9. REFERENCES

Aheeyar, M. B. (2008). *Allocation of water among different.* Colombo: Hector Kobbekaduwa Agrarian Research and Training Institute .

Bari, M. A. (2006). A conceptual model of daily water balance following partial clearing from forest to pasture. *Hydrology and Earth System Sciences,* 17.

Bradford, A. (2001). Implementation of a mean annual water balance model within a GIS famework and application to the Murray Darlin basin. *Cooperative research centre for catchment hydrology*, 40.

C.Y. Xu, V. (1996). A Review on Monthly Water Balance Models for. *Water Resources Management 12: 31–50, 1998*, 20.

Claude.M, Z. &. (1994). *A Two Parameter Monthly Water Balance Model for French Watersheds.* Antoney: Journal of Hydrology.

Darmasena, G. (1992). Mathematical Models for Stream Flow Simulation in Sri Lankan Rivers. 17.

David A. Post, A. J. (1999). Predictig the daily streamflow of unguaged catchments in S.E.Australia by regionalising the parameters of a lumped conceptual rainfall runoff model. *Ecological Modeling 123*, 14.

Dripps, W. R. (2007). A simple daily soil–water balance model for estimating the spatial and temporal distribution of groundwater recharge in temperate humid areas. *Hydrogeology Journal* , 12.

Dzubakova, K. (2010). Rainfall-Runoff Modelling: Its Development, Classification And Possible Applications. *Acta Geographica Universitatis Comenianae, Vol. 54*, 9.

Eder, G. (2002). Water balance in Alpine catchments at different spatial and temporal scales. 145.

F.H.S. Chiew a, P. W. (1994). Simulation of the impacts of climate change on runoff and soil moisture in Australian catchments . *Journal o f Hydrology 167* , 27.

Gjddr. (2015). Development Of A Rainfall Runoff Model For Kalu Ganga Basin Of Sri Lanka Using HEC HMS . 205.

Green, I. R. (2001). Criteria for comparison of single event models . *Hydrological Science,* 18.

Grimmond, C. S. (1986). Urban Water Balance - A Model for Daily Totals. *WATER Resources Research, VOL. 22*, 7.

H. Vernon Knapp, A. D. (1991). A Review Of Rainfall-Runoff Modeling For Stormwater Management . *SWS Contract Report 516* , 96.

Haan.C.T. (1972). A Water Yield. Mde! for Small Watersheds. *Water Resources Research*, 12.

Habte A., C. J.-B. (2007). Application of Wasim Distributed Water Balance Simulation Model to the Abbay River Basin . *Catchment and Lake Research* , 8.

Hoad.K.et.al. (2008). *Automating Warm-Up Length Estimation.* Warwick Business School, The University of Warwick, Coventry, UK.

Houghton-Carr, H. A. (1999). Assessment criteria for simple conceptual daily rainfall-runoff models. *HydroIogical Sciences-Journal-des Sciences Hydrologiques*.

Hyndman.R.J. (2006). Another look at measures of forcast accuracy. International Journal of Forcasting 22 (2006) 679-688.

Kanchanamala, D. H. (2016). Impact of Catchment Scale on Rainfall Runoff Modeling: Kalu Ganga River Catchment upto Ratnapura . *ENGINEER - Vol. XLIX, No. 02*, 8.

Kathryn Hoad., S. R. (2008). *Automating Warm-Up Length Estimation* . Warwick Business School, The University of Warwick, Coventry, UK .

Khandu, D. (2015). *A monthly water balance model for evaluation of climate change impacts on the streamflow of Ginganga and Kelani Basin.*

Krause, P. P. (2005). Comparison of different efficiency criteria for hydrological model. *Advances in*, 9.

Kuczera.G. (1982). On the Relationship Between the Reliability of Parameter Estimates and Hydrologic Time Series Data Used in Calibration. *Water Resources Research, VOL. 18, NO. 1*, 9.

Makhlouf, Z. (1994). A two-parameter monthly water balance model for French watersheds . *Journal of Hydrology 16*, 20.

Makridakis.S. (1993) Accuracy measures: theoretical and practical concerns. International Journal of Forcasting 9 (1993) 527-529.

MiHy, P. C. (1994). Climate, interseasonal storage of soil water, and the annual water balance . *Advances in Water Resources 17* , 6.

Models, T. P.-u.-E. (n.d.). *The Problem of the Initial Transient: Techniques for Estimating the Warm-up Period for Discrete-Event Simulation Models* .

Mouelhi, S. (2006). Stepwise development of a two parameter monthly water balance model. *Hydrology*, 15.

Priyani, M. (2016). *Development Of A Rainfall Runoff Model For Kalu Ganga Basin Of Sri Lanka Using HEC HMS.*

Qingyun Duan, S. S. (1994). *Optimal use of the SCE-UA global optimization method for calibrating watershed models* . NWS/NOAA, 1325 East West Highway, Silver Spring, MD 20910, USA : Journal of Hydrology 158 (1994) 265-284 .

Radm. (n.d.). Prediction of management river basin for hydropawer potential aand flood risomitigation - Case studuat Ginganga.

Robinson, S. (2002). *A Statistical Process Control Approach For Estimating The Warm-Up Period* . Warwick Business School, University of Warwick Coventry, CV4 7AL, United Kingdom .

Sally, H. (n.d.). Application of mathematical models for simulation of canal operations at Kirindi oya, Sri Lanka:Preliminary results. 26.

Sampath, D. (2015). HEC-HMS Model for Runoff Simulation in a Tropical Catchment with Intra-Basin Diversions – Case Study of the Deduru Oya River Basin, Sri Lanka . *Engineer - Vol. XLVIII, No. 01*, 9.

Sharifi.M.B.,(2015,unpuble). Calibration and verification of a two parameter monthly water balance model and its application potential for evaluation of water resources - A case study of Kalu and Mahaweli rivers of Sri Lanka

Tan, K. S. (n.d.). Calibration of a Daily Rainfall-Runoff Model to Estimate High Daily Flows. 7.

Tofallis.C.(2014). A better measure of relative prediction accuracy for model selection and model eestimation. Journal of the Operational Research Society (2014), 1-11

Wijesekara. N.T.S. (2000). Parameter Estimation in Watershed Model: A case Study Using Gin Ganga Watershed.

Wijesekara.N.T.S. & Ghanapala.P.P. (2003). Modeling of Two Low Lying Urban Watersheds in the Greater Colombo Area for Draingage and Environmenta Improvement. Journal of the Institute of Engineers, Sri Lanka.

Xiong, L. &. (1999). A two-parameter monthly water balance model and its application. *Journal of Hydrology 216*, 13.

ANNEX A - DATA

Table A-1: Thiessen Average Rainfall Data – Tawalama Watershed

Year	Monthly rainfall (mm/month)			Annual rainfall (mm/year)
	Maximum	Mean	Minimum	
2000/01	503.77	251.68	71.13	3,020.14
2001/02	539.91	236.94	105.37	2,843.23
2002/03	596.33	313.20	160.37	3,758.38
2003/04	521.52	309.89	119.69	3,718.64
2004/05	306.75	202.80	127.01	2,433.60
2005/06	578.93	313.62	184.89	3,763.39
2006/07	645.45	332.43	77.93	3,989.19
2007/08	546.88	361.58	145.53	4,338.95
2008/09	526.26	347.22	50.50	4,166.66
2009/10	451.88	259.15	95.08	3,109.82
2010/11	692.34	345.51	131.77	4,146.10
2011/12	526.06	285.31	84.51	3,423.78
2012/13	580.93	359.43	91.87	4,313.12
2013/14	483.75	306.86	95.66	3,682.29
2014/15	641.36	387.07	185.69	4,644.82

Table A-2: Streamflow Data – Tawalama Watershed

Year	Monthly Streamflow (mm/month)			Annual Streamflow (mm/year)
	Maximum	Mean	Minimum	
2000/01	308.81	159.95	43.62	1,919.37
2001/02	288.58	161.14	46.84	1,933.63
2002/03	839.41	254.47	86.99	3,053.69
2003/04	358.88	222.74	91.88	2,672.82
2004/05	290.79	200.69	112.37	2,408.31
2005/06	377.39	203.61	58.08	2,443.29
2006/07	492.15	209.36	58.08	2,512.28
2007/08	494.30	290.56	127.92	3,486.77
2008/09	346.30	225.44	35.16	2,705.34
2009/10	474.87	228.61	51.70	2,743.34
2010/11	488.47	252.80	78.32	3,033.66
2011/12	337.46	197.50	81.22	2,370.06
2012/13	710.37	331.34	163.83	3,976.06
2013/14	407.28	207.98	70.56	2,495.75
2014/15	503.11	269.64	126.78	3,235.66

Table A-3: Evaporation Data – Rathnapura Station

Year	Monthly Evaporation (mm/month)			Annual Evaporation (mm/year)
	Maximum	Mean	Minimum	
2000/01	92.04	64.10	48.62	769.18
2001/02	107.55	79.45	48.06	953.43
2002/03	99.17	76.71	56.84	920.50
2003/04	100.39	76.10	44.14	913.19
2004/05	104.44	77.00	50.61	924.05
2005/06	91.70	76.77	58.89	921.26
2006/07	123.66	82.84	57.01	994.03
2007/08	97.09	77.01	61.70	924.07
2008/09	114.14	88.38	66.42	1,060.59
2009/10	103.19	78.67	57.01	944.03
2010/11	88.86	72.43	48.51	869.18
2011/12	113.70	82.83	65.20	994.01
2012/13	98.43	72.52	52.98	870.27
2013/14	107.35	74.91	54.51	898.86
2014/15	96.47	74.80	48.39	897.63

Table A-4: Thiessen Average Rainfall Data – Ellagawa Watershed

Year	Monthly rainfall (mm/month)			Annual rainfall (mm/year)
	Maximum	Mean	Minimum	
2006/07	484.76	261.48	29.63	3,137.81
2007/08	446.31	265.57	113.21	3,186.81
2008/09	504.15	235.07	24.87	2,820.80
2009/10	579.33	290.35	62.10	3,484.24
2010/11	562.23	281.85	120.31	3,382.20
2011/12	442.50	228.08	84.27	2,736.95
2012/13	490.91	325.11	141.68	3,901.29
2013/14	557.49	290.07	60.22	3,480.89

Table A-5: Streamflow Rainfall Data – Ellagawa Watershed

Year	Monthly Streamflow (mm/month)			Annual Streamflow (mm/year)
	Maximum	Mean	Minimum	
2006/07	307.18	116.17	20.74	1,394.02
2007/08	509.39	174.06	40.08	2,088.69
2008/09	201.72	116.90	21.28	1,402.81
2009/10	523.21	135.11	30.02	1,621.34
2010/11	259.33	147.50	45.50	1,769.99
2011/12	127.08	62.83	27.99	754.01
2012/13	365.57	146.76	47.93	1,761.13
2013/14	436.91	112.70	26.42	1,352.37

ANNEX B - DATA CHECKING (ELLAGAWA BASIN)

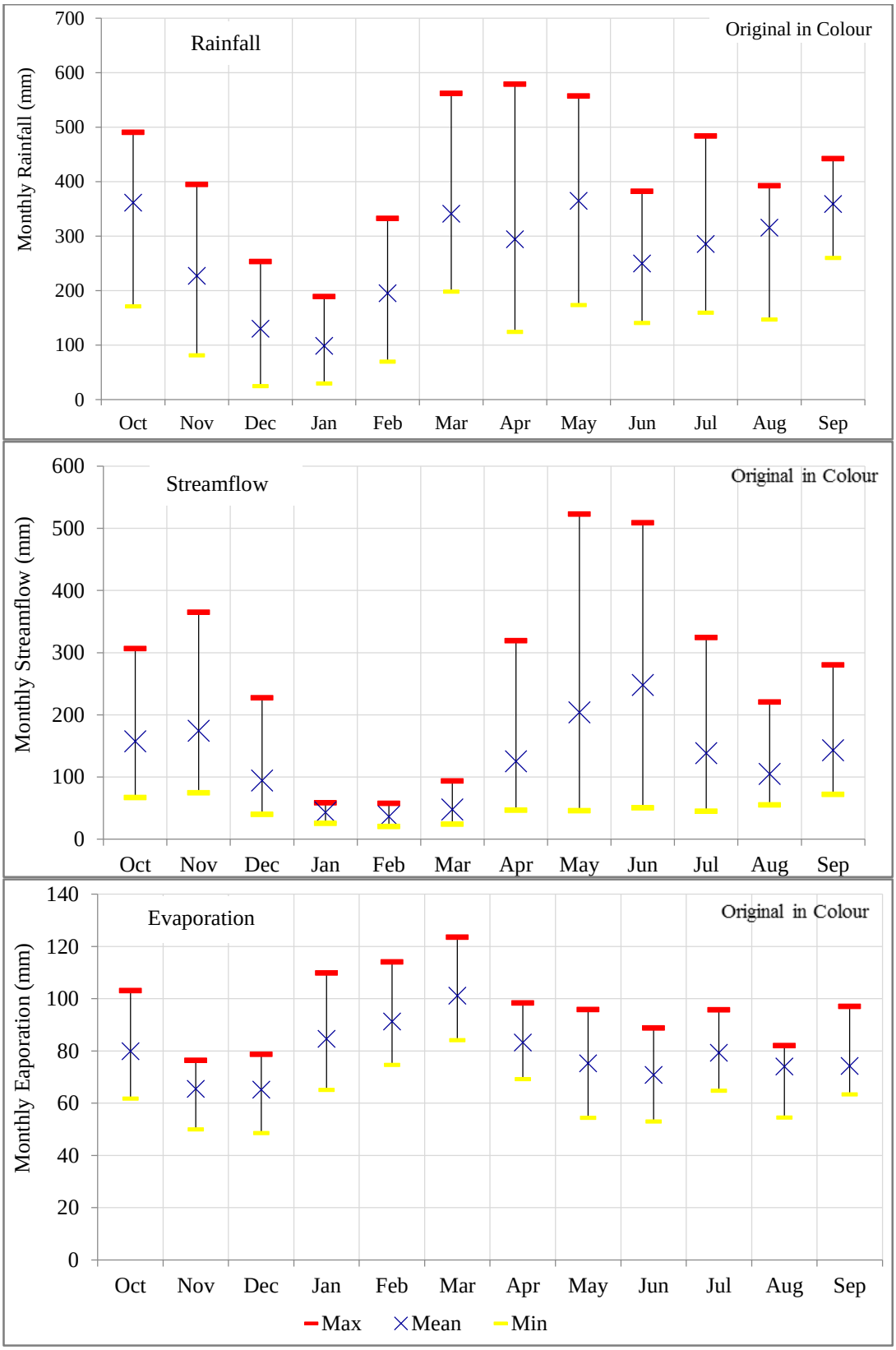

Figure B-1: Variation of Maximum, Mean and average monthly rainfall, streamflow & evaporation

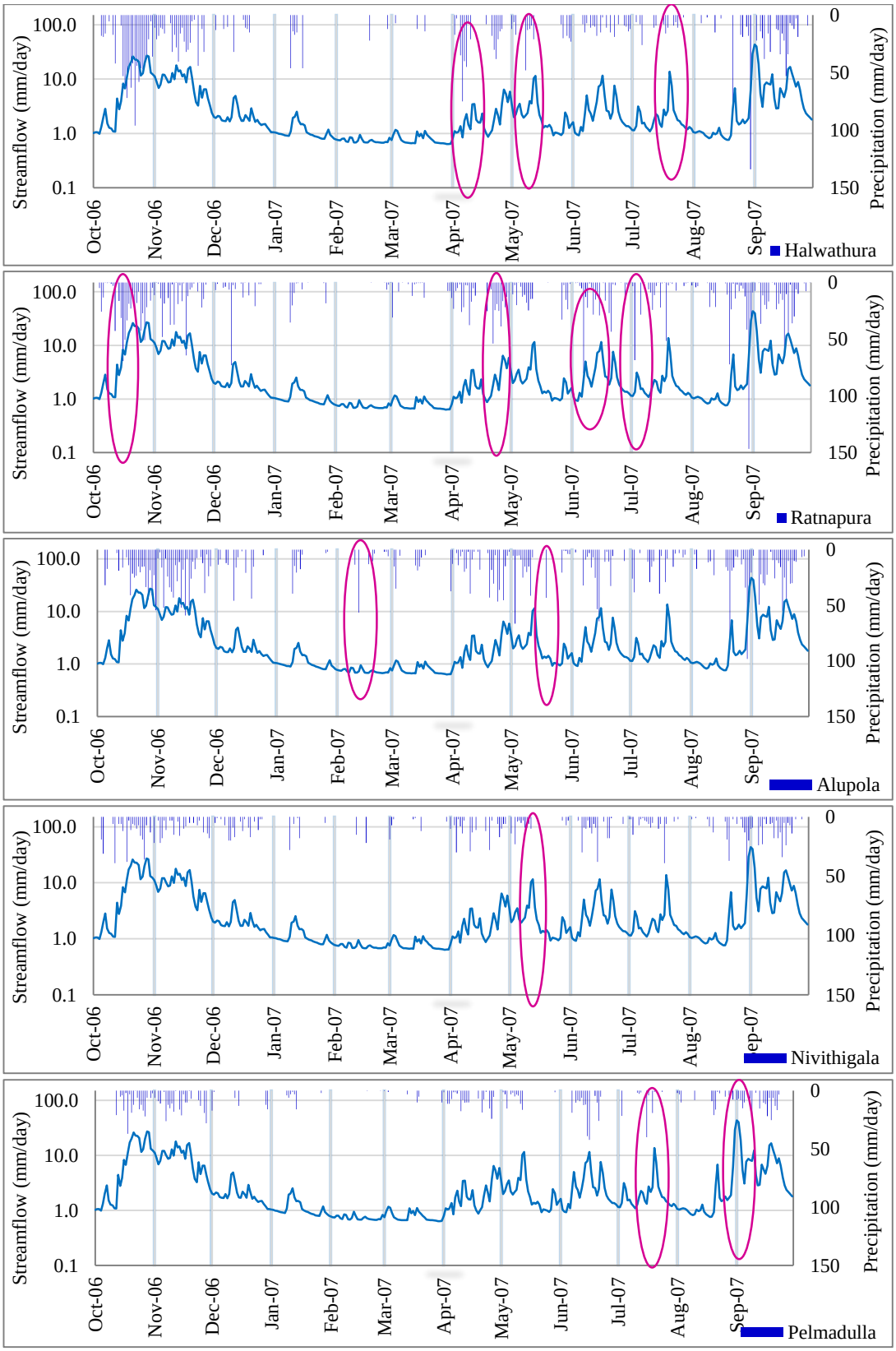

Figure B-2 : Rainfall response to Ellagawa Streamflow in year 2006/2007- Semi Logarithmic scale

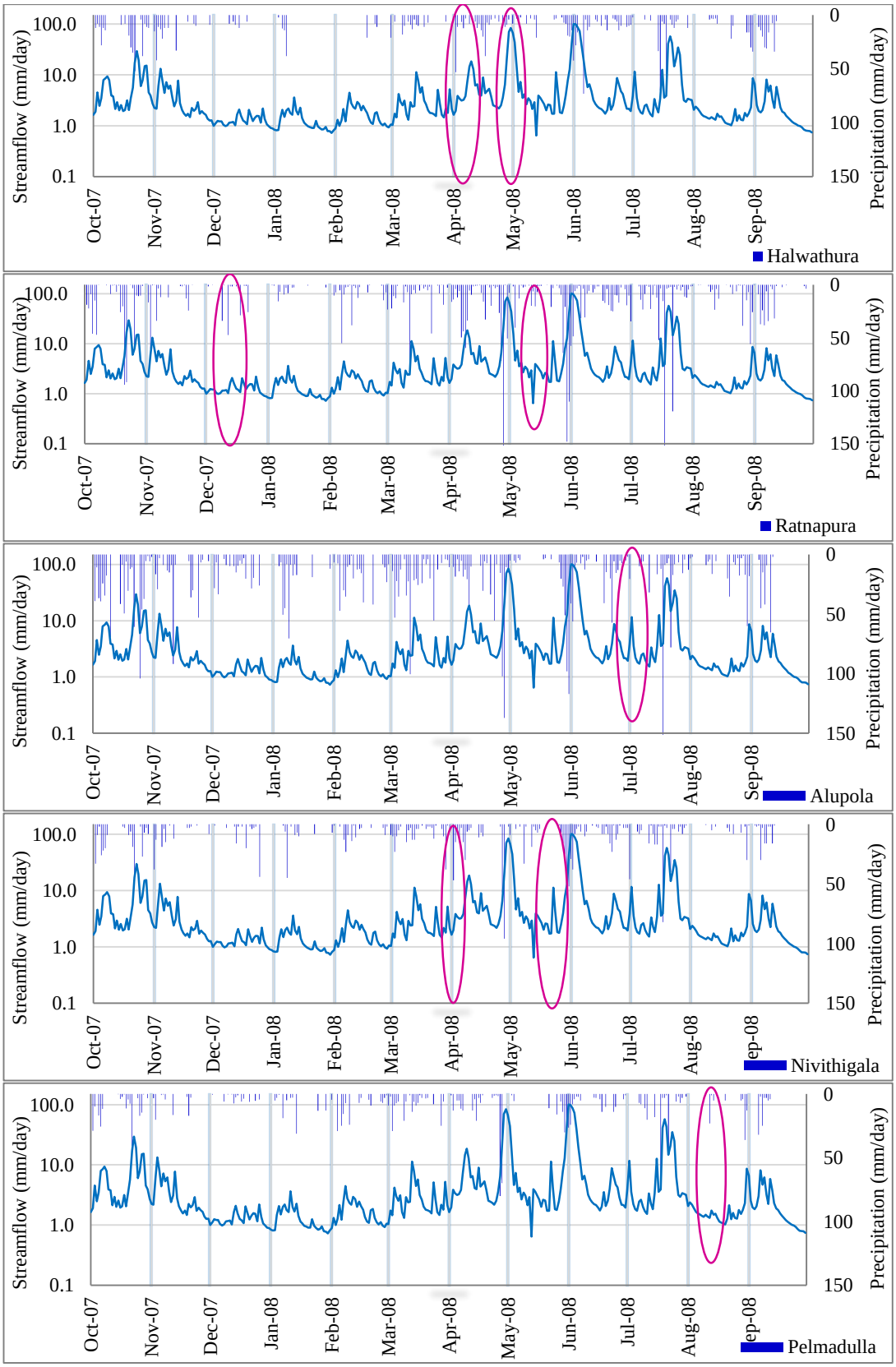

Figure B-3 : Rainfall response with Ellagawa Streamflow in 2007/2008 - Semi Logarithmic scale

