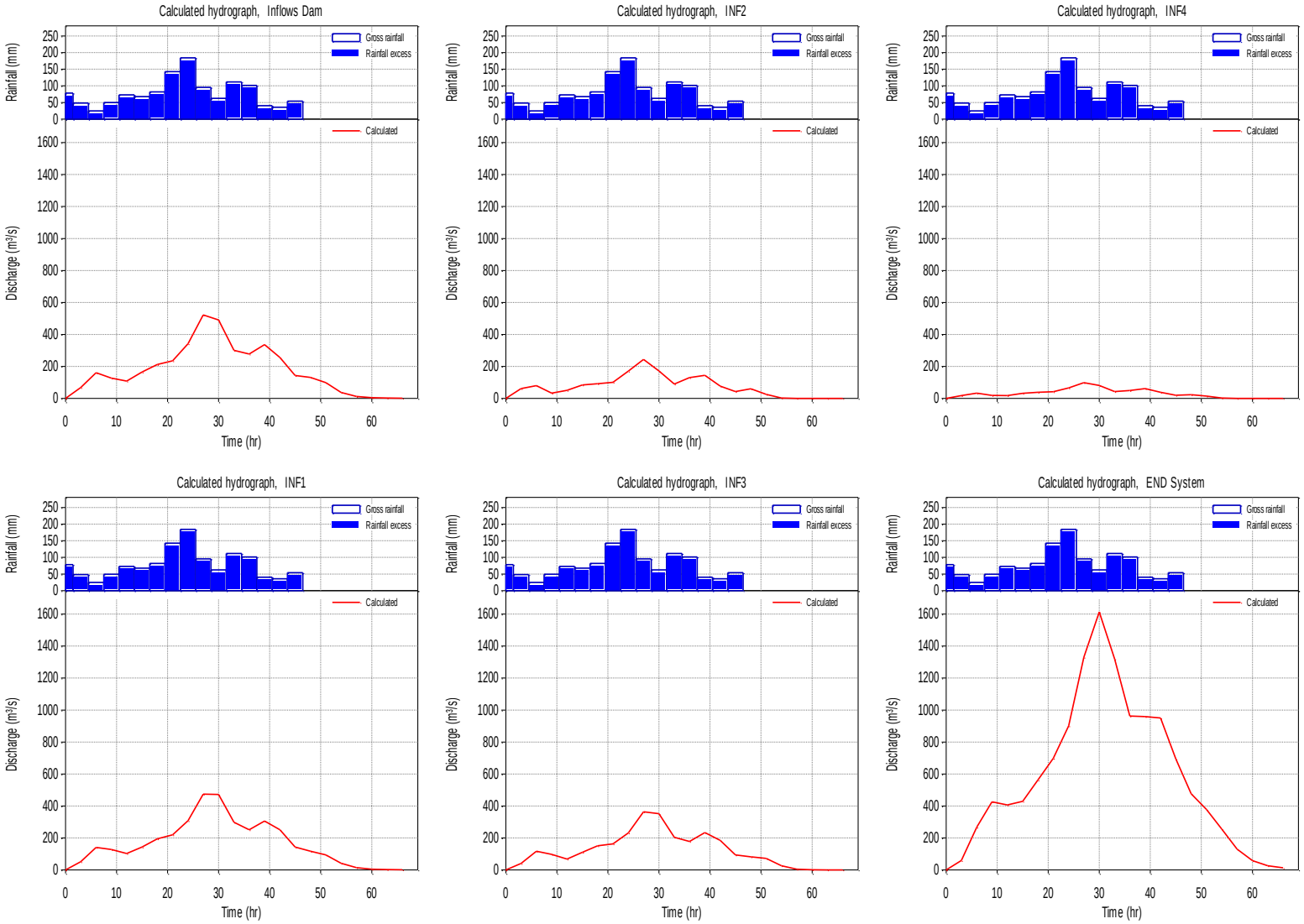
PMF HYDROGRAPHS – 24 HOUR STORM DURATION



PMF Design Hydrographs at Various Locations –24 hour storm duration

APPENDIX G

PMF HYDROGRAPHS – 48 HOUR STORM DURATION



PMF Design Hydrographs at Various Locations – 48 hour storm duration