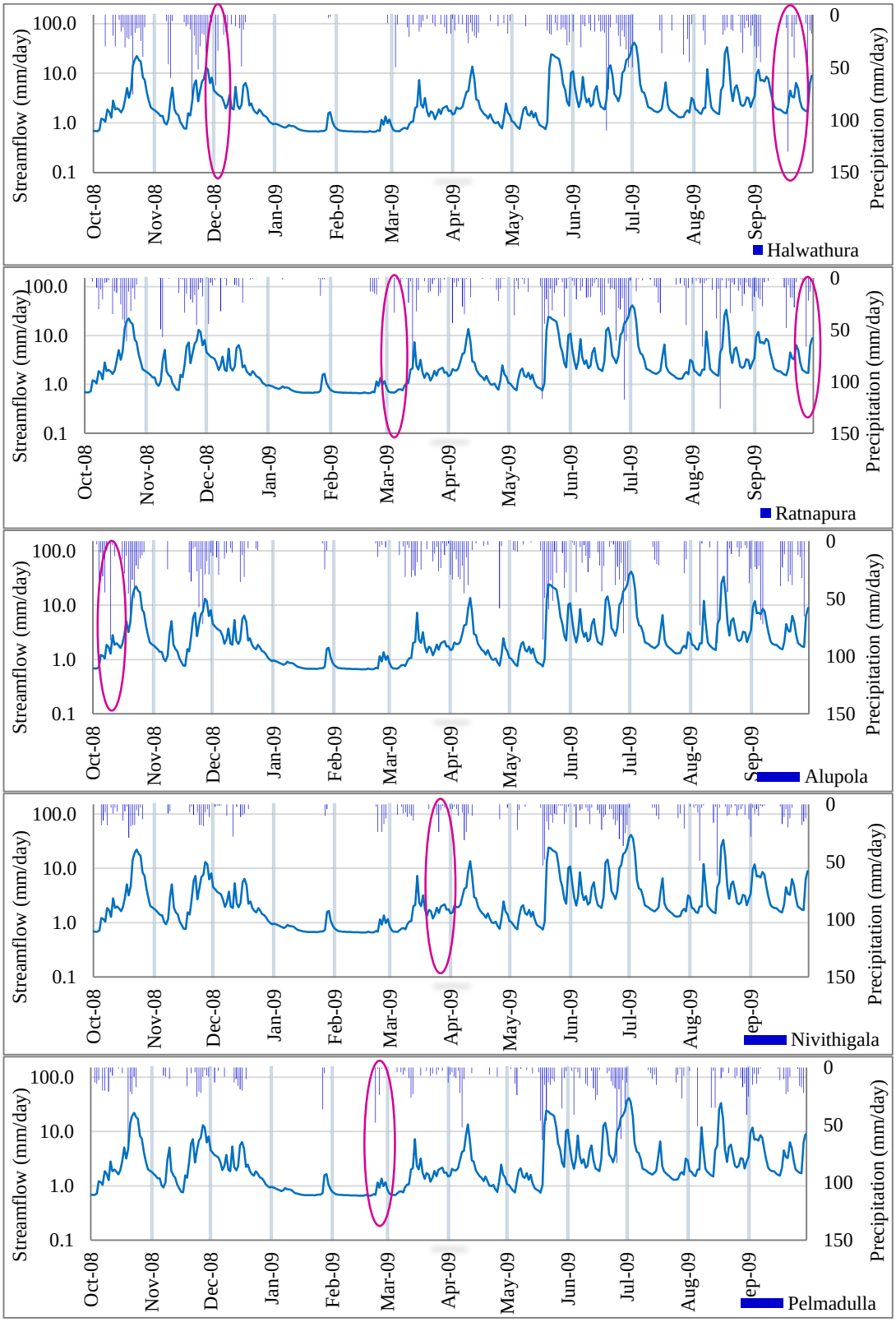

Figure B -4 : Rainfall response with Ellagawa Streamflow in 2008/2009 - Semi Logarithmic scale

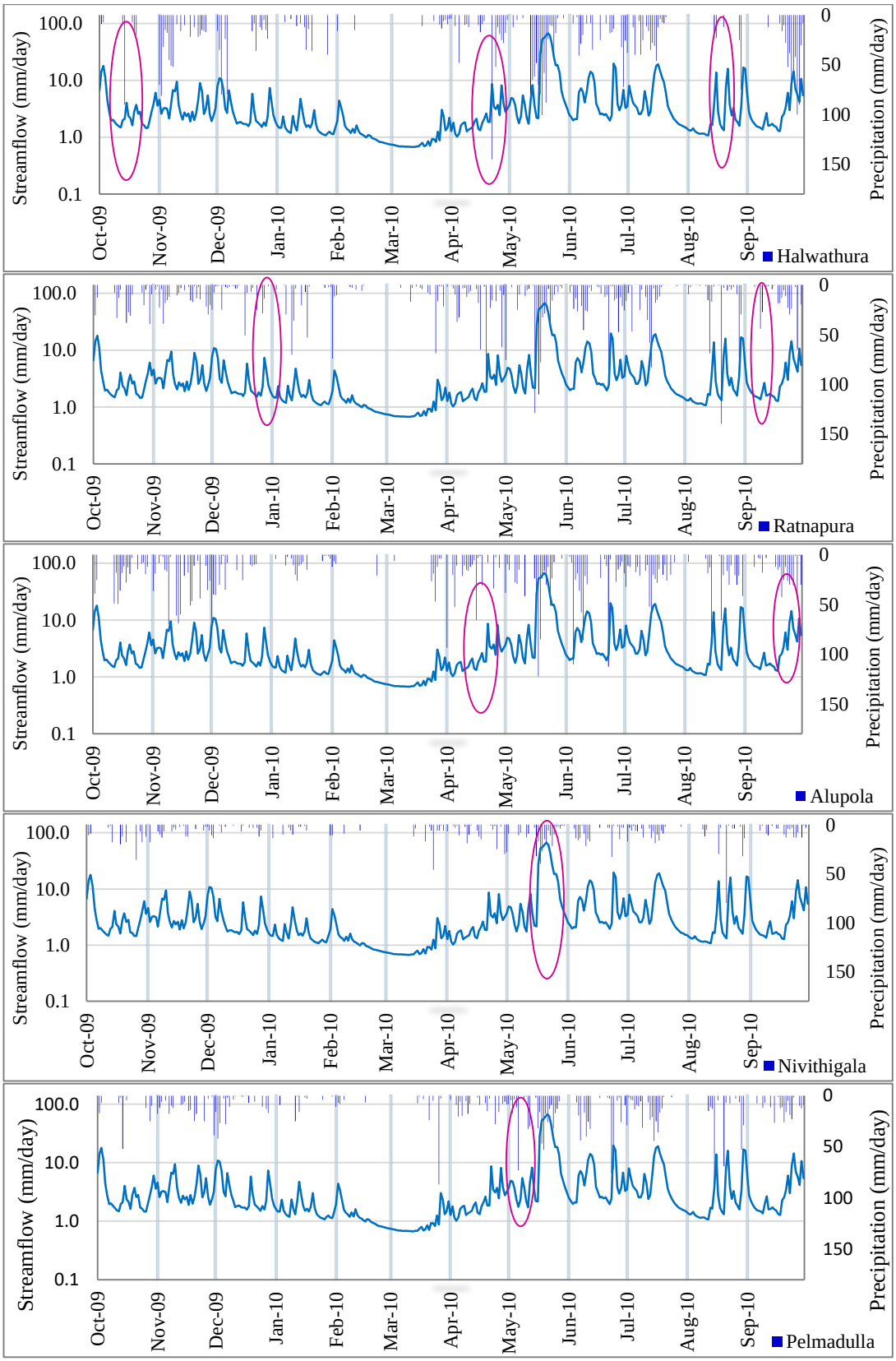

Figure B -5: Rainfall response with Ellagawa streamflow in 2009/2010- Log scale

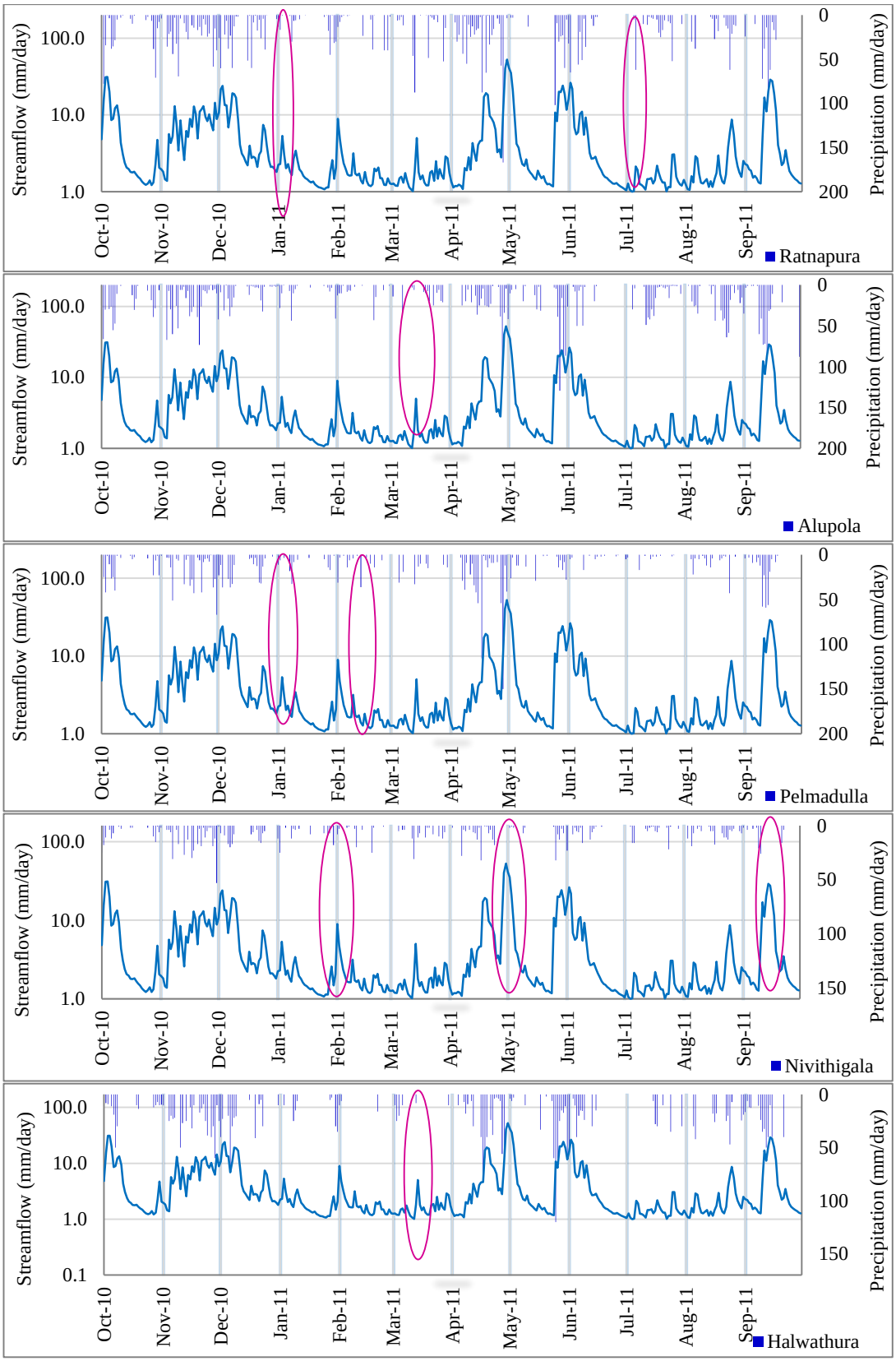

Figure B -6: Rainfall response with Ellagawa streamflow in 2010/2011- Log scale

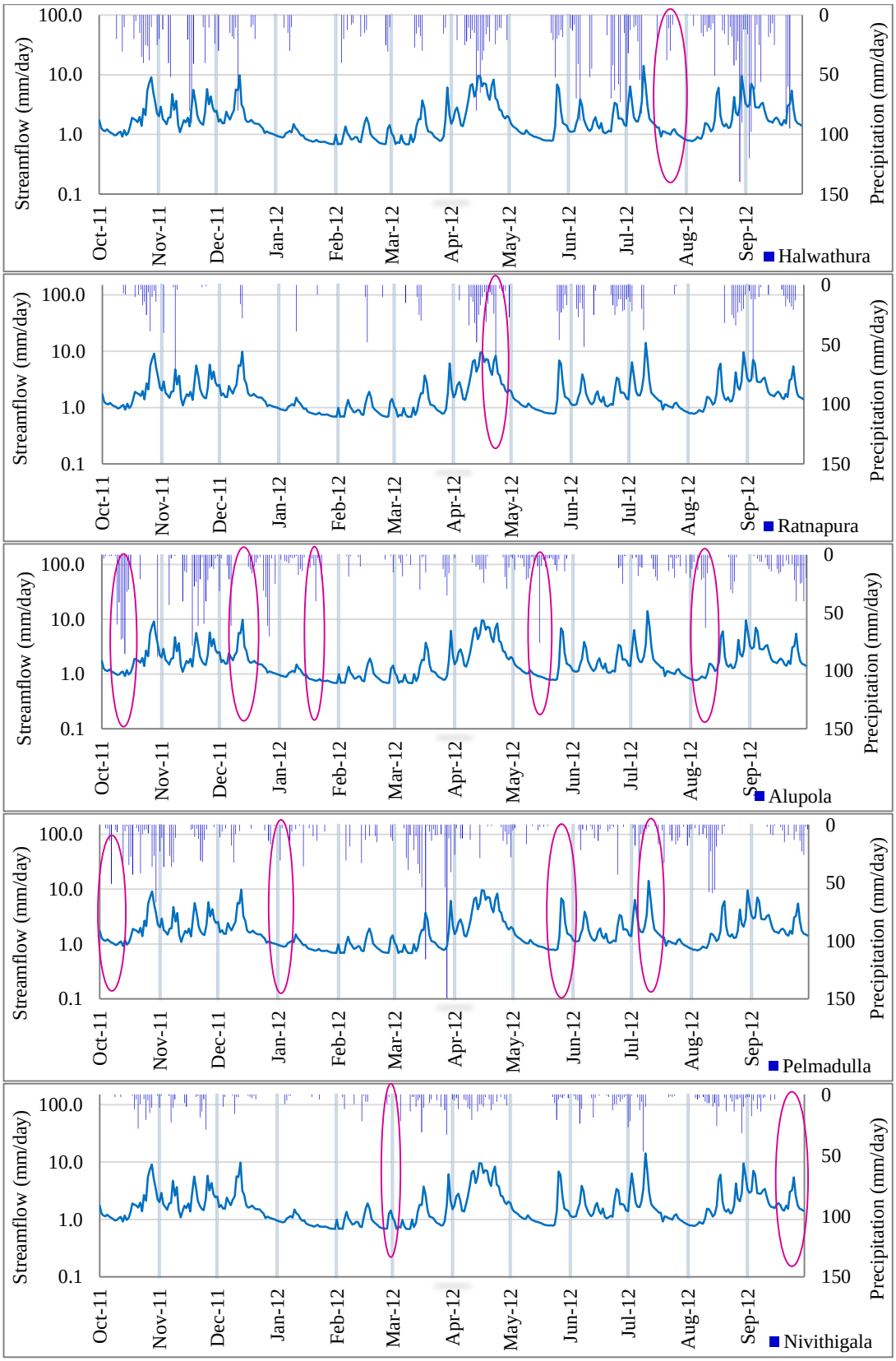

Figure B -7: Rainfall response with Ellagawa stream flow in 2011/2012- Log scale

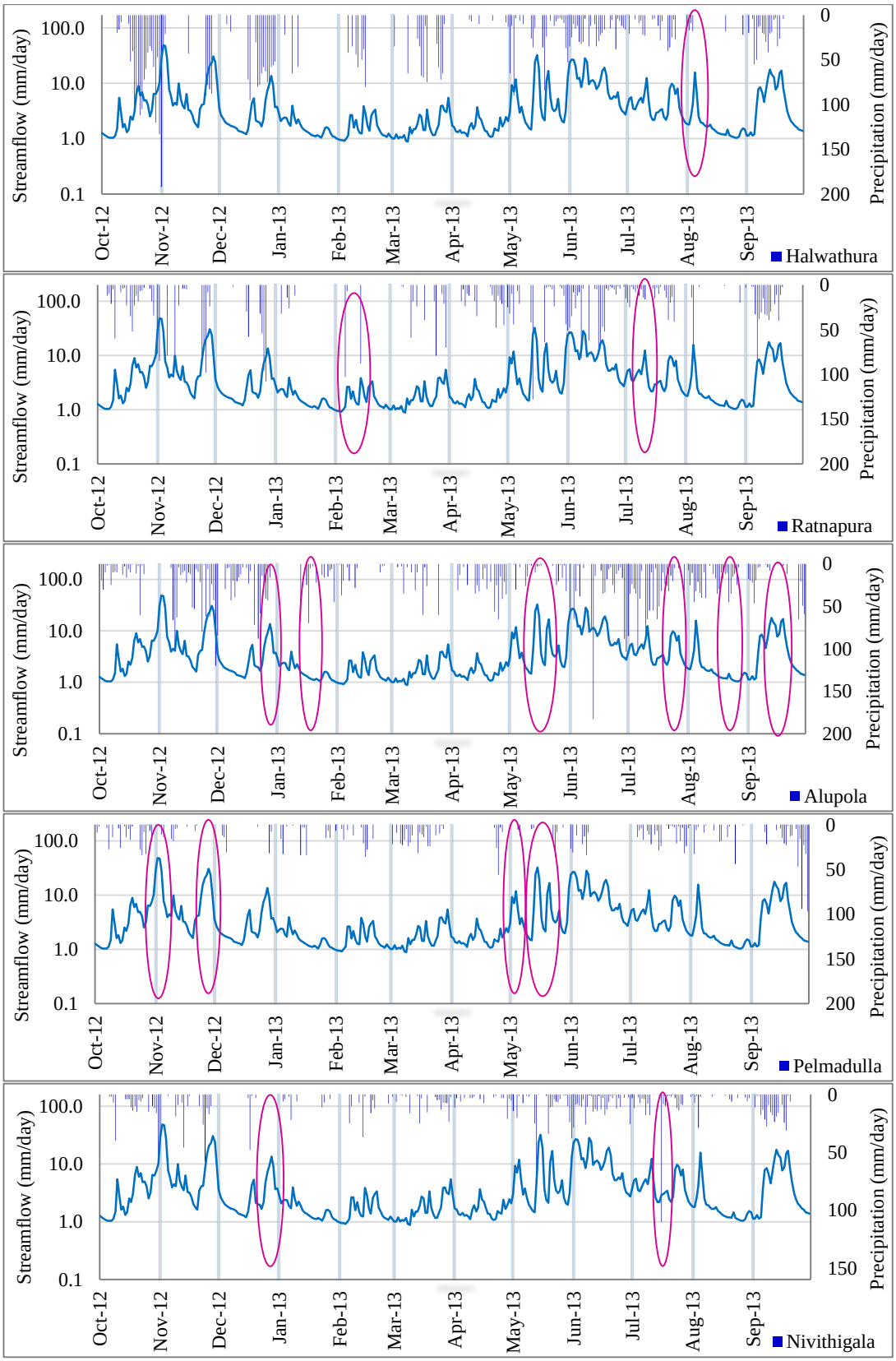

Figure B -8: Rainfall response with Ellagawa stream flow in 2012/2013- Log scale

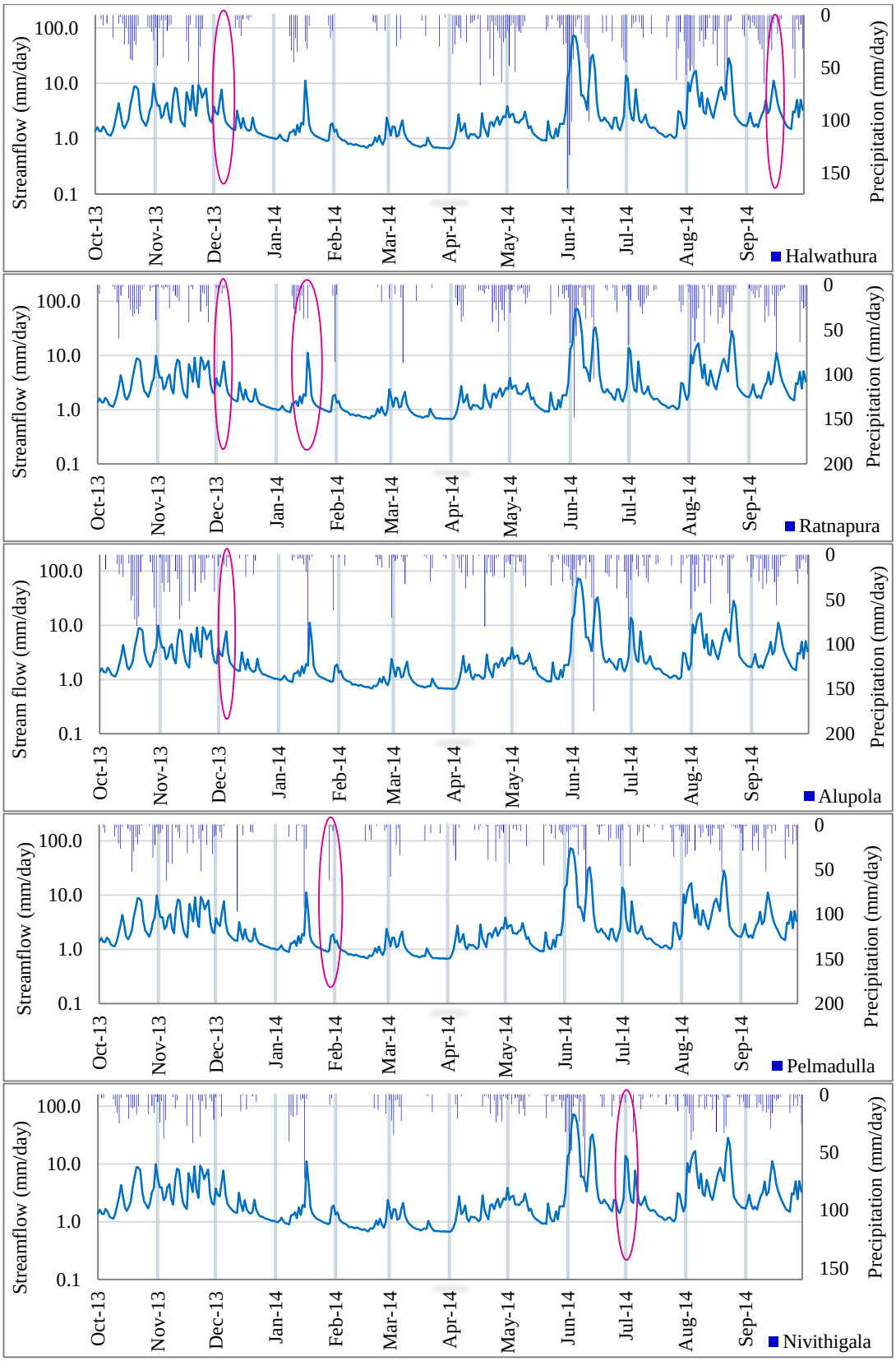

Figure B -9: Rainfall response with Ellagawa stream flow in 2013/2014- Log scale

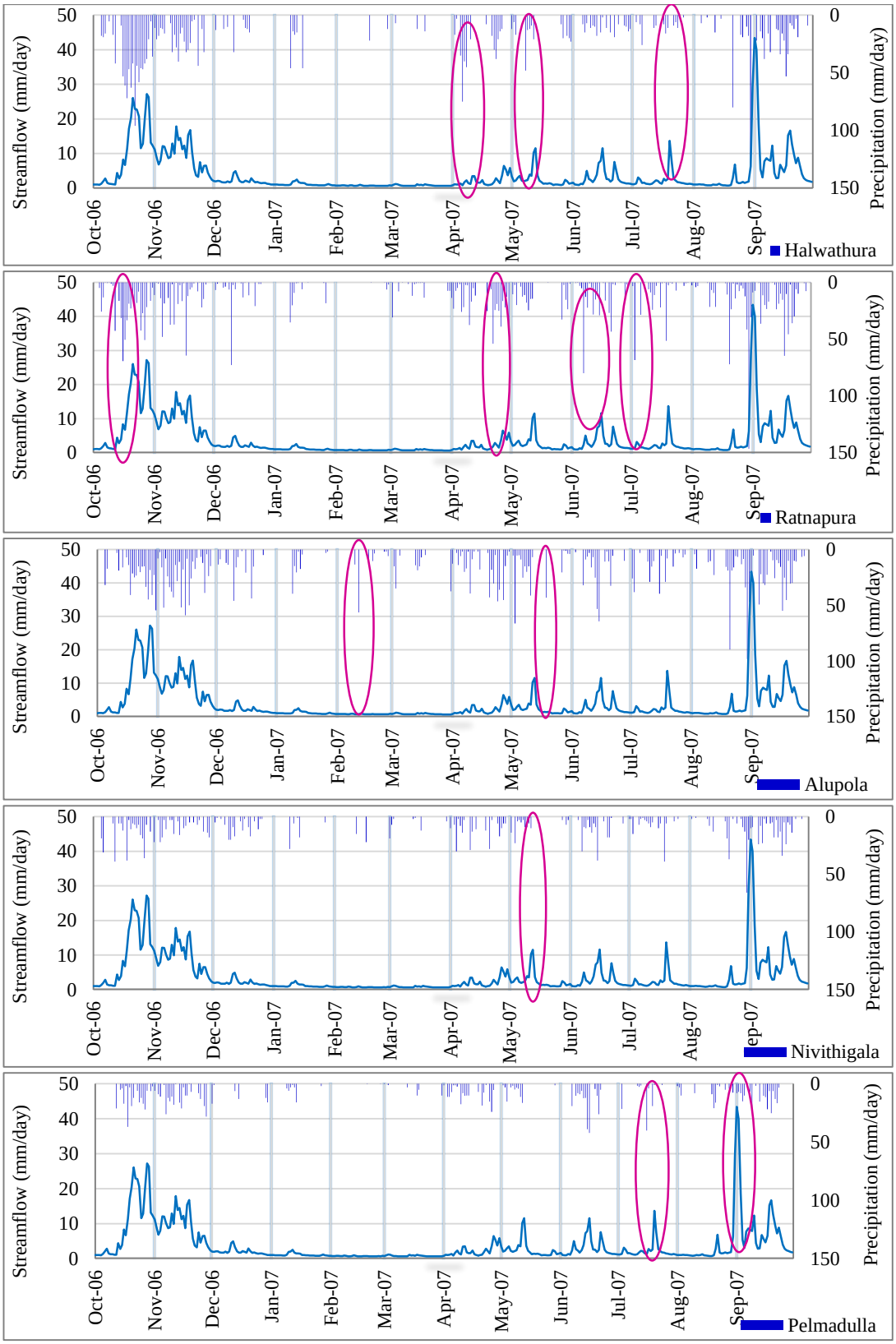

Figure B -10 : Rainfall response to Ellagawa Streamflow in year 2006/2007- Normal scale

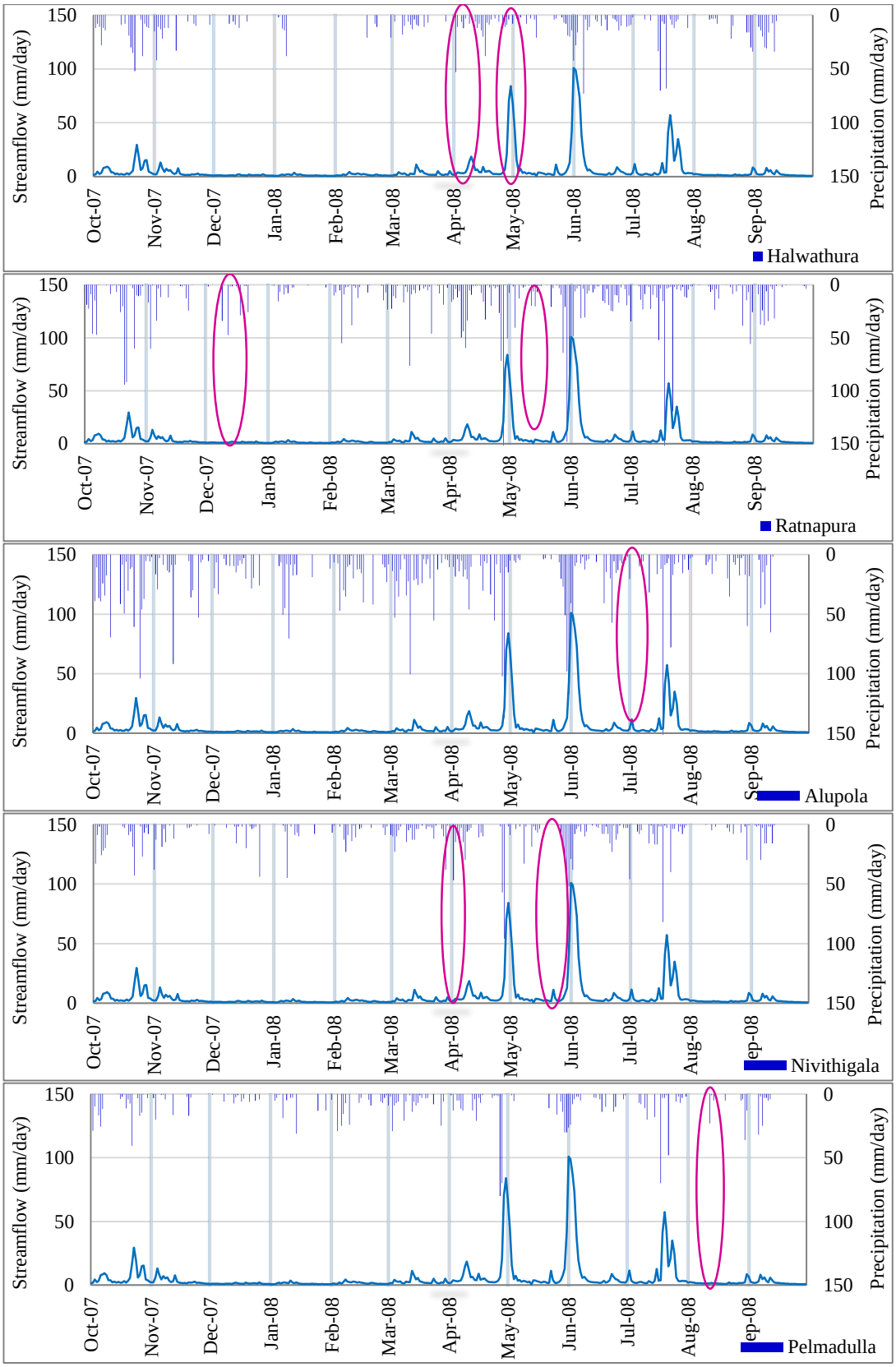

Figure B -11 : Rainfall response with Ellagawa Streamflow in 2007/2008 - Normal scale

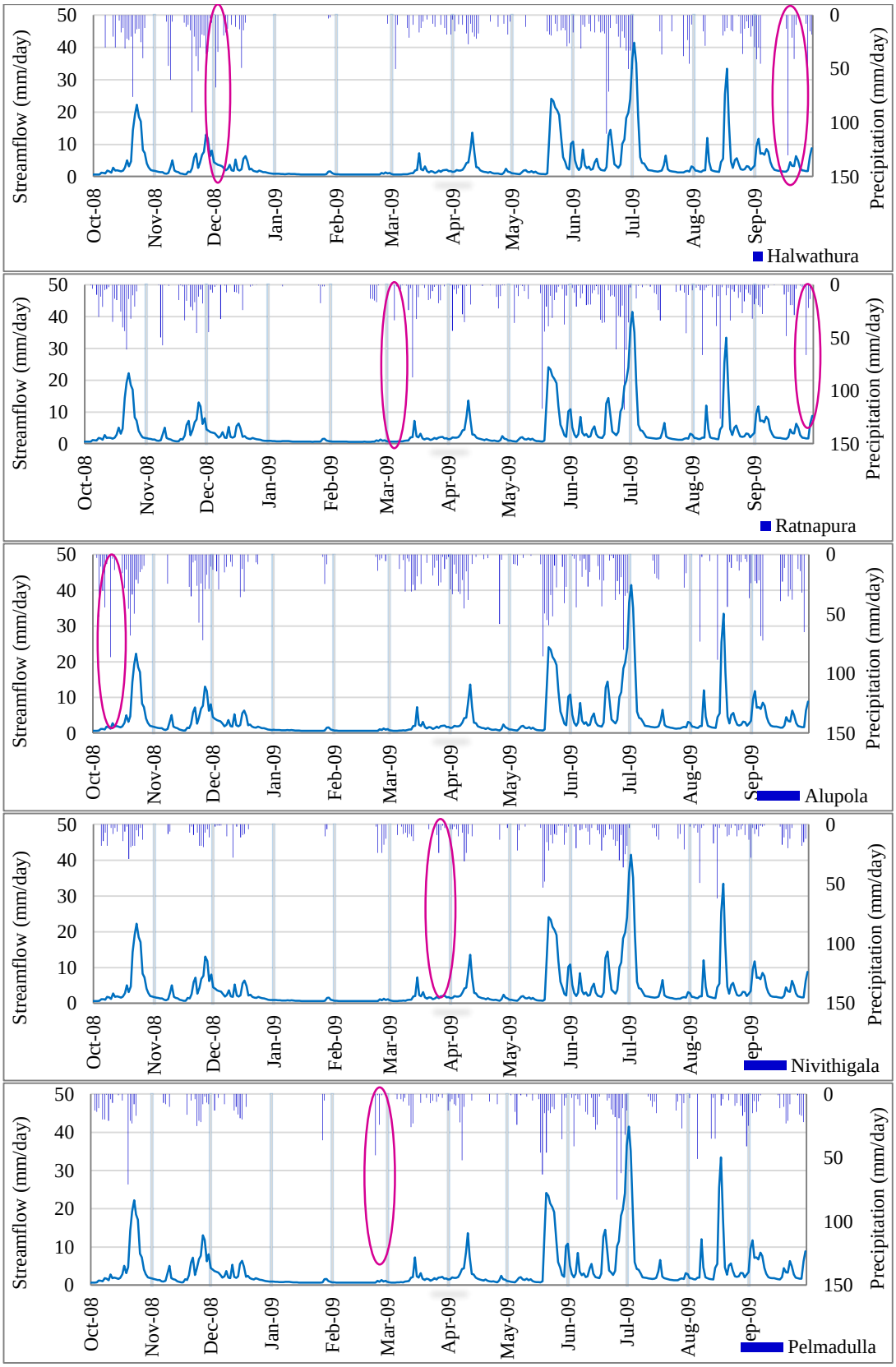

Figure B -12 : Rainfall response with Ellagawa Streamflow in 2008/2009- Log scale

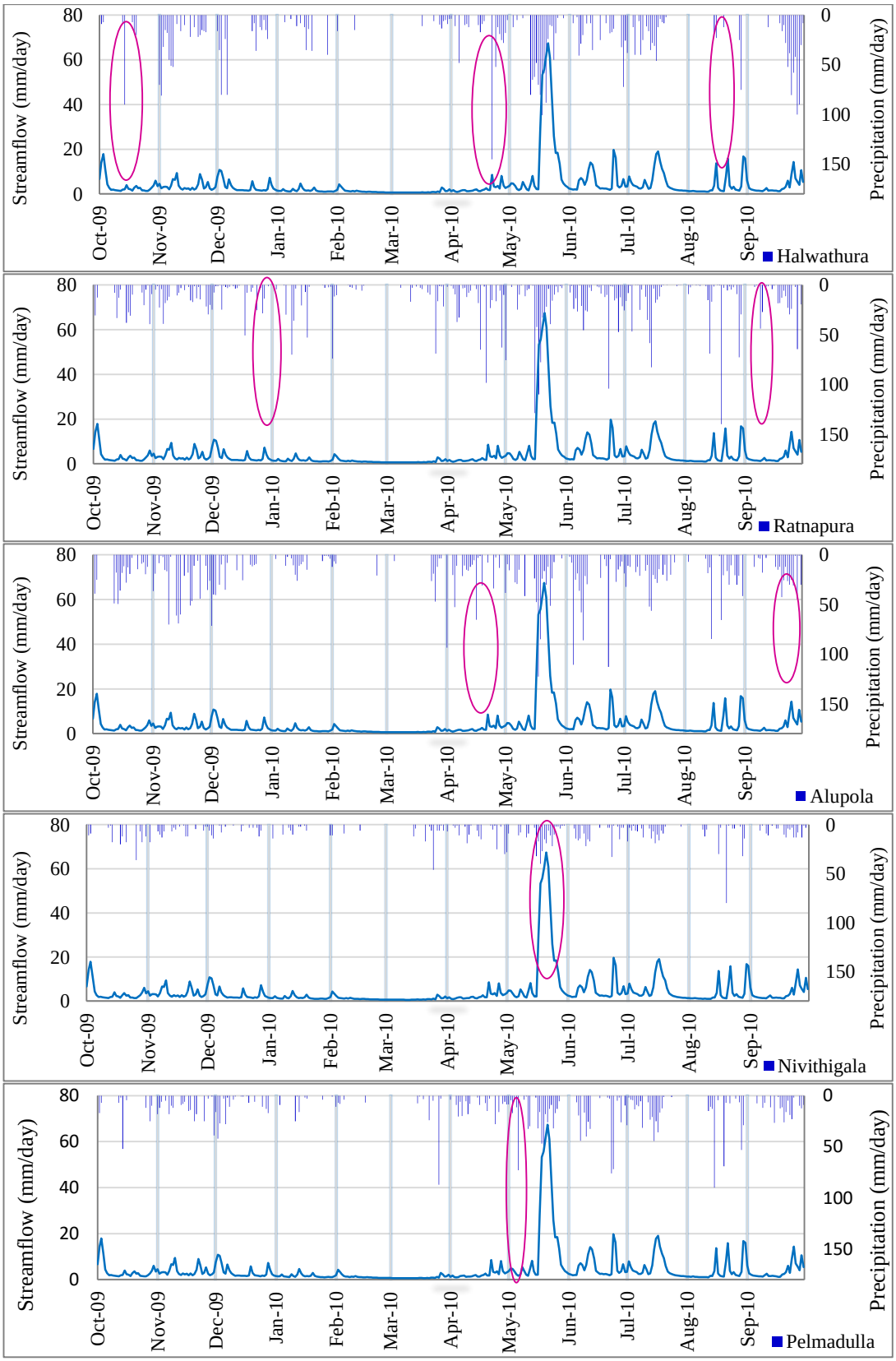

Figure B -13: Rainfall response with Ellagawa streamflow in 2009/2010 - Normal scale

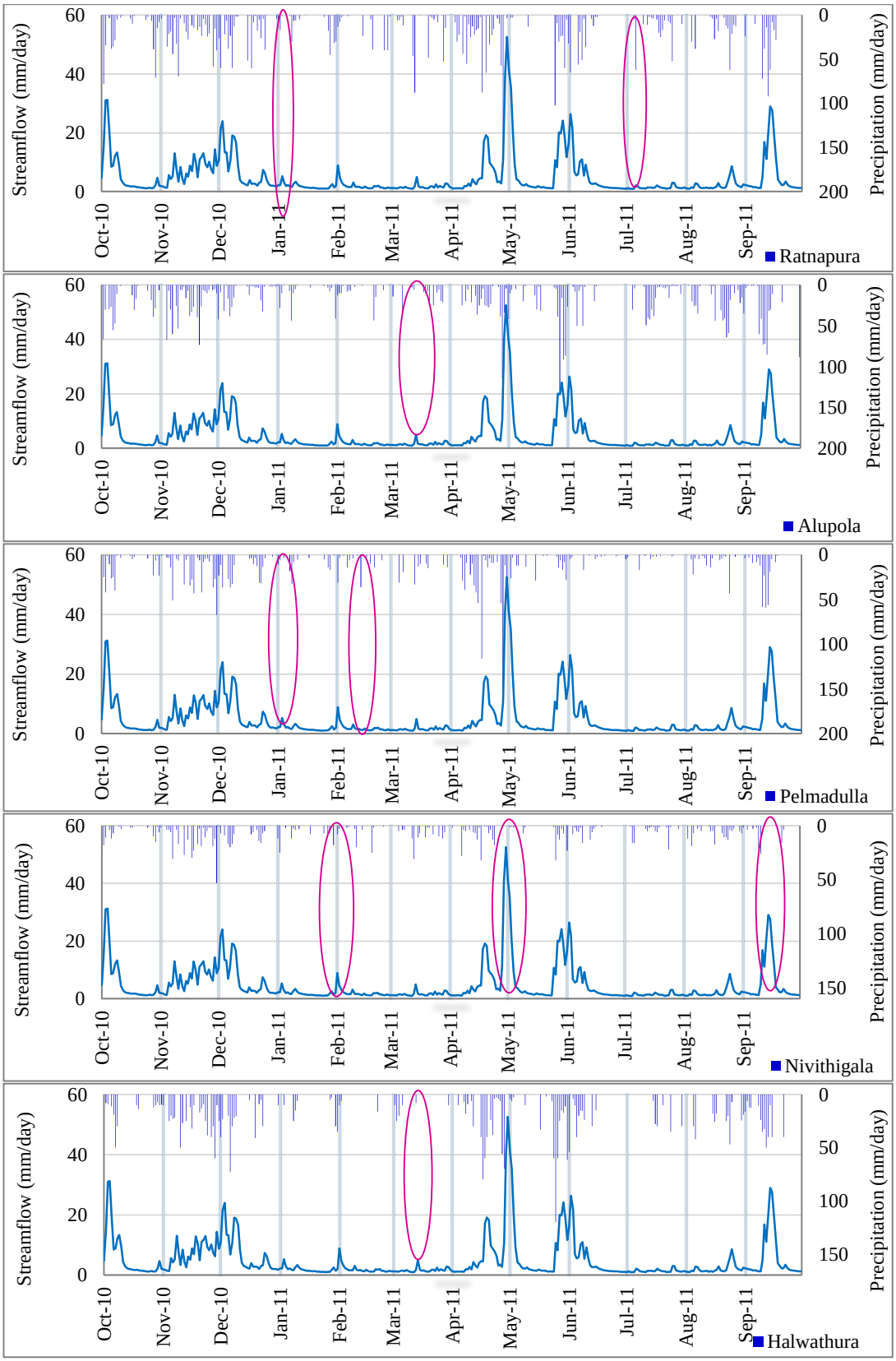

Figure B -14: Rainfall response with Ellagawa streamflow in 2010/2011- Normal scale

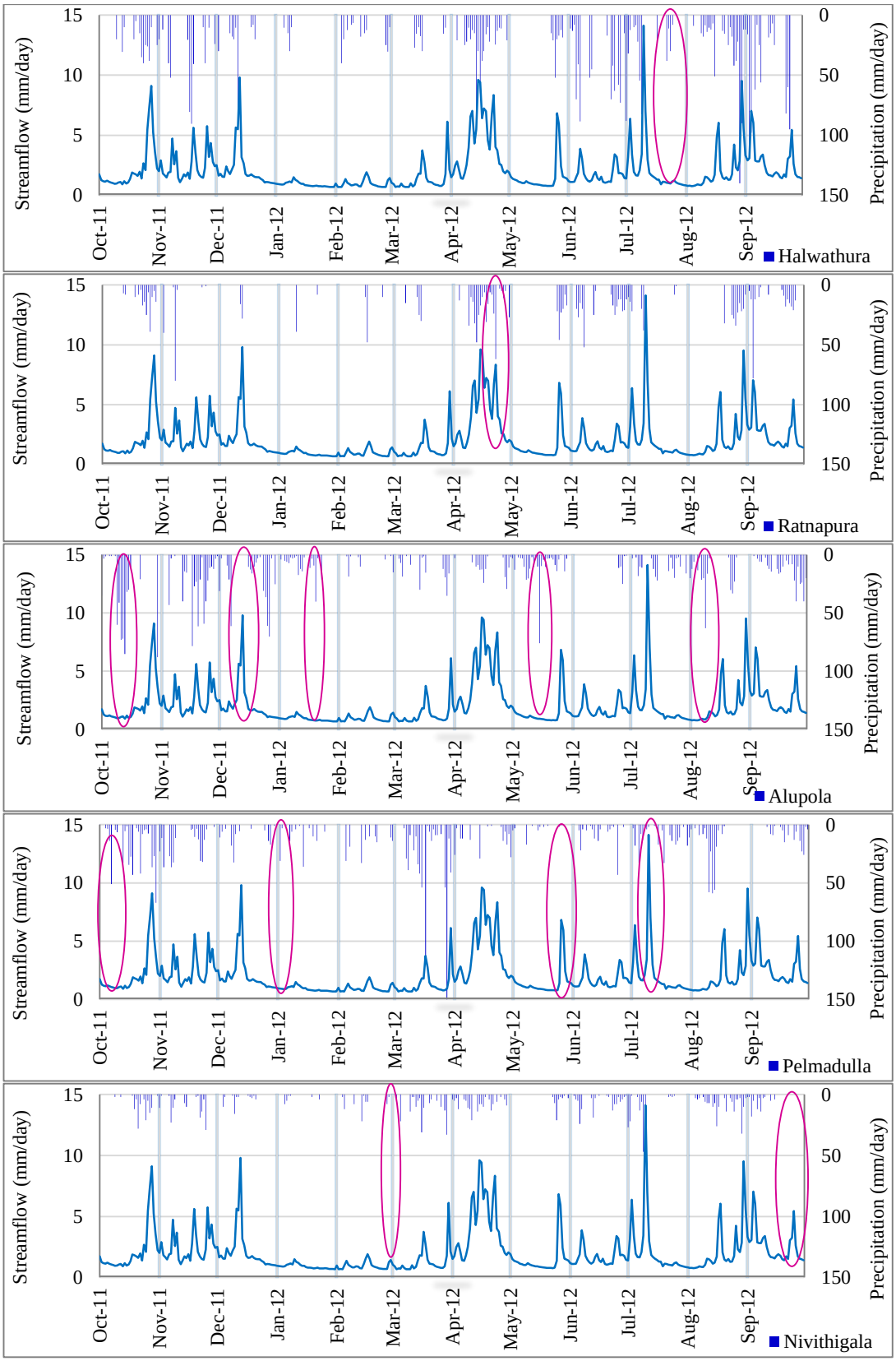

Figure B -15: Rainfall response with Ellagawa stream flow in 2011/2012 - Normal scale

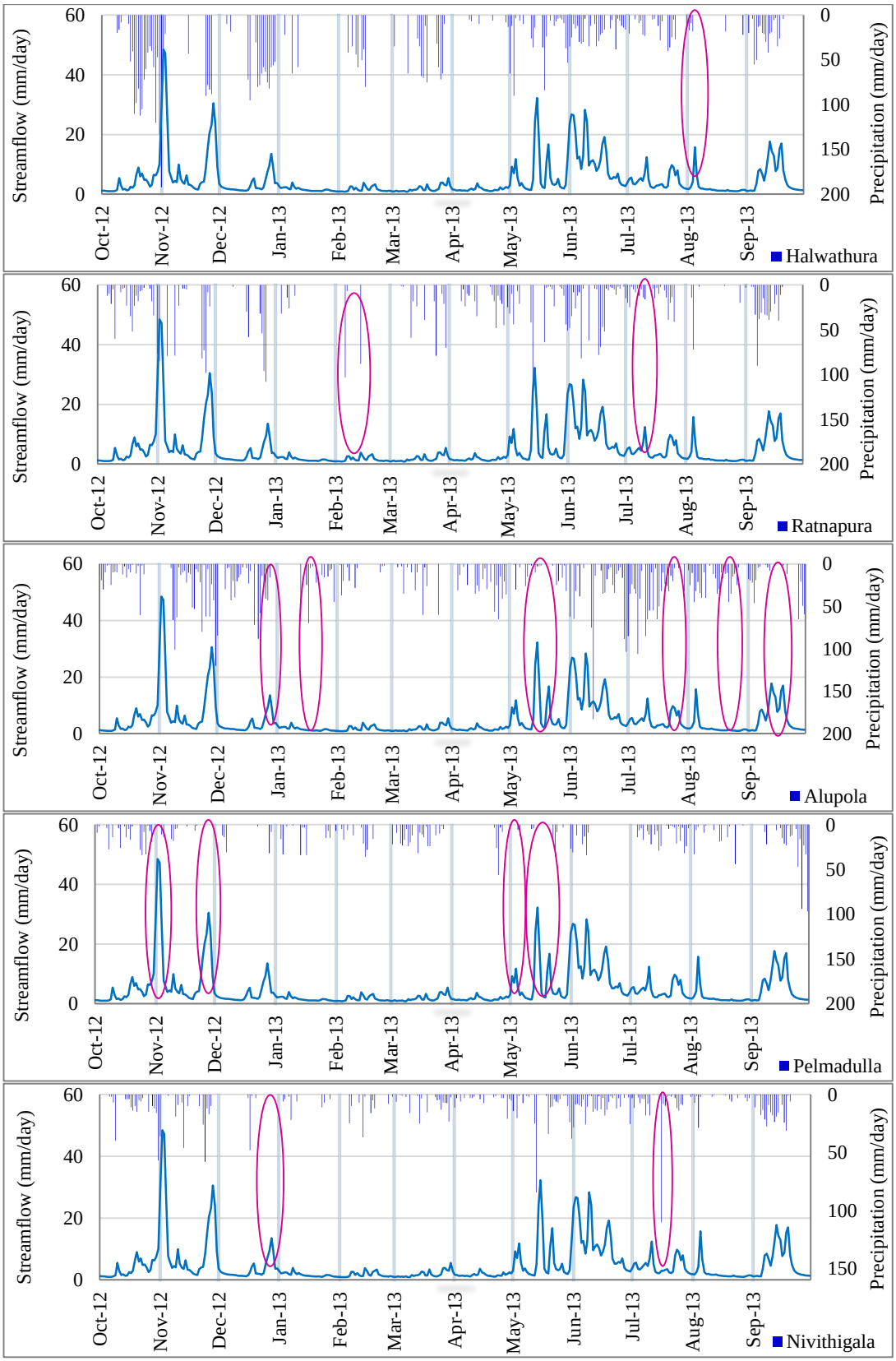

Figure B -16: Rainfall response with Ellagawa stream flow in 2012/2013- Log scale

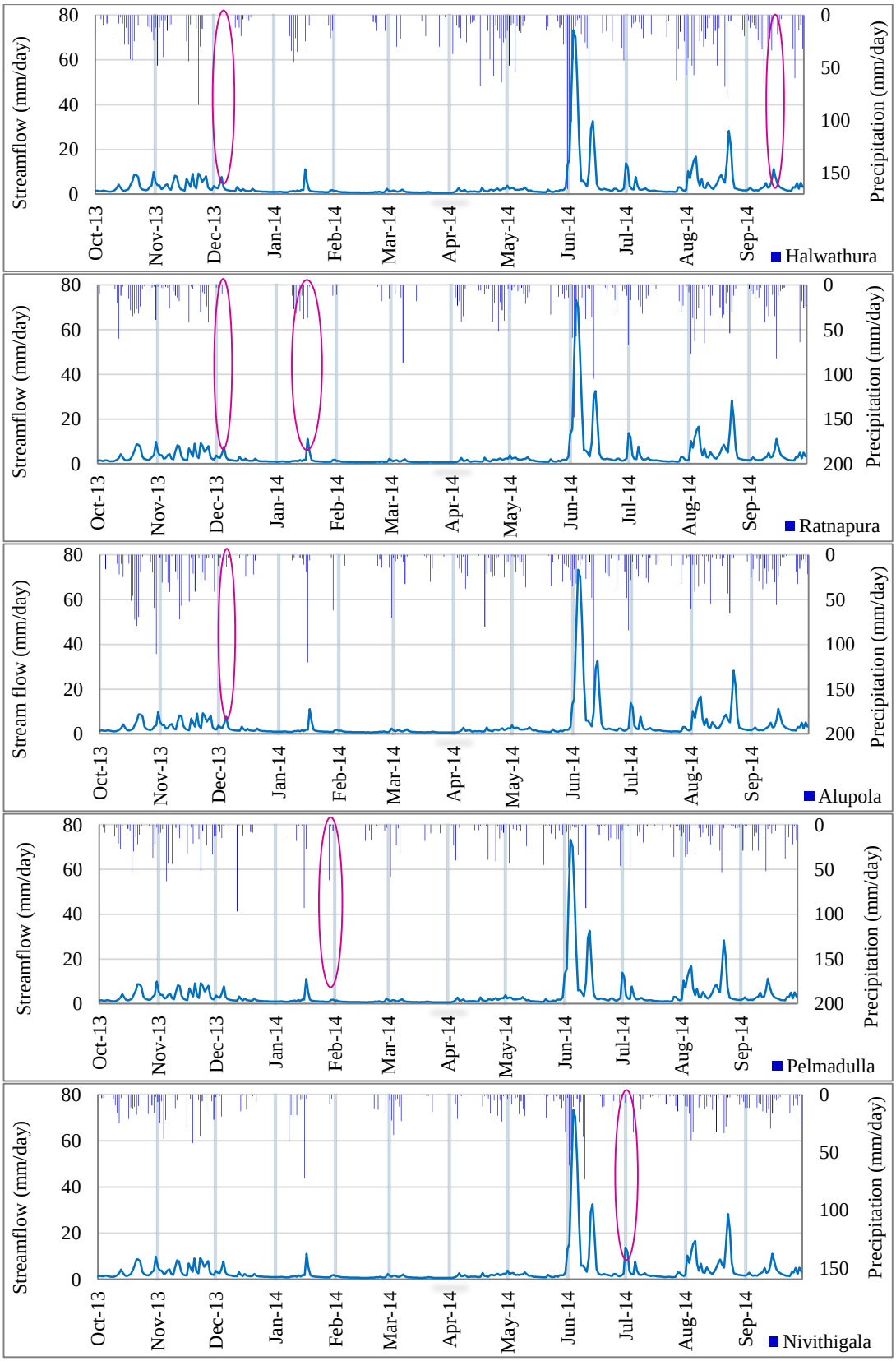

Figure B -17: Rainfall response with Ellagawa stream flow in 2013/2014 - Normal scale

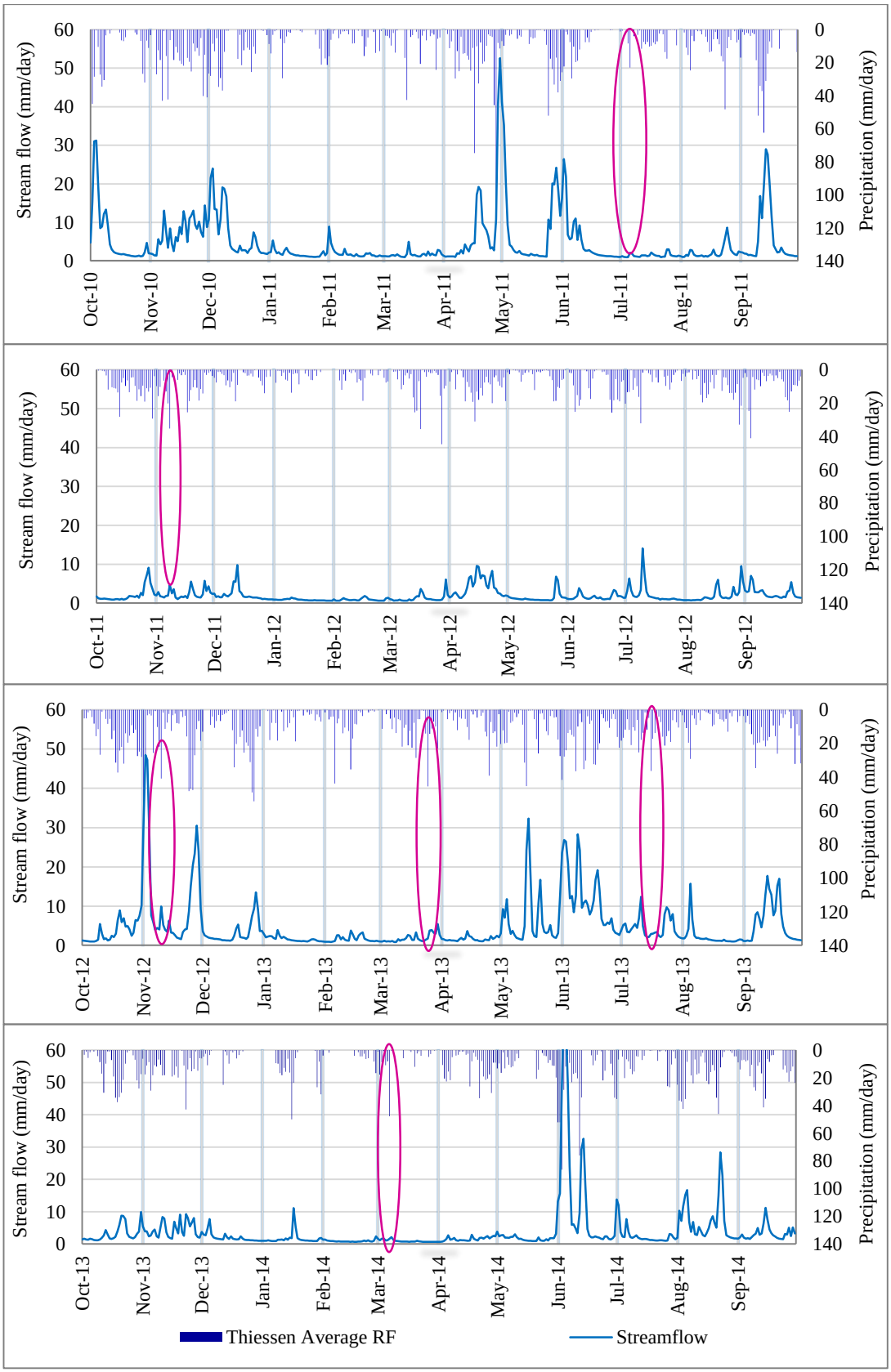

Figure B -18: Theissen Average Rainfall response with Ellagawa stream flow in 2010-2014- Normal scale

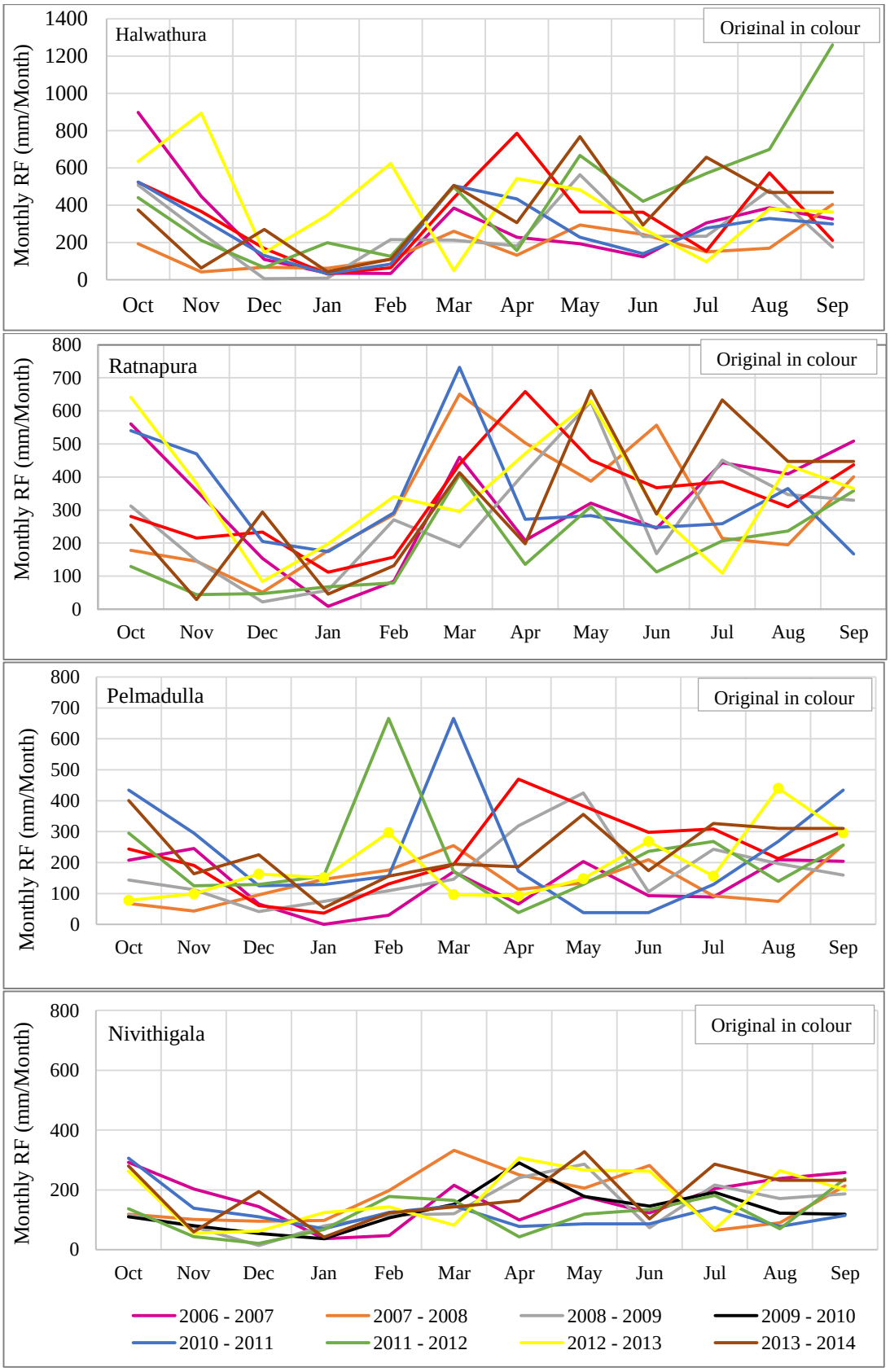

Figure B -19: Monthly Rainfall Comparison – Ellagawa Watershed

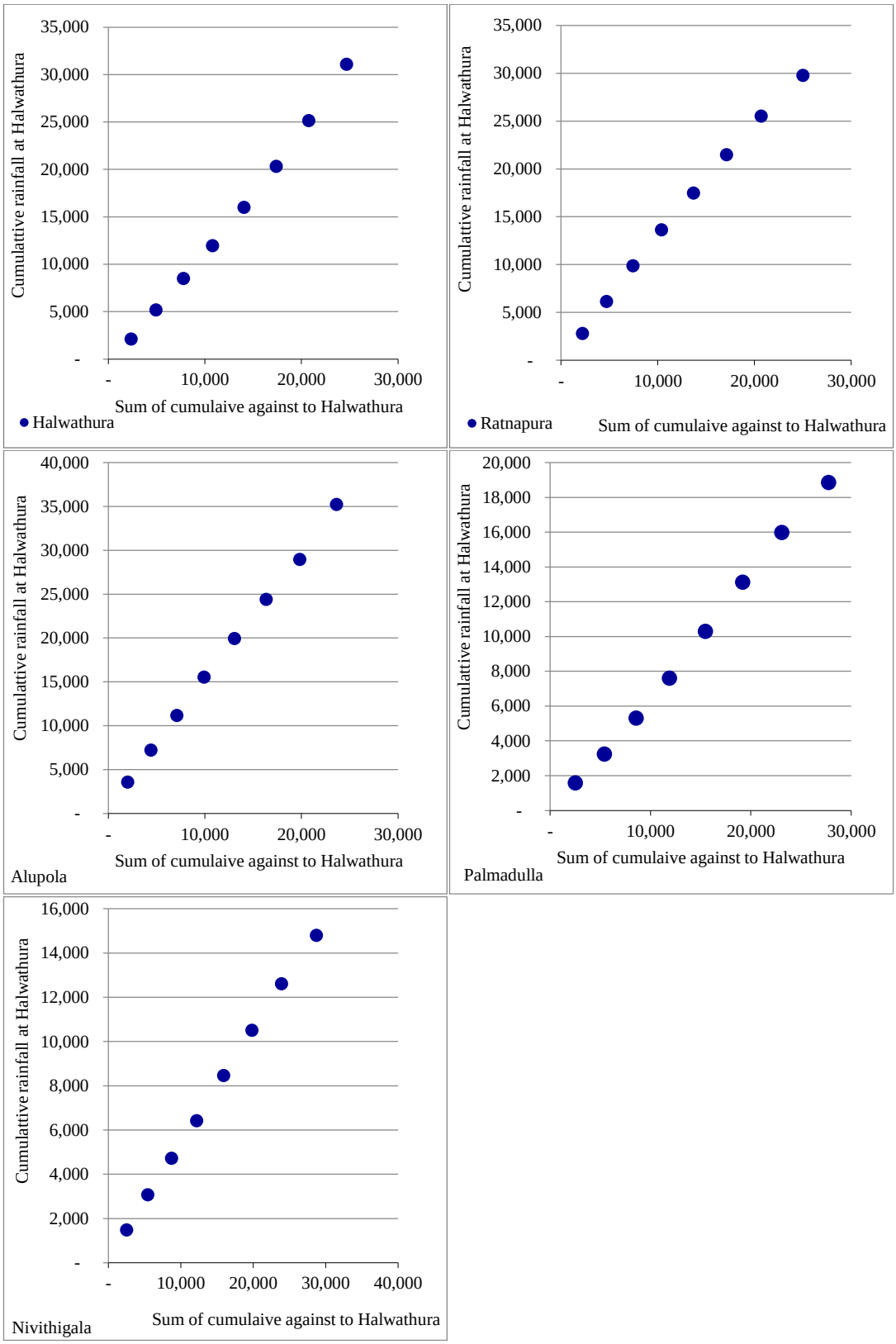

Figure B -20: Double Mass Curve for Rainfall Data – Ellagawa basin

Table B -1: Cumulative Average Rainfall for Double Mass Curve – Ellagawa Watershed

Water Year	For Halwathura	For Ratnapura	For Alupola	For Pelmadulla	For Nivithigala
2006 / 2007	2,958	2,883	2,712	3,427	3,314
2007 /2008	5,925	5,444	5,107	6,509	6,299
2008 / 2009	8,601	8,051	7,649	9,433	9,317
2009/ 20010	11,854	11,301	10,774	12,987	13,183
2010 / 2011	15,039	14,310	13,695	16,277	16,823
2011 / 2012	17,732	17,796	16,962	19,785	20,588
2012 / 2013	21,455	21,665	20,326	24,144	24,995
2013 / 2014	24,662	24,994	23,630	27,719	28,737

Table B -2: Cumulative Average Rainfall for Double Mass Curve – Tawalama Watershed

Water Year	For Tawalama	For Neluwa	For Aningkanda	For Deniyaya
2000 - 2001	-	-	2,685	2,101
2001 - 2002	3,136	1,464	5,530	4,478
2002 - 2003	7,082	4,684	8,402	7,098
2003 - 2004	11,171	7,938	11,305	9,968
2004 - 2005	15,510	11,669	14,221	12,998
2005 - 2006	19,877	15,404	17,259	16,151
2006 - 2007	24,269	19,290	20,365	19,341
2007 - 2008	28,685	23,192	23,597	22,604
2008 - 2009	33,143	27,202	26,875	26,142
2009 - 2010	37,711	31,300	30,305	29,825
2010 - 2011	42,389	35,406	33,736	33,754
2011 - 2012	47,114	39,685	37,240	37,721
2012 - 2013	51,916	44,032	40,752	41,780
2013 - 2014	56,932	48,422	44,811	45,958
2014 - 2015	62,084	53,972	49,124	50,311

ANNEX C - DATA CHECKING (TAWALAMA WATERSHED)

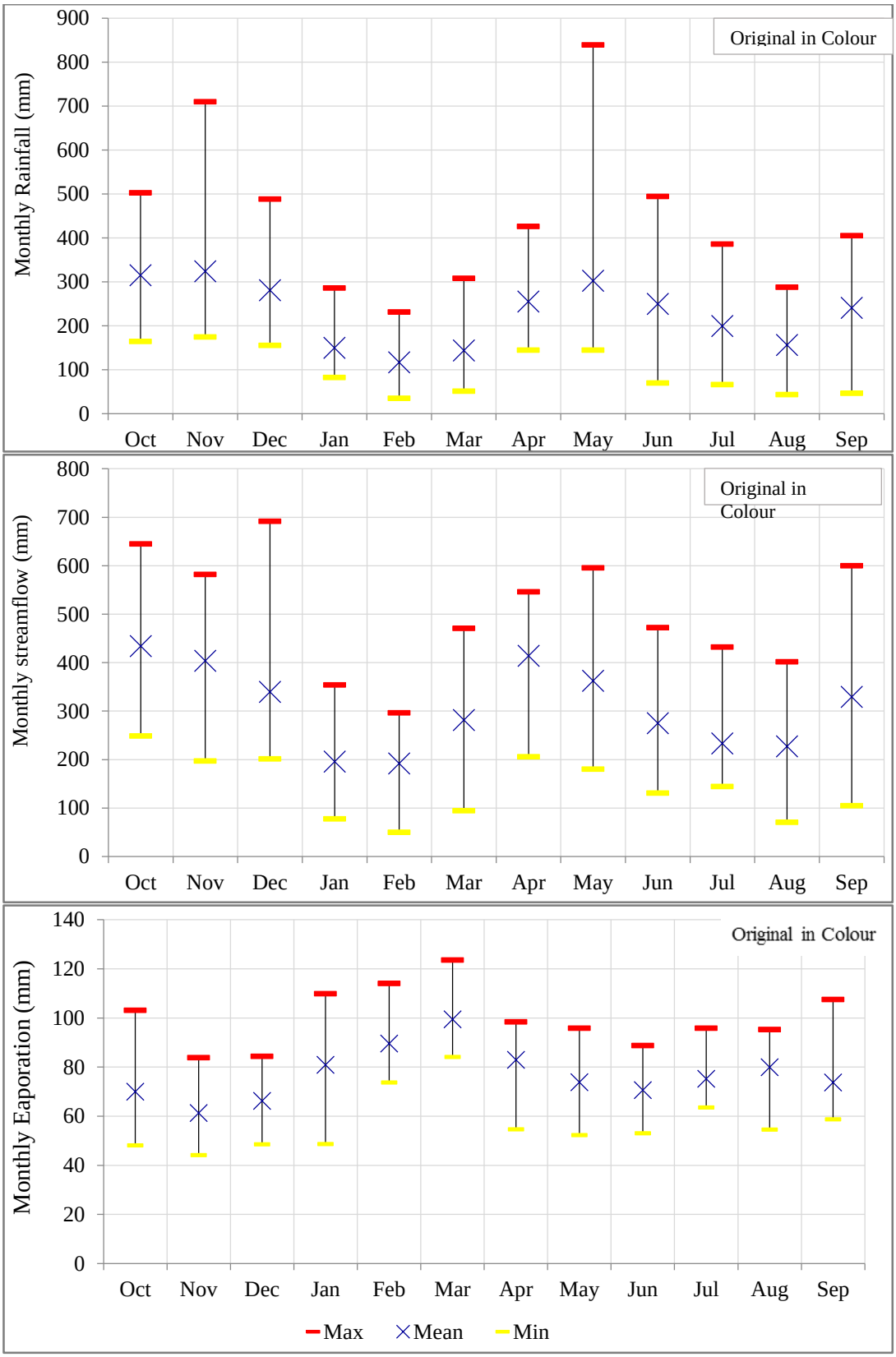

Figure C-1: Variation of high, medium and minimum flows – Tawalama Watershed

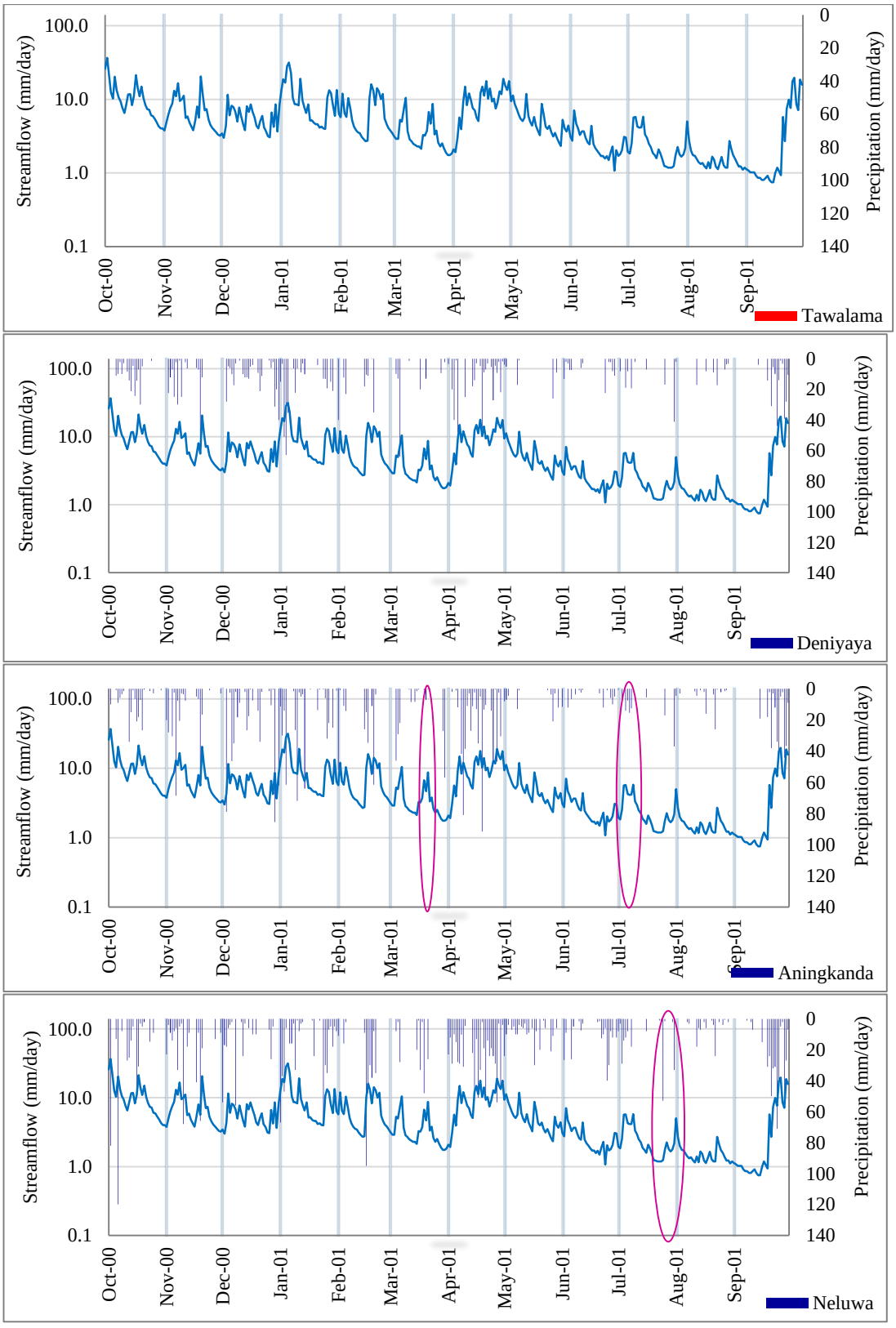

Figure C-2: Rainfall response to Tawalama Stream flow in year 2000/2001 –Log scale

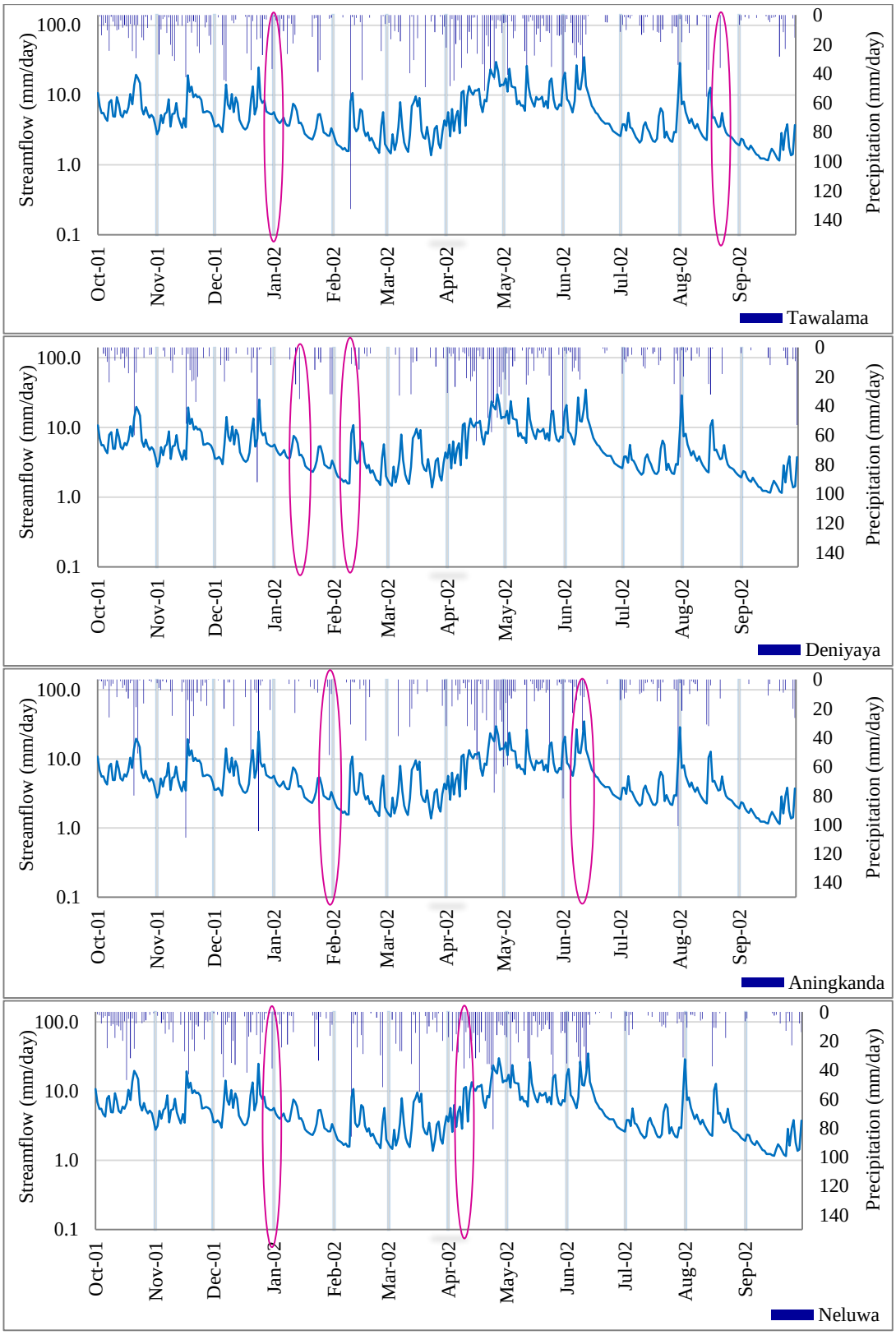

Figure C -3: Rainfall response to Tawalama Stream flow in year 2001/2002 – Log scale

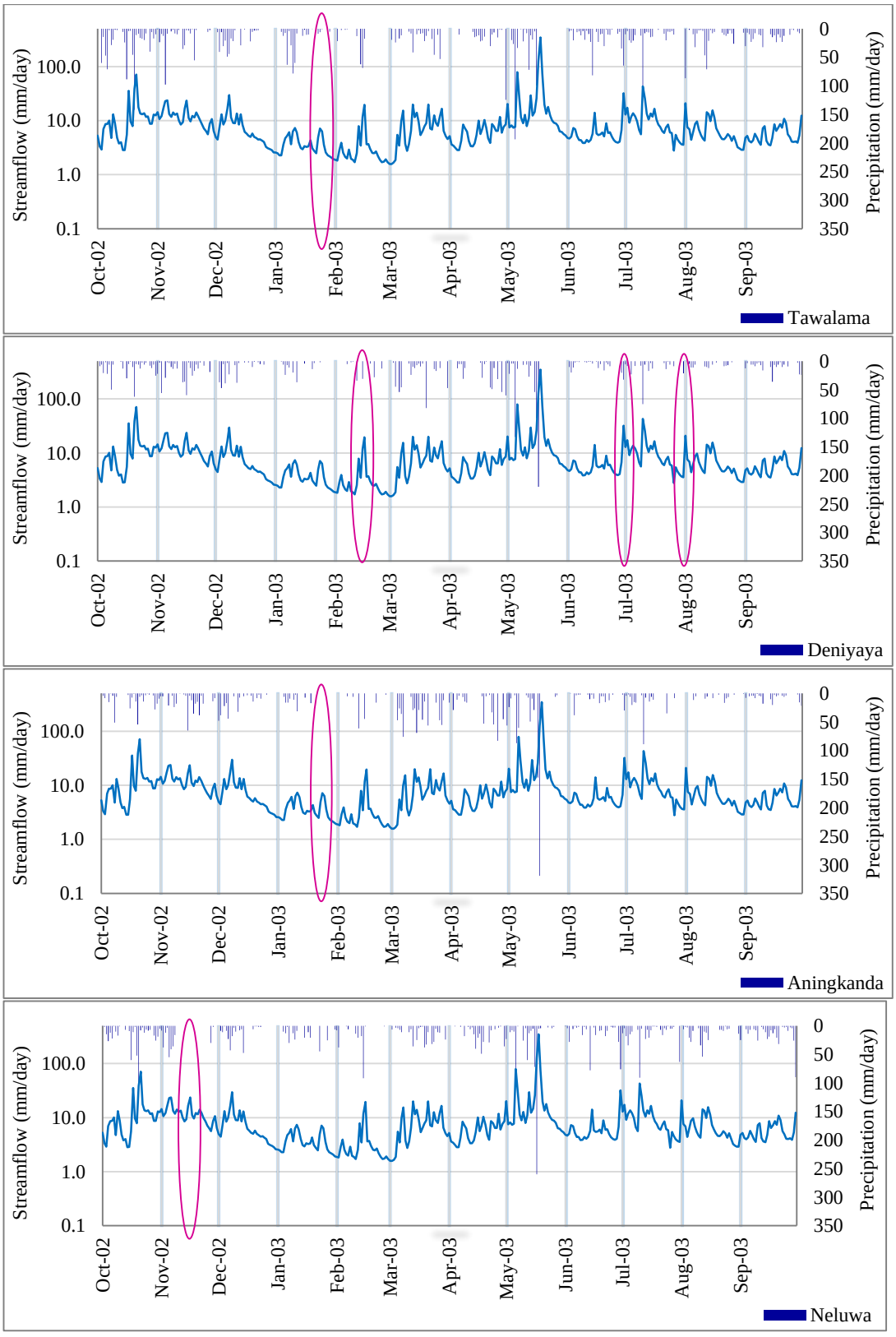

Figure C -4: Rainfall response to Tawalama Stream flow in year 2002/2003 – Log scale

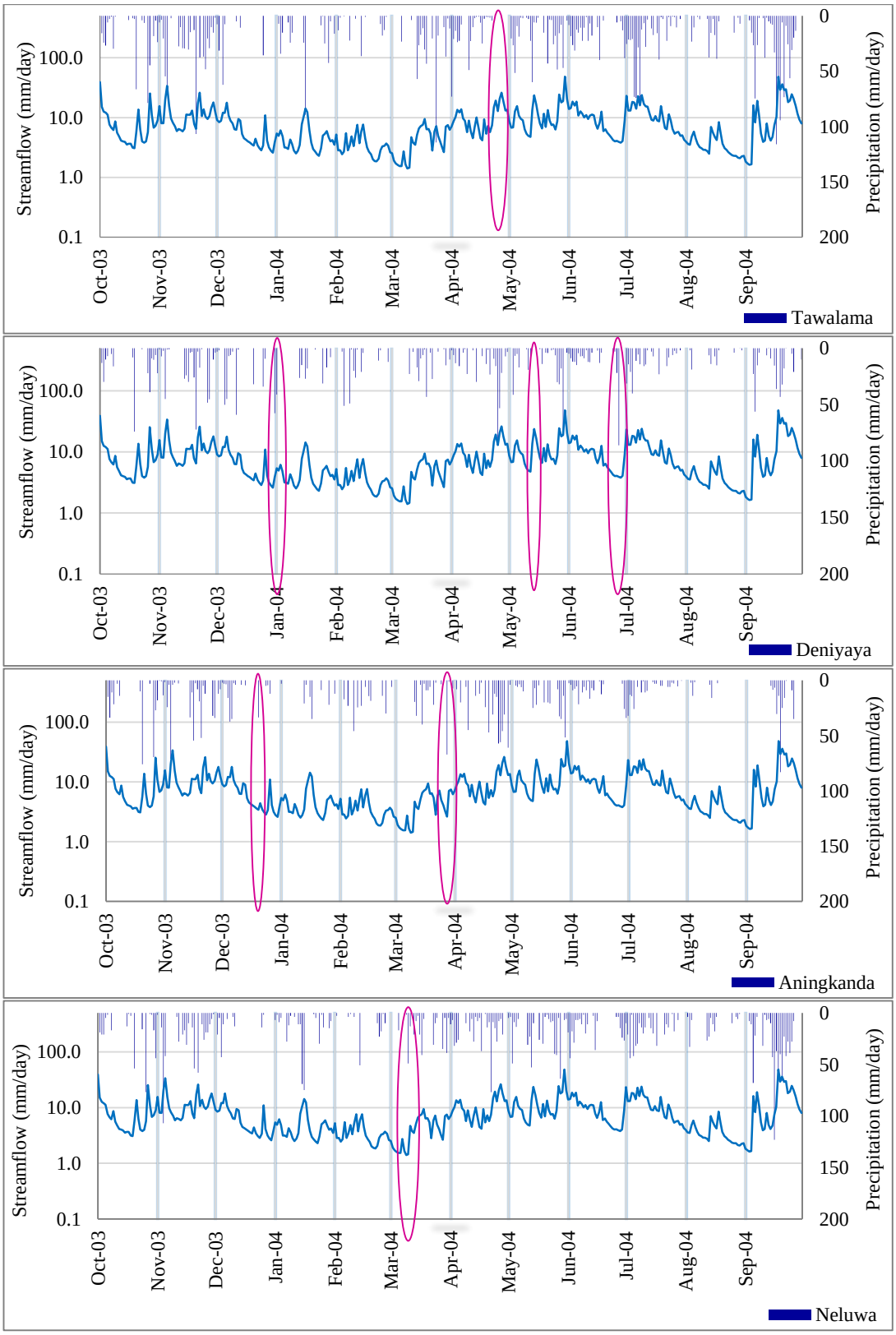

Figure C -5: Rainfall response to Tawalama Stream flow in year 2003/2004– Log scale

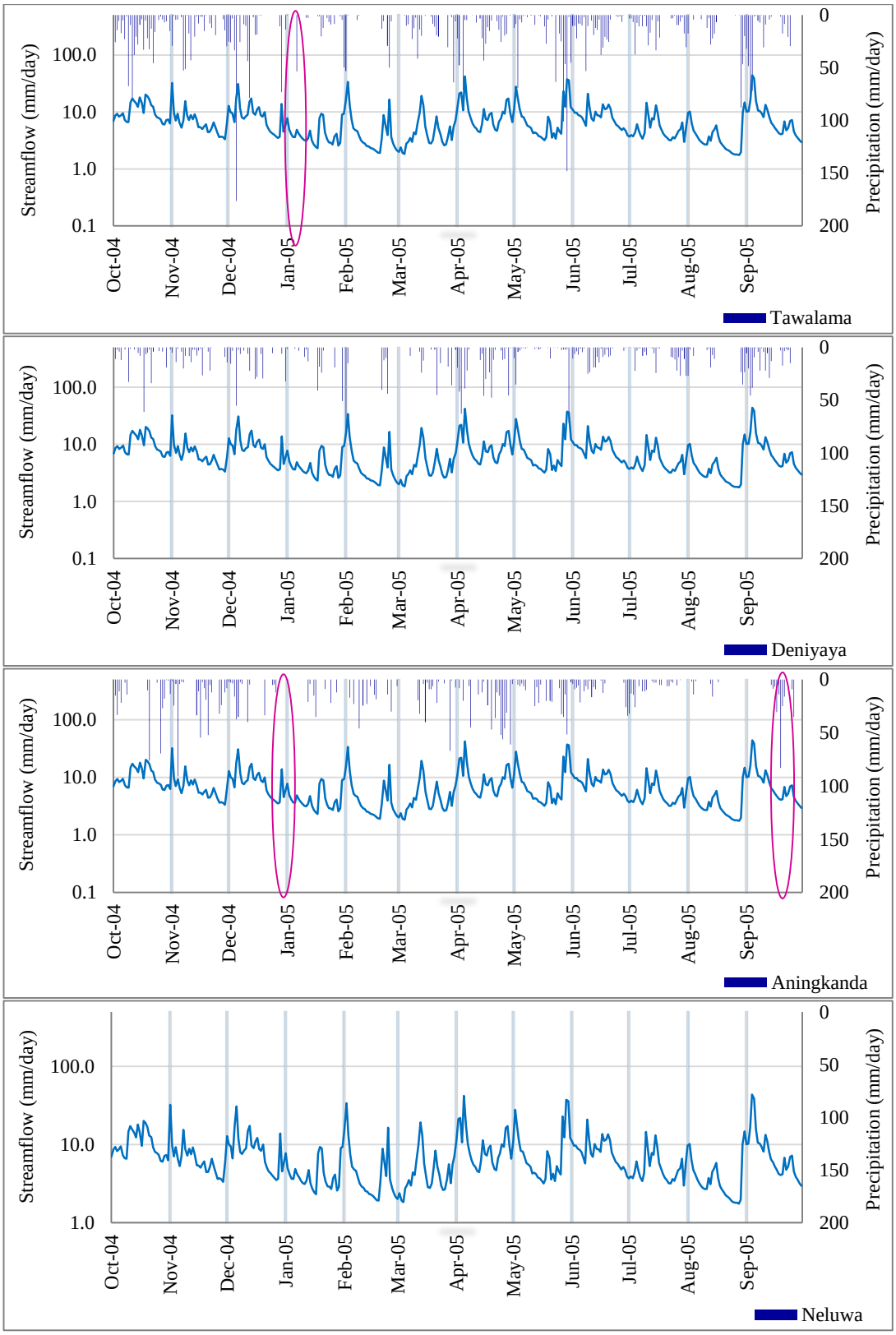

Figure C -6: Rainfall response to Tawalama Stream flow in year 2004/2005– Log scale

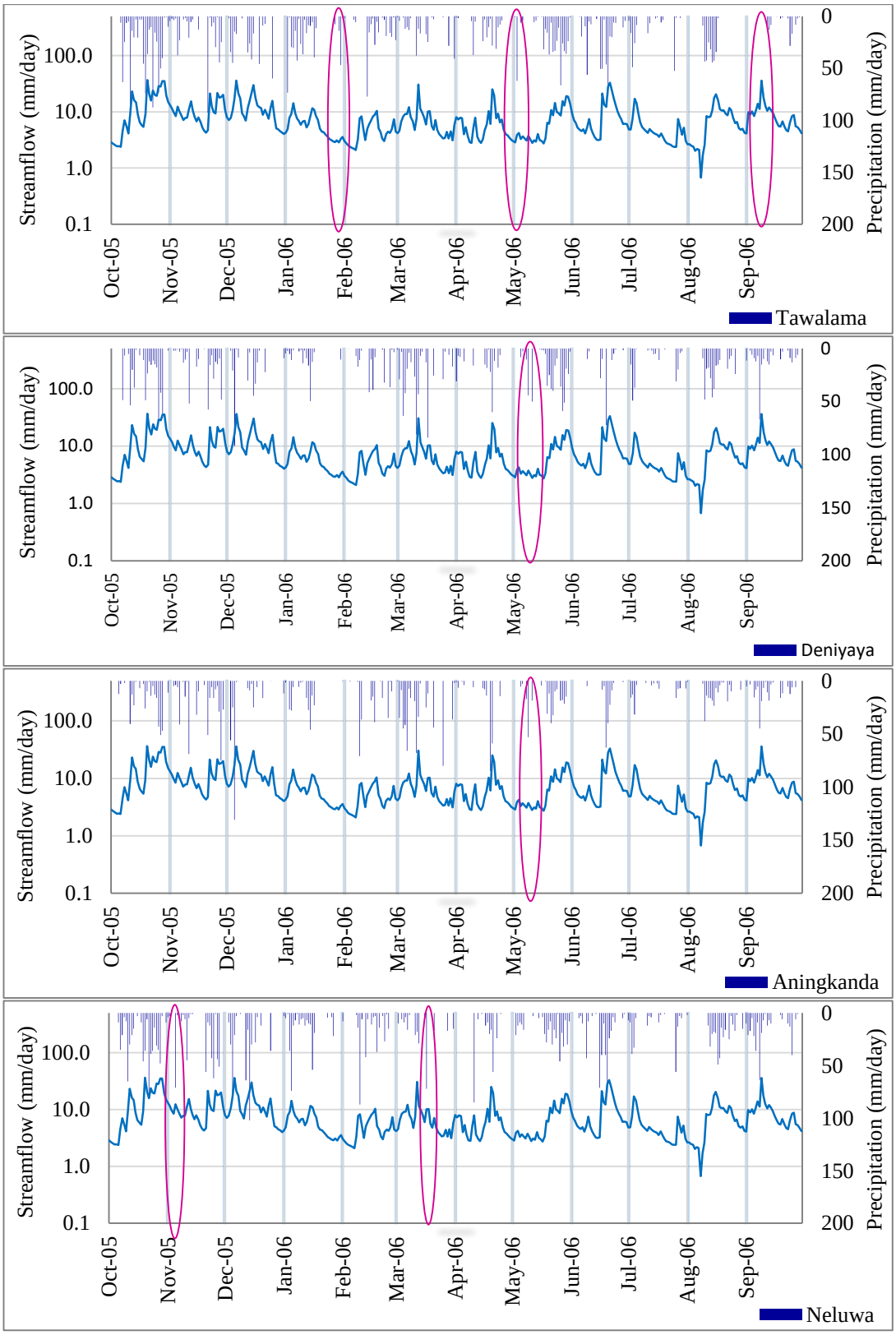

Figure C -7: Rainfall response to Tawalama Stream flow in year 2005/2006 – Log scale

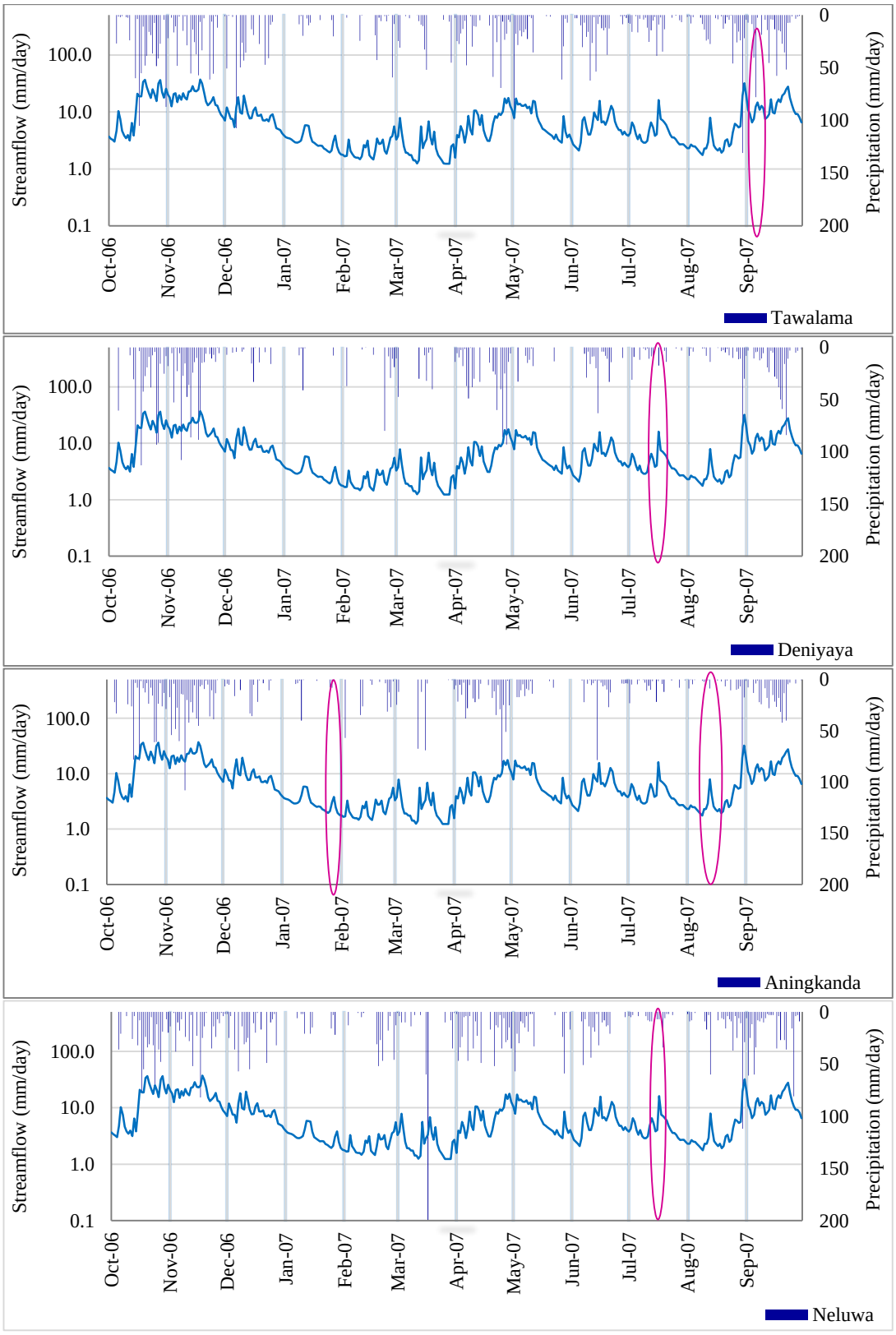

Figure C -8: Rainfall response to Tawalama Stream flow in year 2006/2007– Log scale

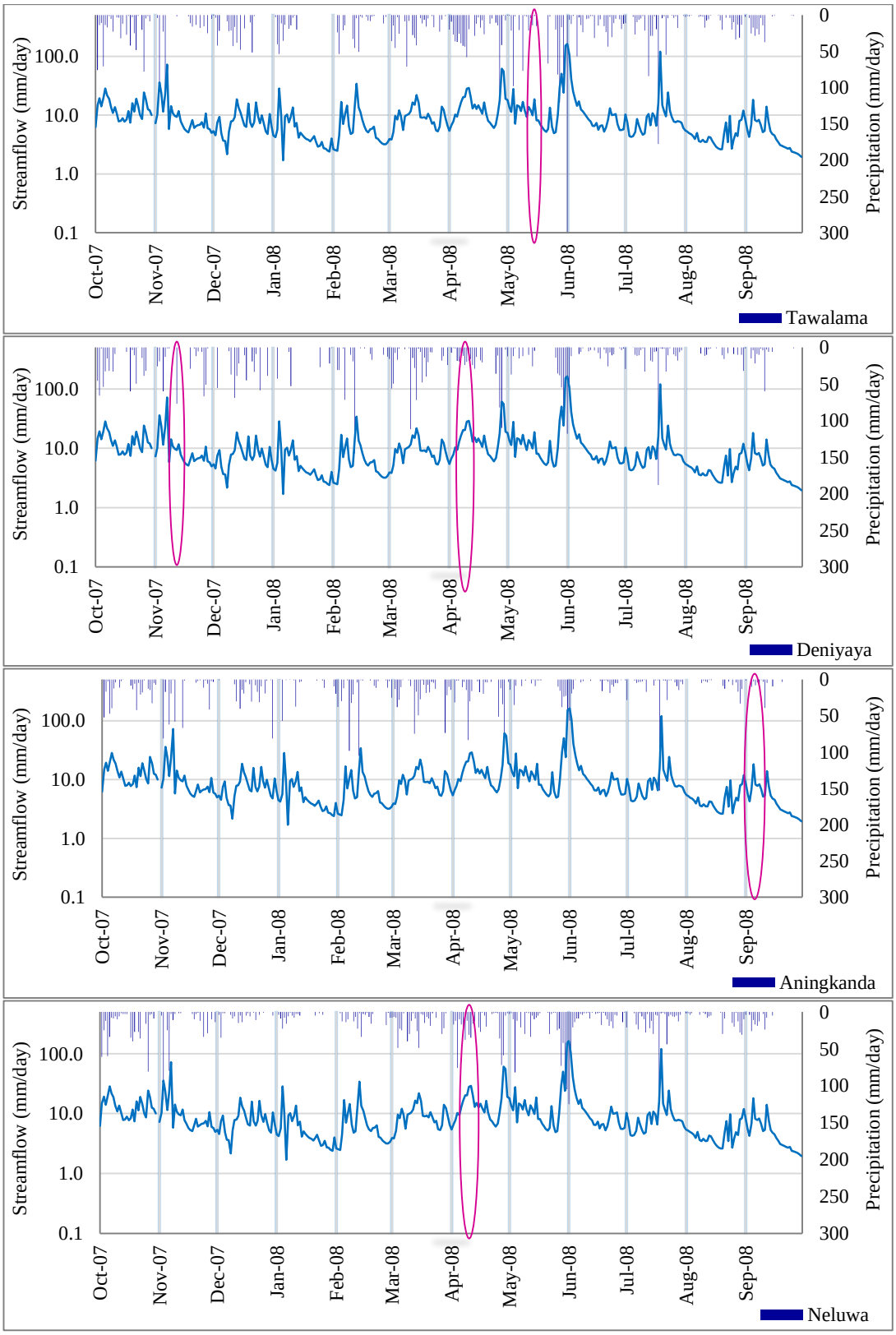

Figure C -9: Rainfall response to Tawalama Stream flow in year 2007/2008– Log scale

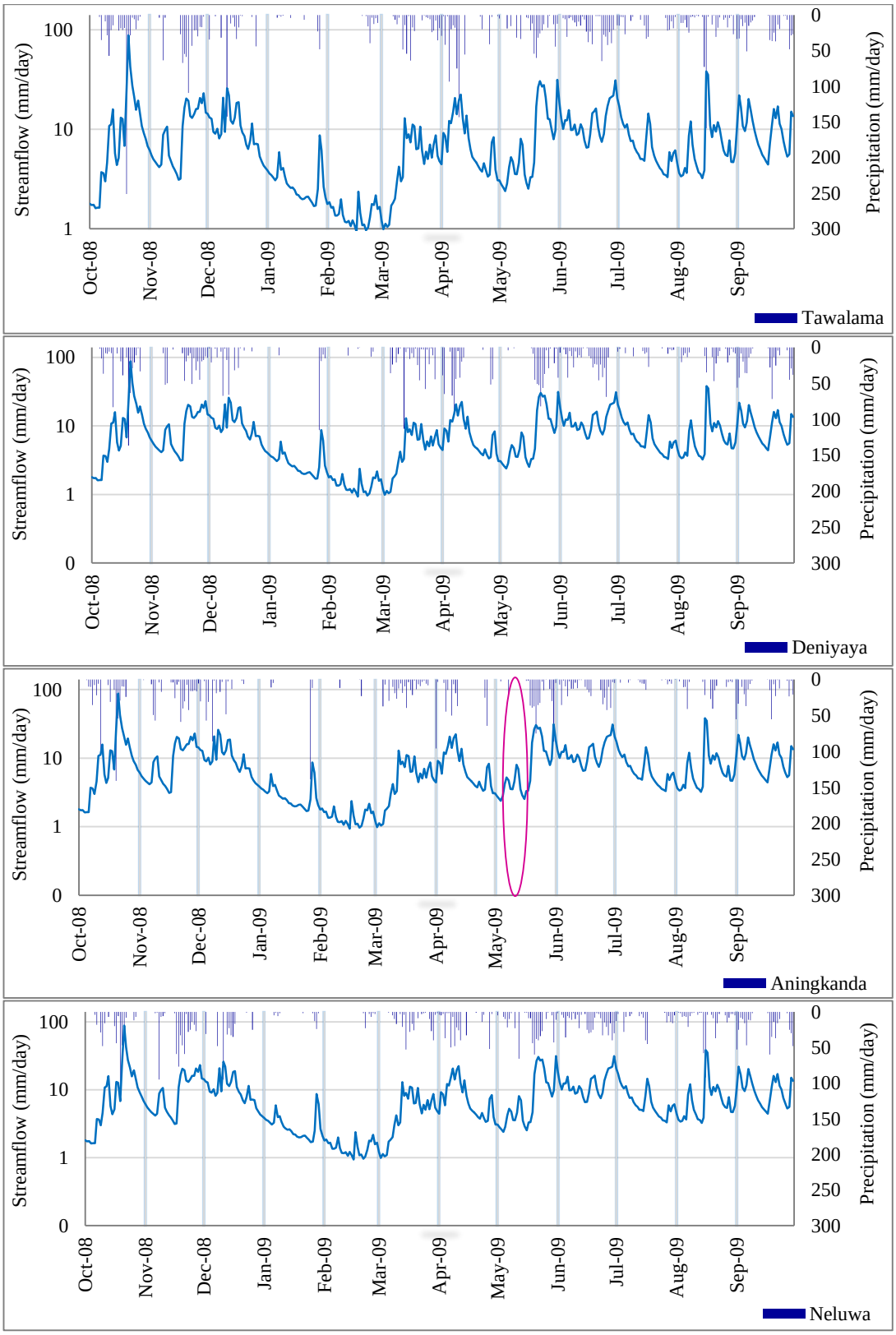

Figure C -10: Rainfall response to Tawalama Stream flow in year 2008/2009– Log scale

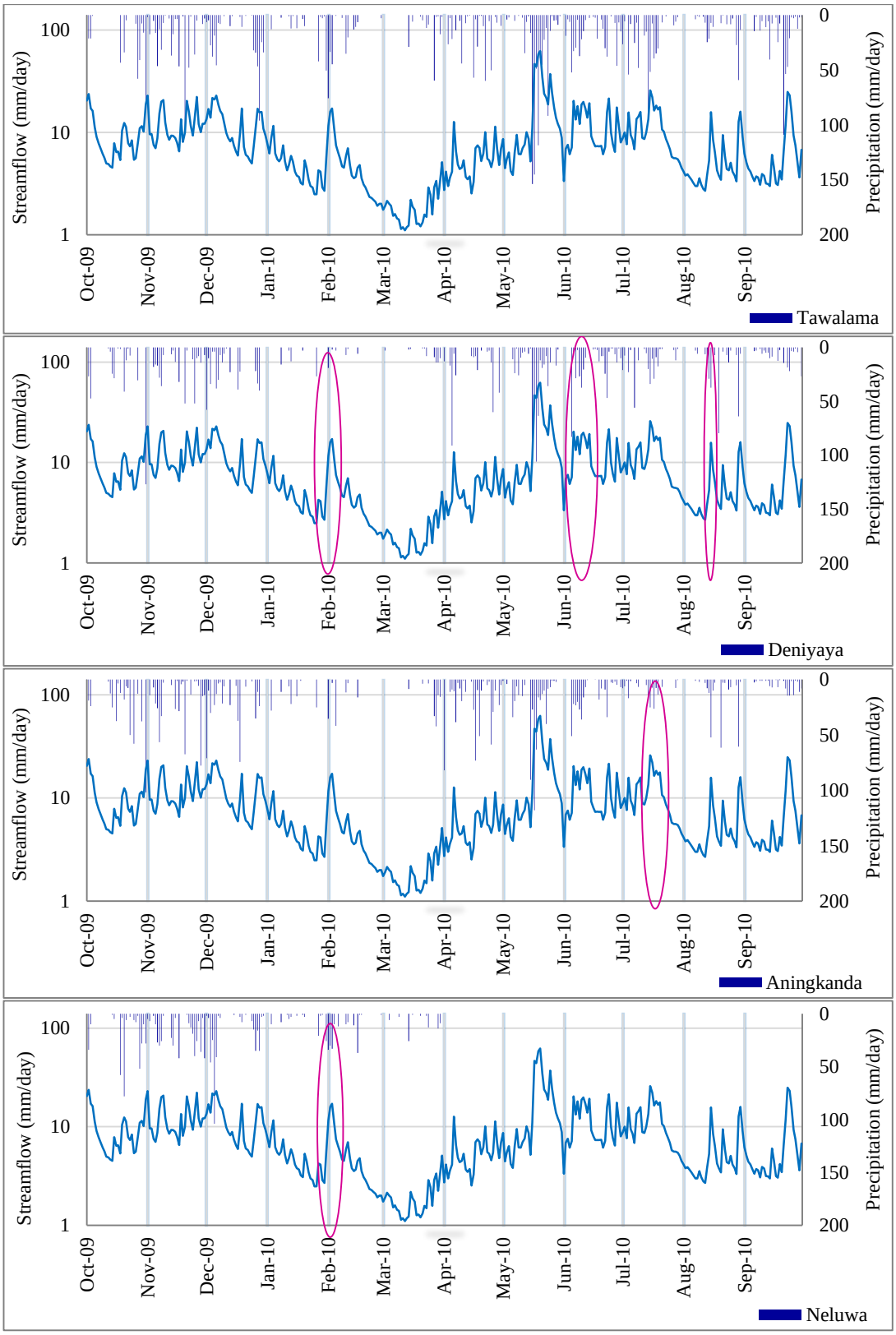

Figure C -11: Rainfall response to Tawalama Stream flow in year 2009/2010– Log scale

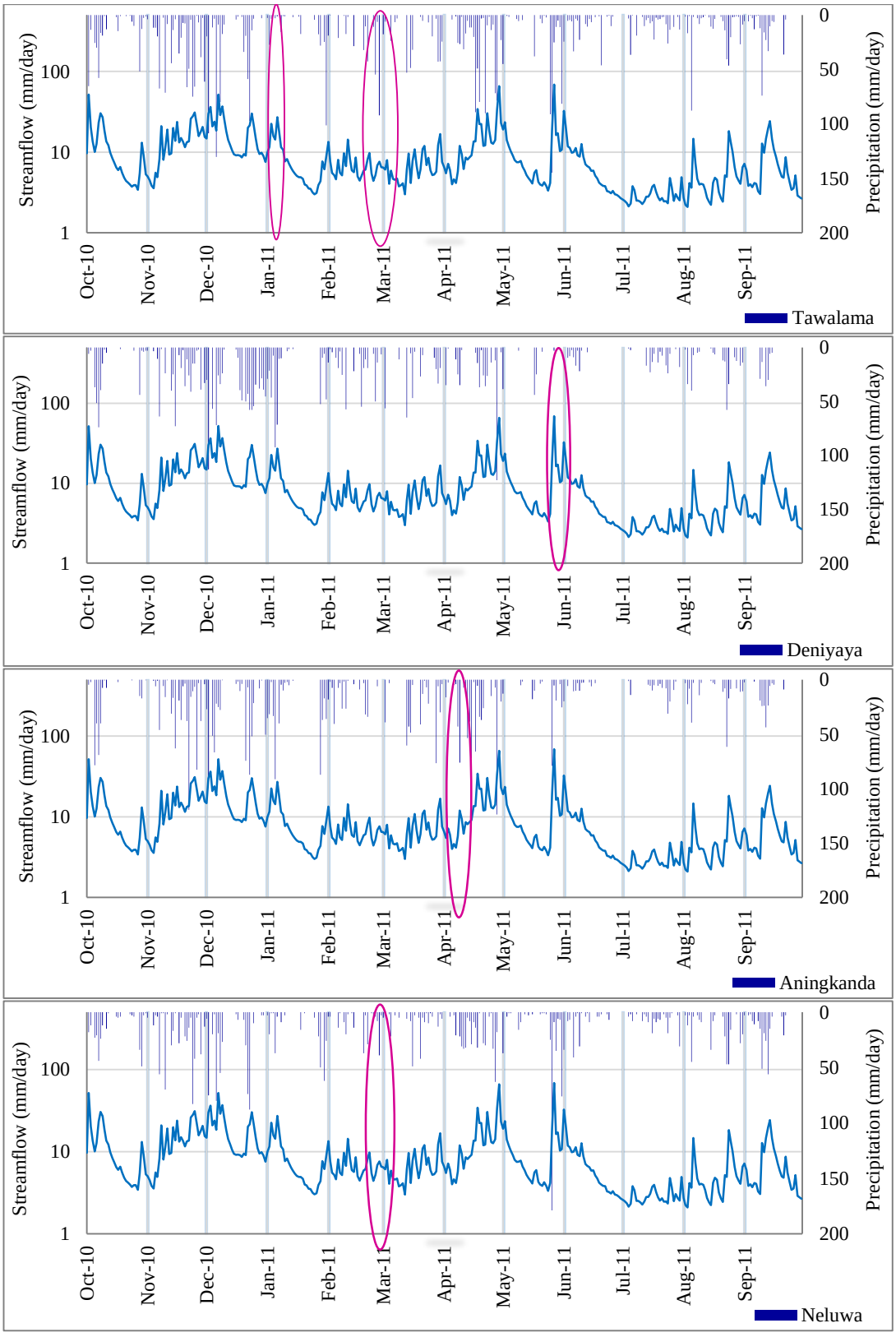

Figure C -12: Rainfall response to Tawalama Stream flow in year 2010/2011– Log scale

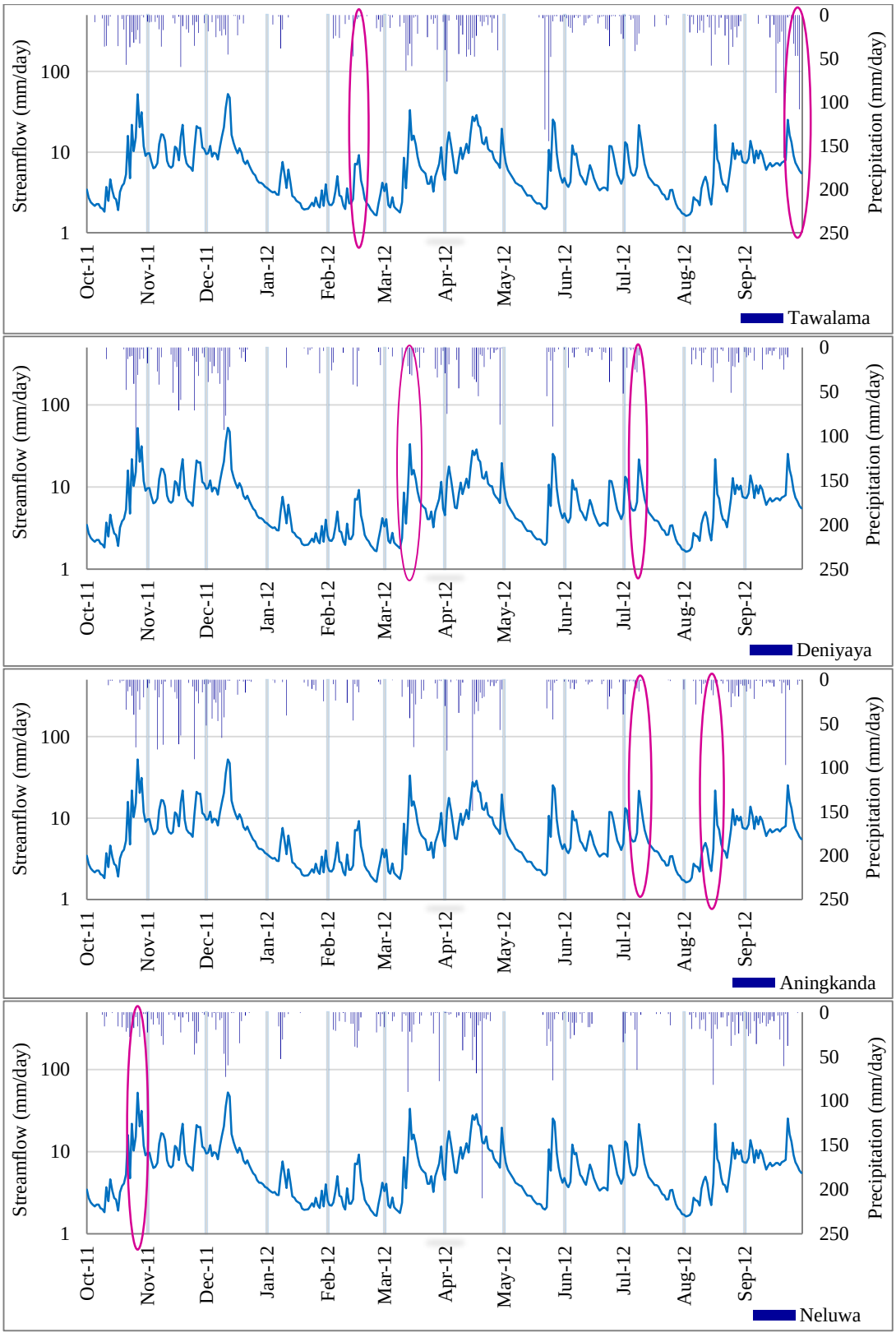

Figure C -13: Rainfall response to Tawalama Stream flow in year 2011/2012– Log scale

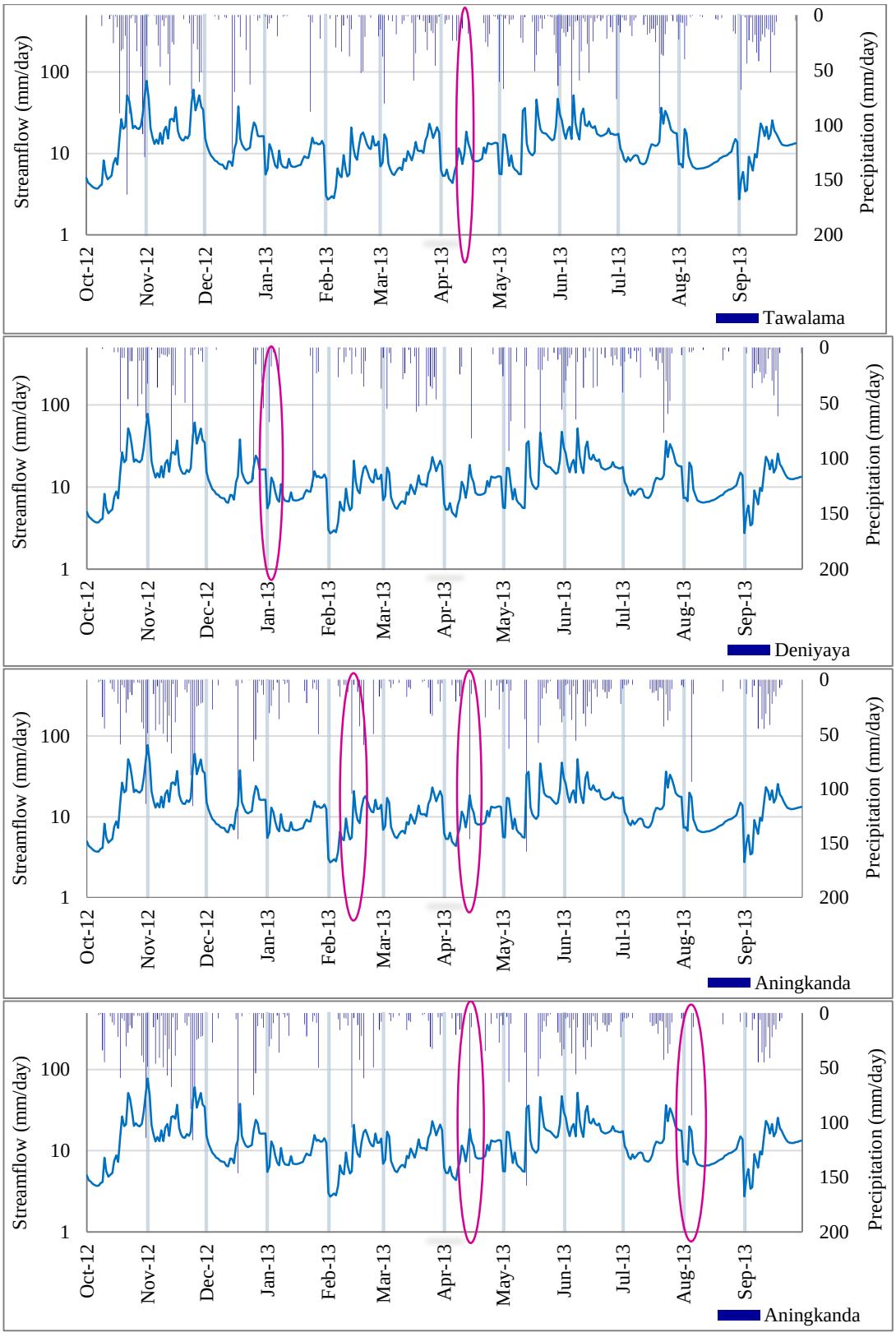

Figure C -14: Rainfall response to Tawalama Stream flow in year 2012/2013 – Log scale

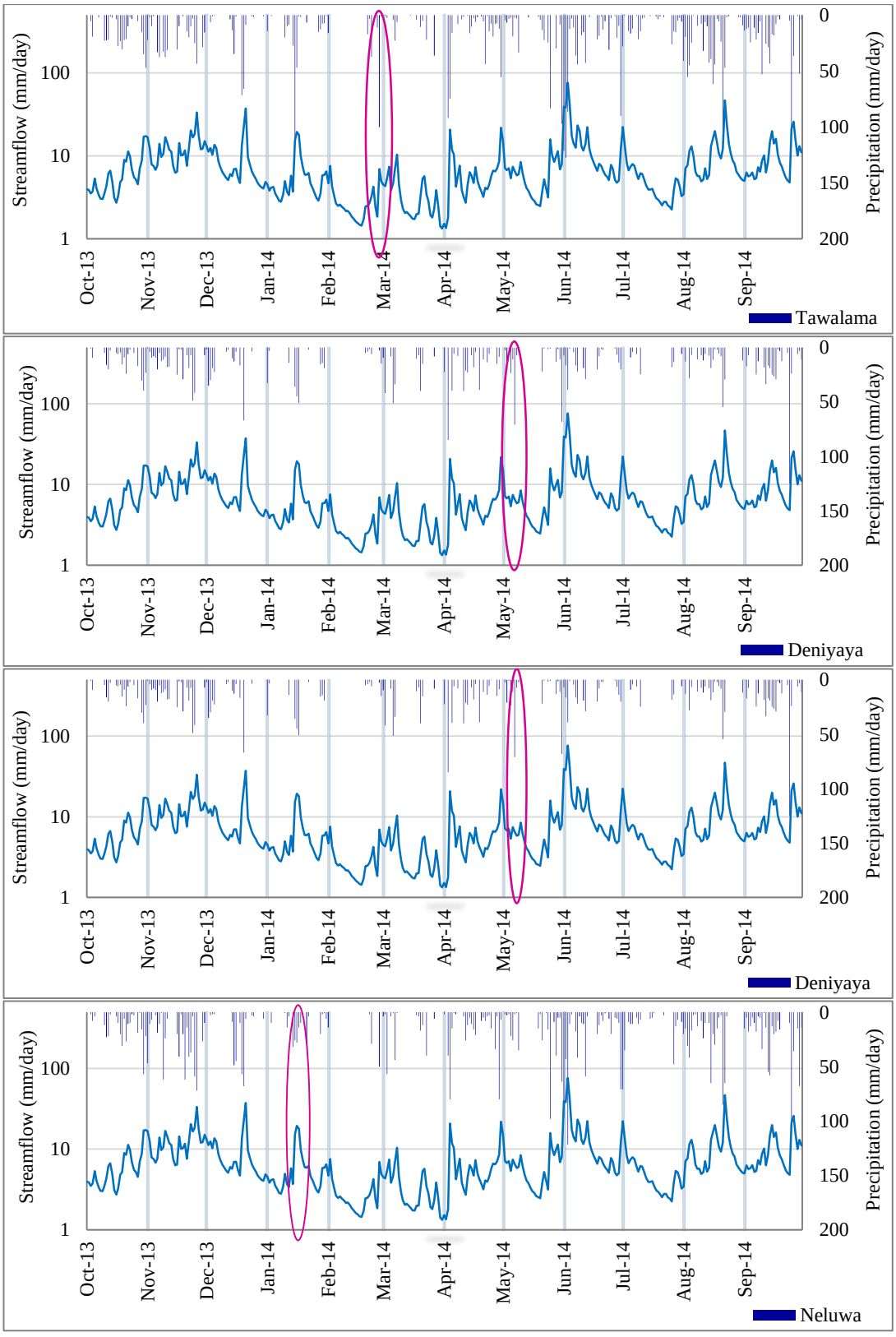

Figure C -15: Rainfall response to Tawalama Stream flow in year 2013/2014 – Log scale

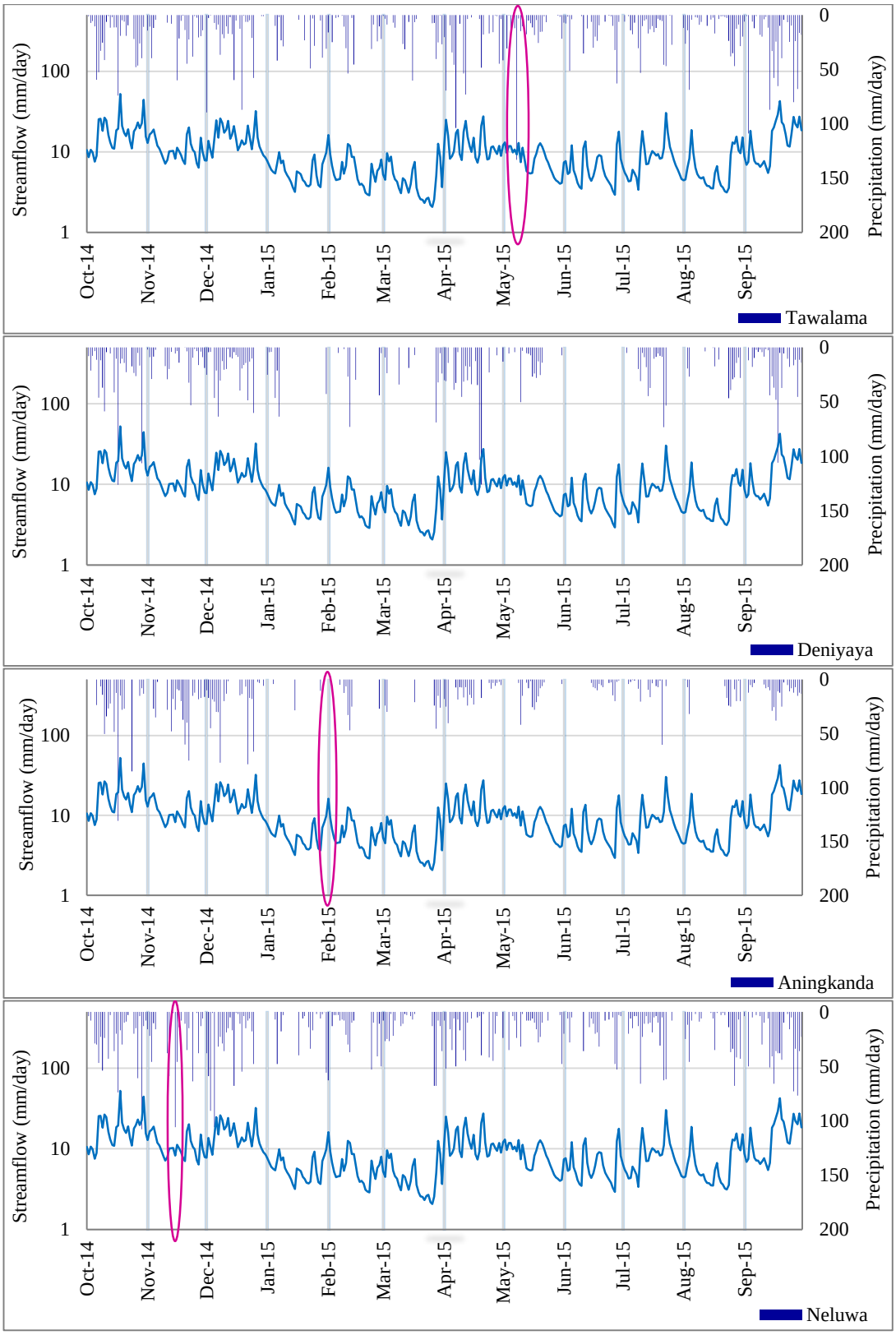

Figure C -16: Rainfall response to Tawalama Stream flow in year 2014/2015– Log scale

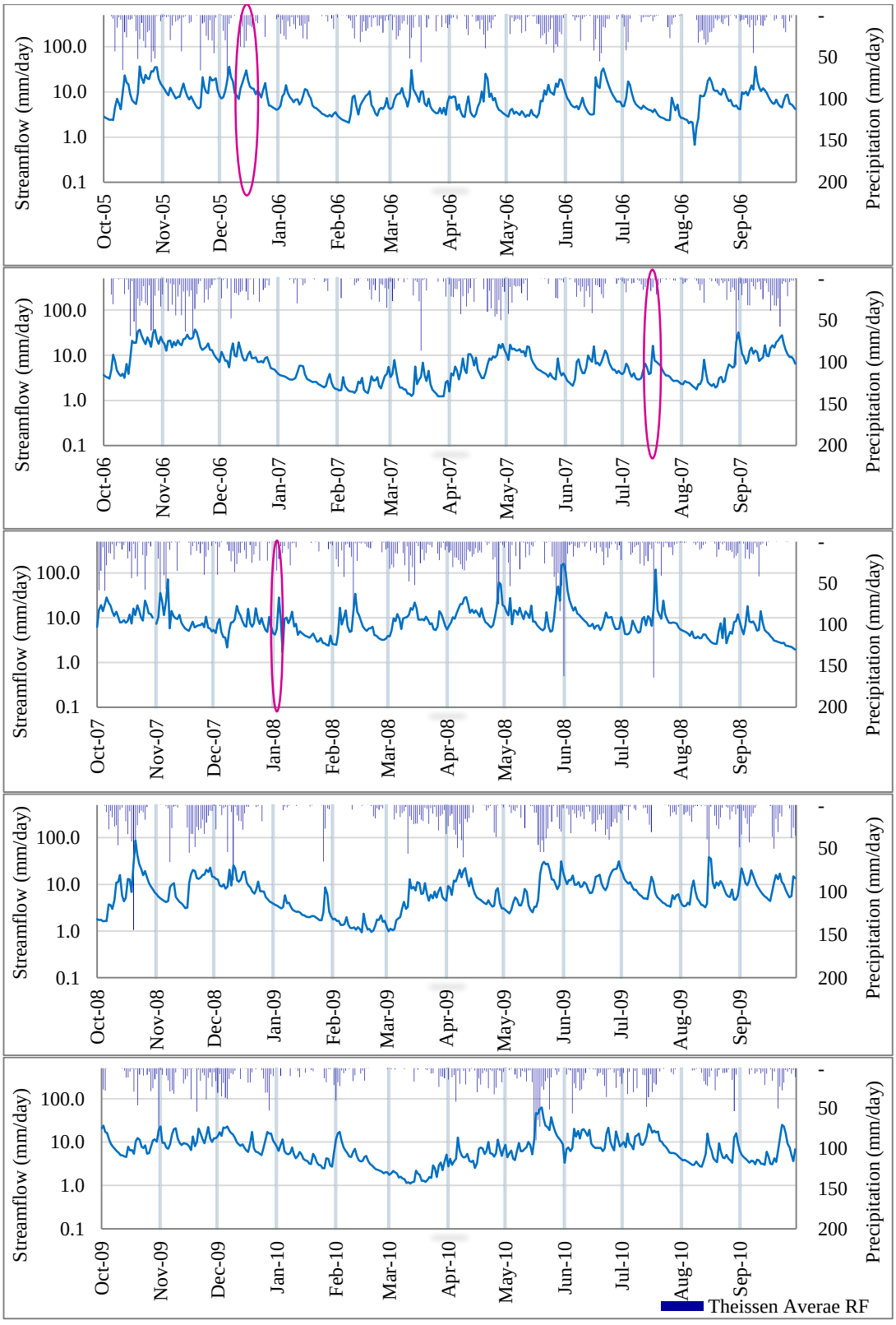

Figure C -17: Thiessen Average Rainfall response to Tawalama Stream flow 2005~2010– Log scale

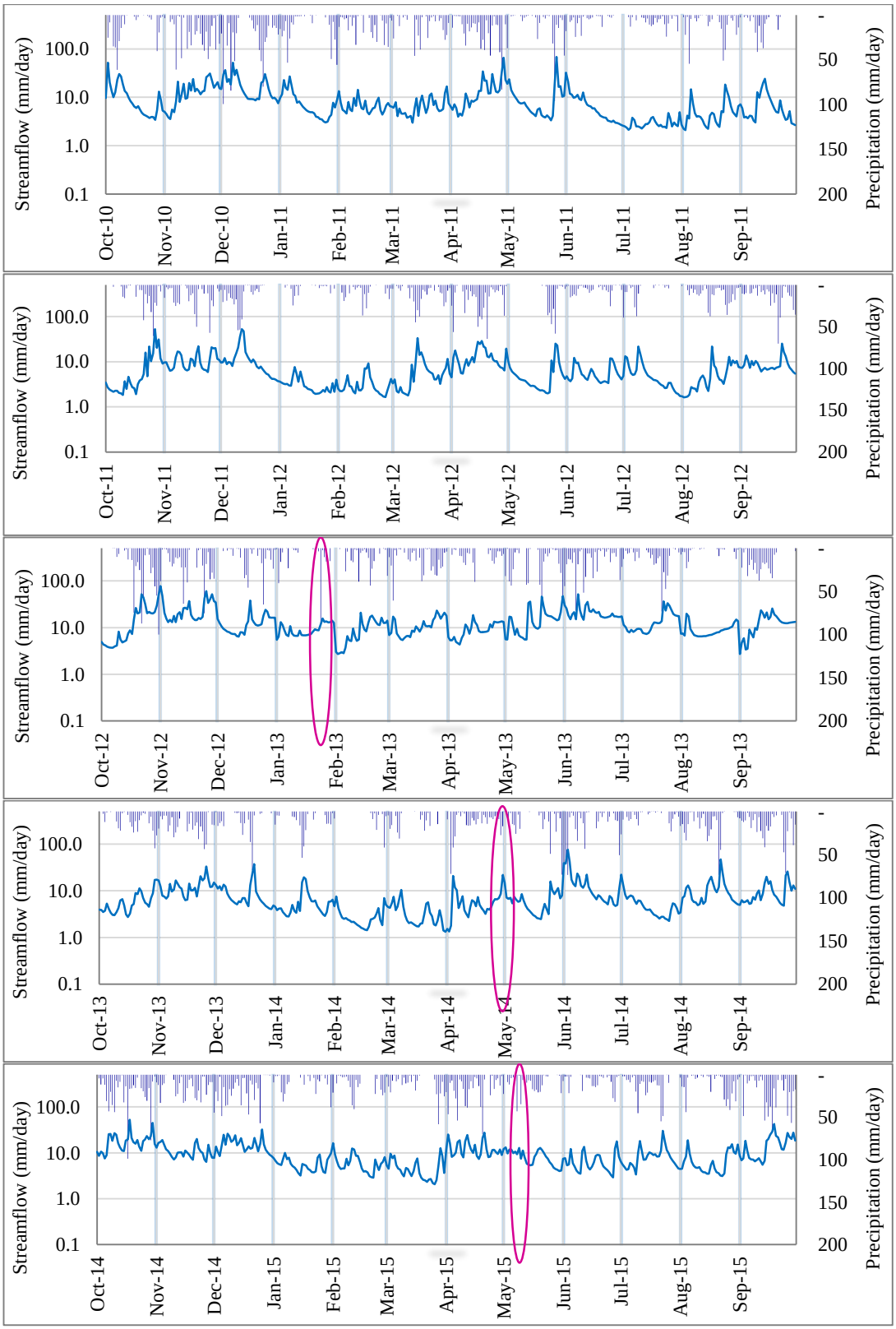

Figure C -18: Thiessen Average Rainfall response to Tawalama Stream flow 2010~2015– Log scale

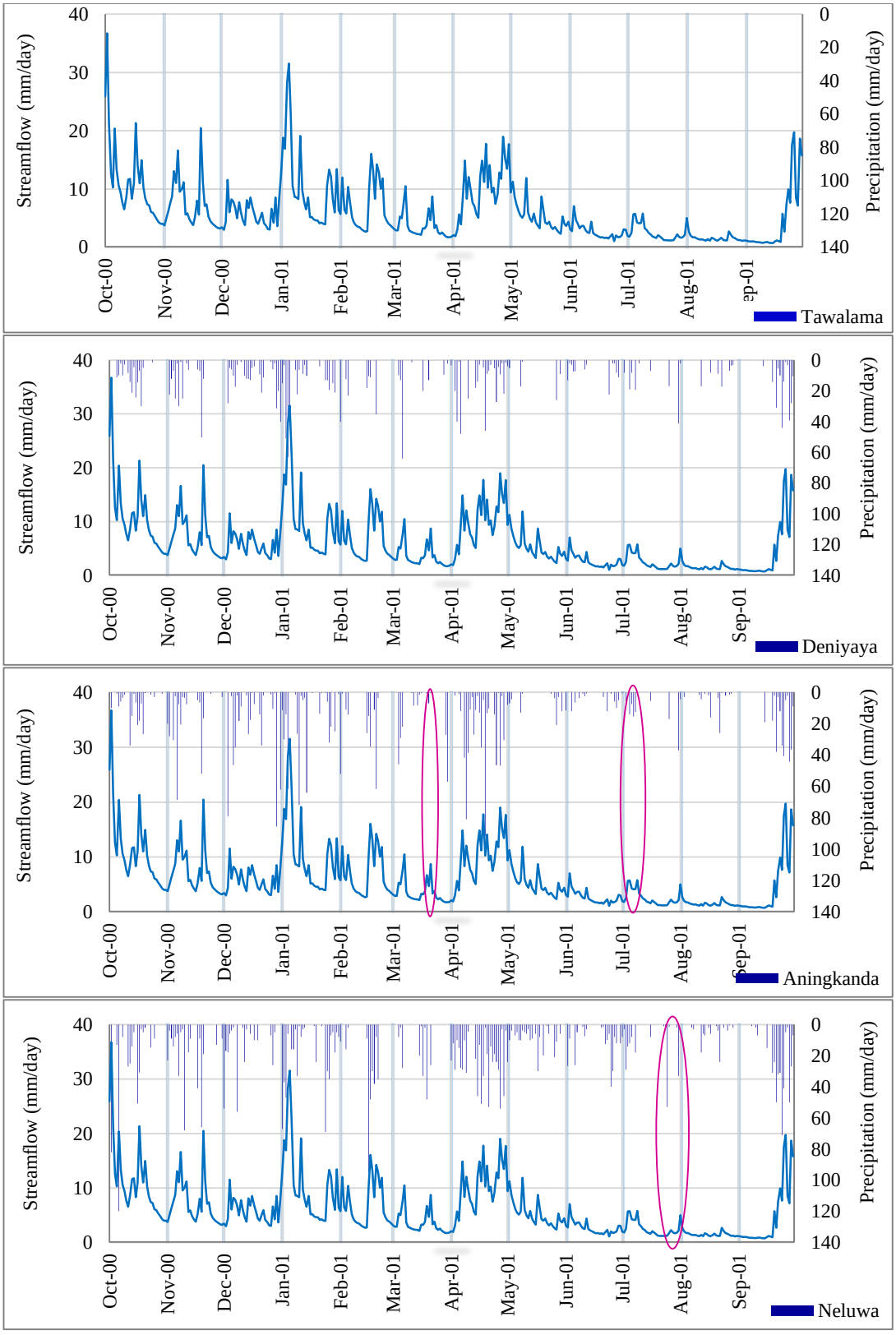

Figure C -19: Rainfall response to Tawalama Stream flow in year 2000/2001 – Normal scale

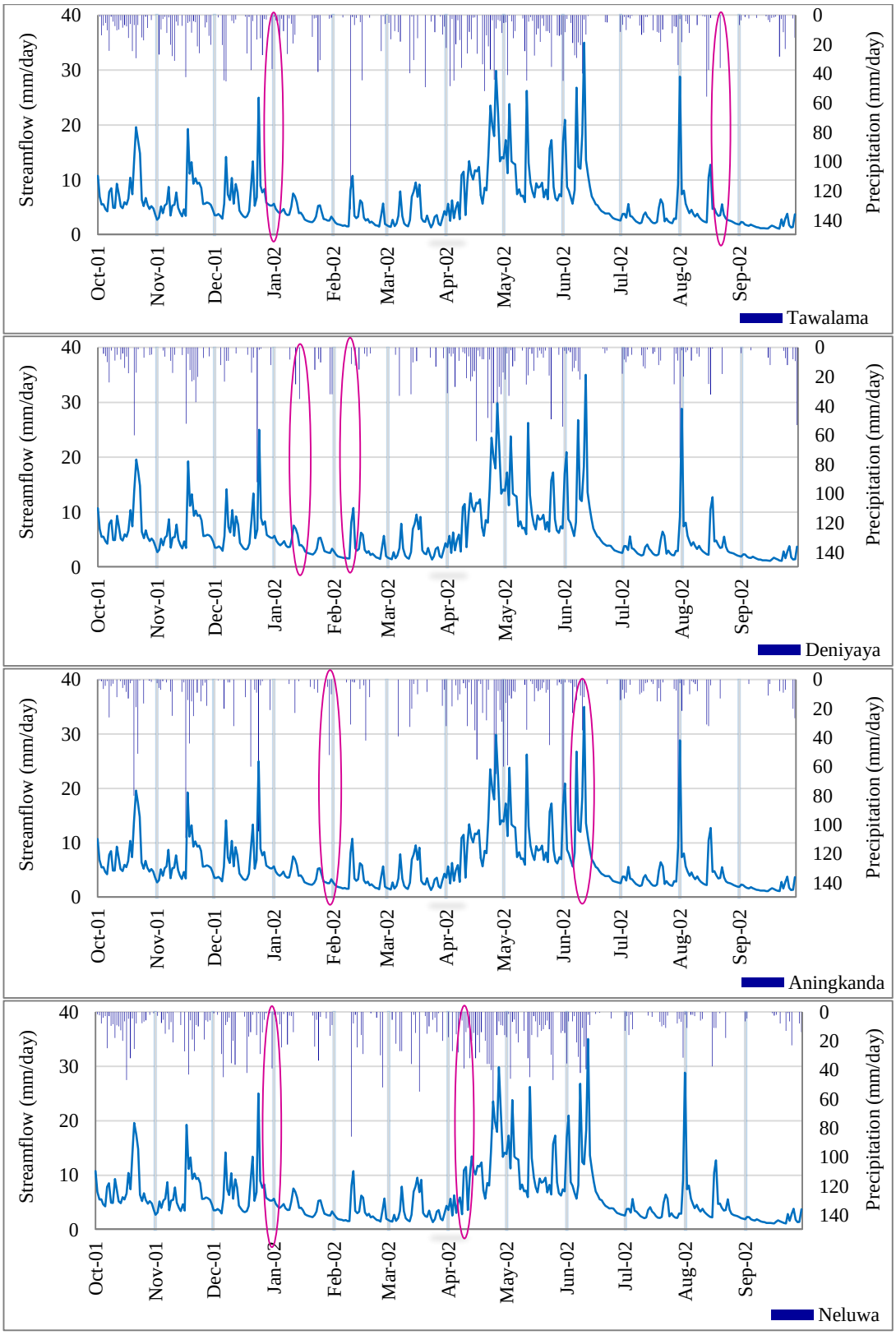

Figure C -20: Rainfall response to Tawalama Stream flow in year 2001/2002 – Normal scale

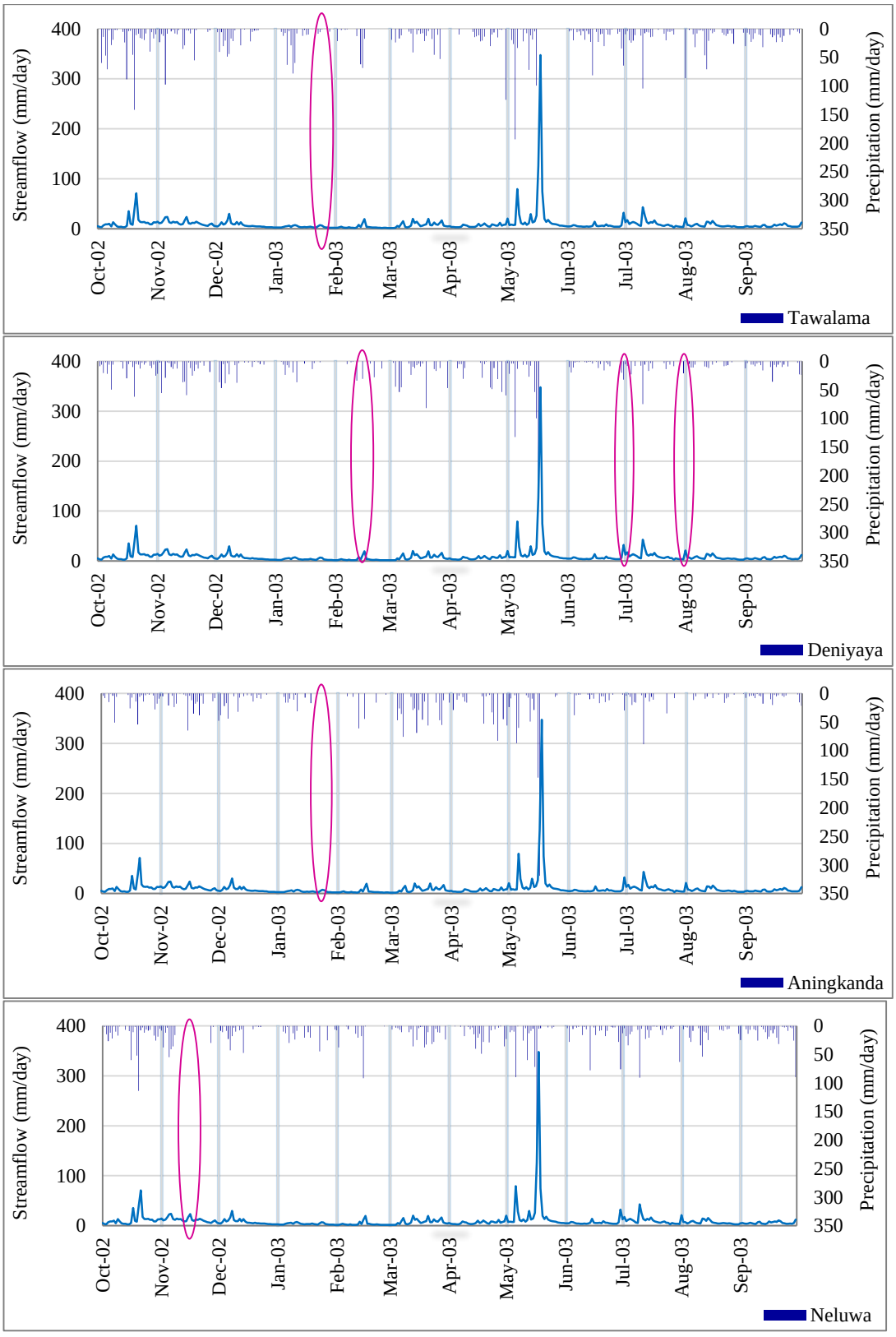

Figure C -21: Rainfall response to Tawalama Stream flow in year 2002/2003 – Normal scale

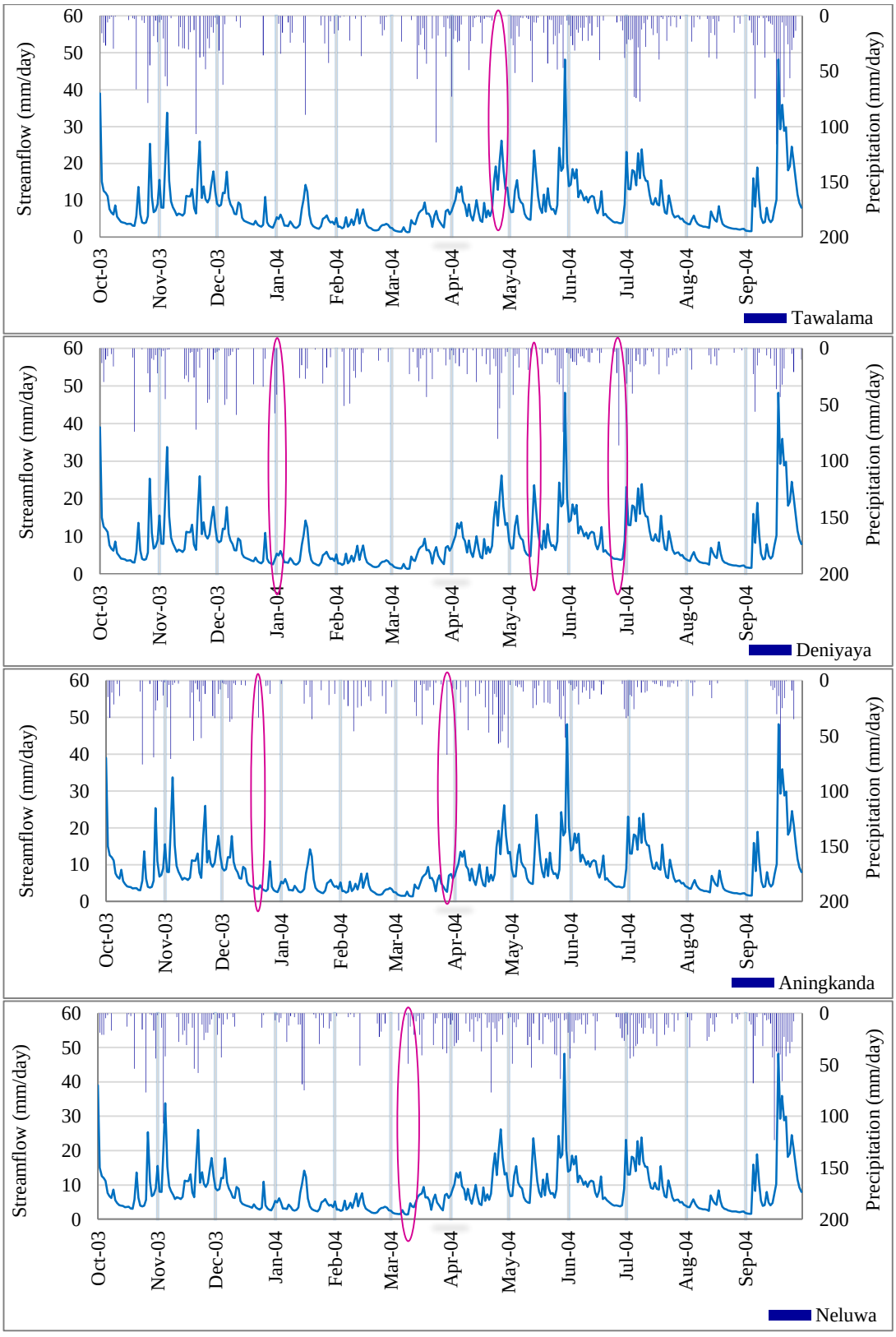

Figure C -22: Rainfall response to Tawalama Stream flow in year 2003/2004 – Normal scale

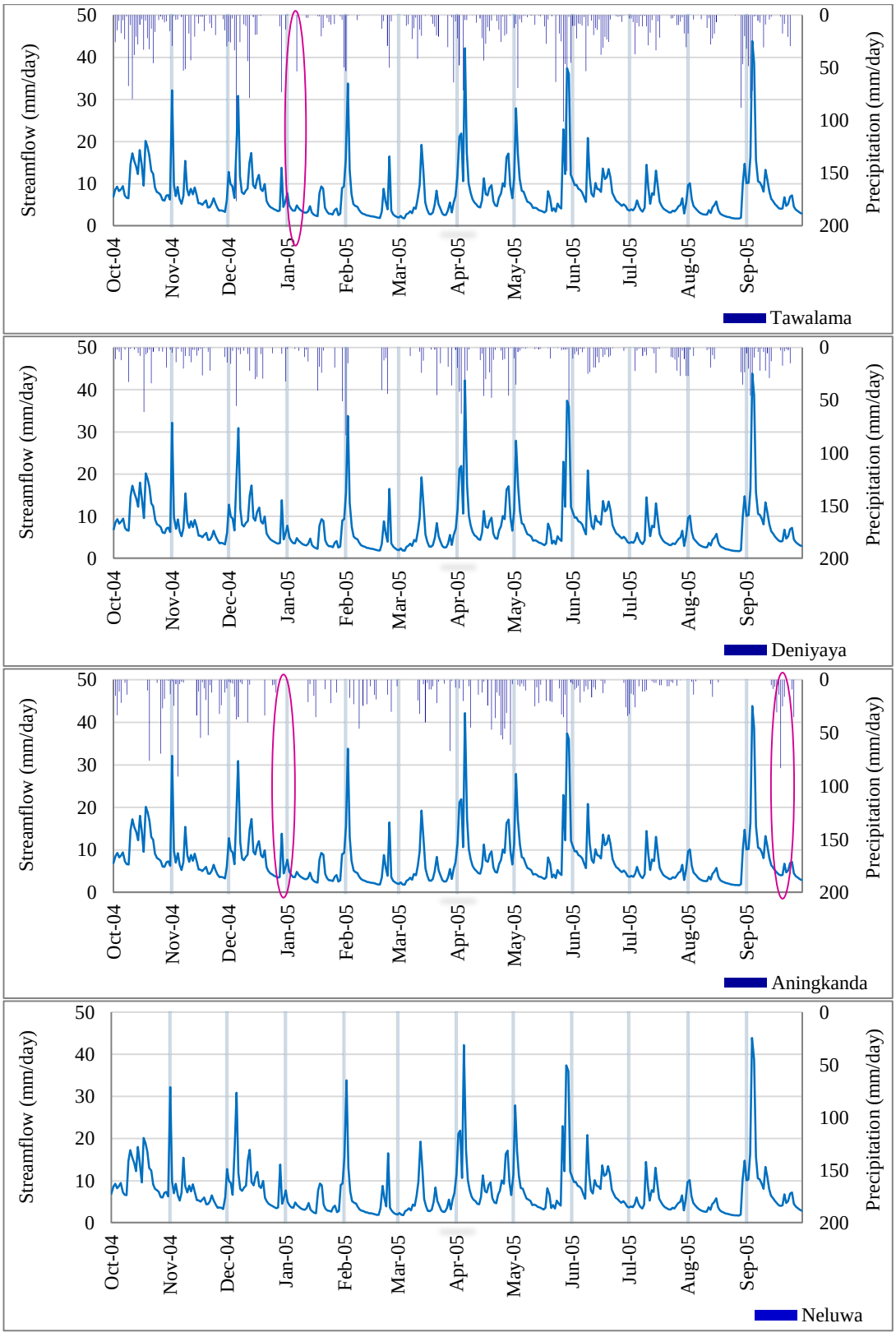

Figure C -23: Rainfall response to Tawalama Stream flow in year 2004/2005 – Normal Log scale

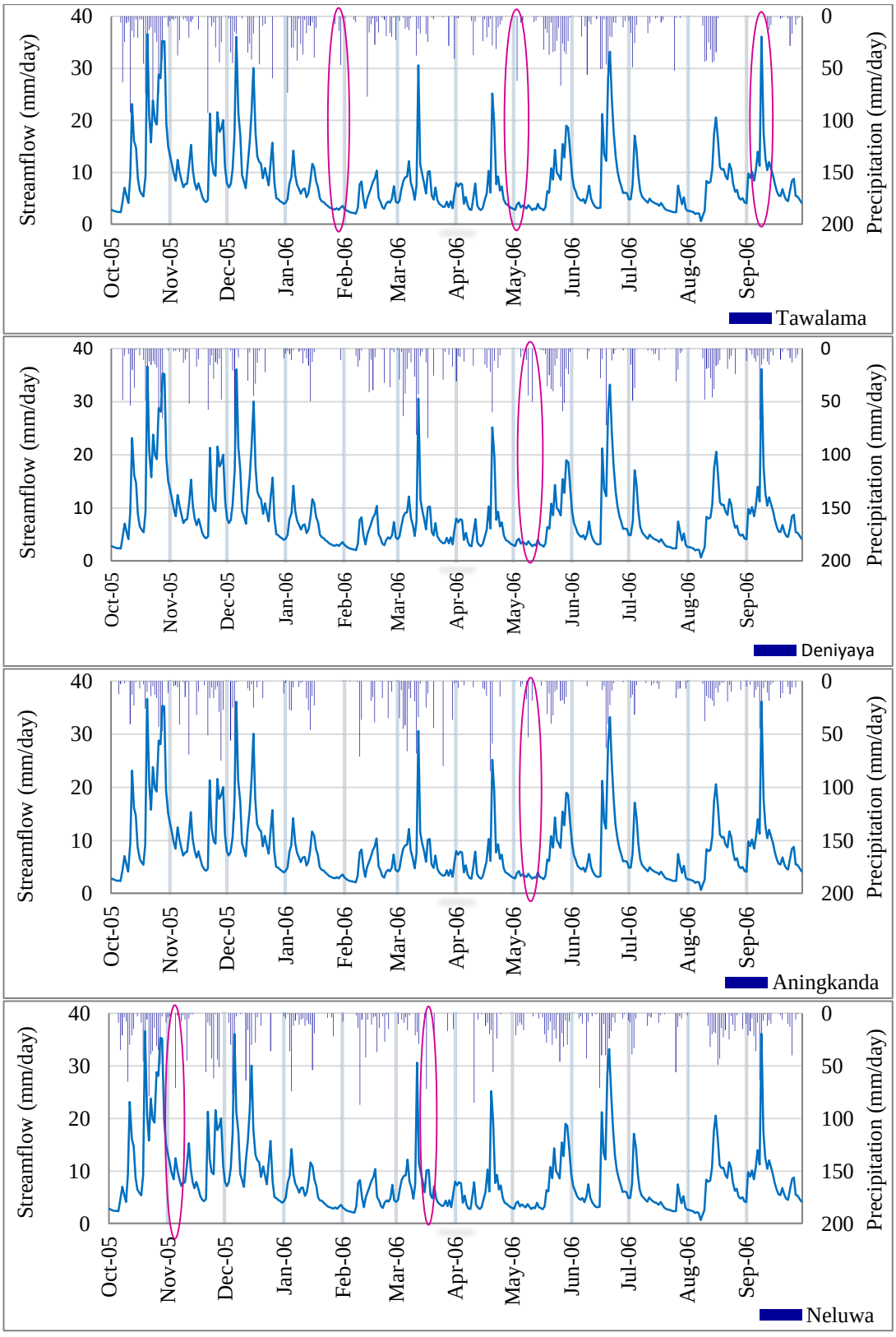

Figure C -24: Rainfall response to Tawalama Stream flow in year 2005/2006 – Normal scale

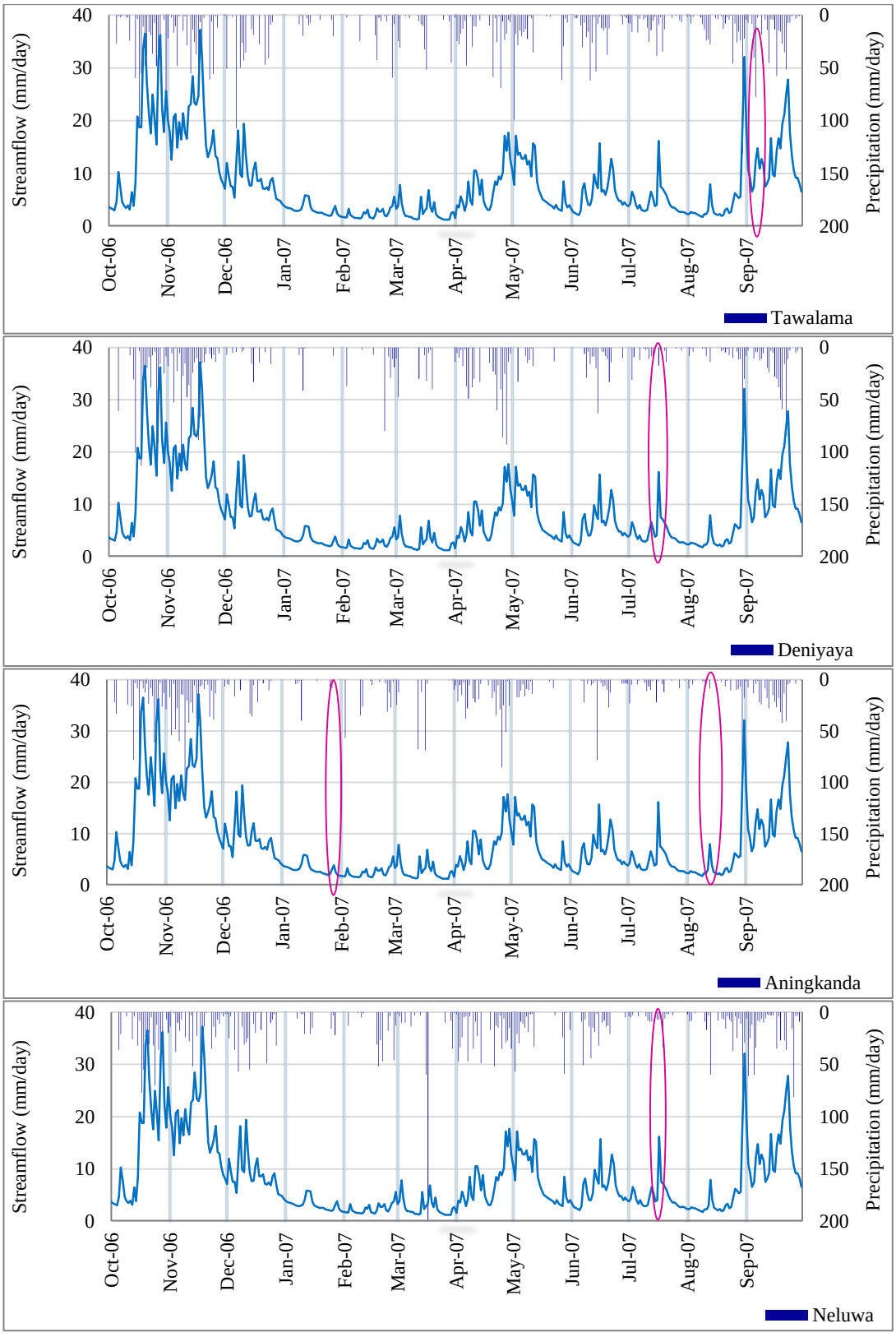

Figure C -25: Rainfall response to Tawalama Stream flow in year 2006/2007– Normal scale

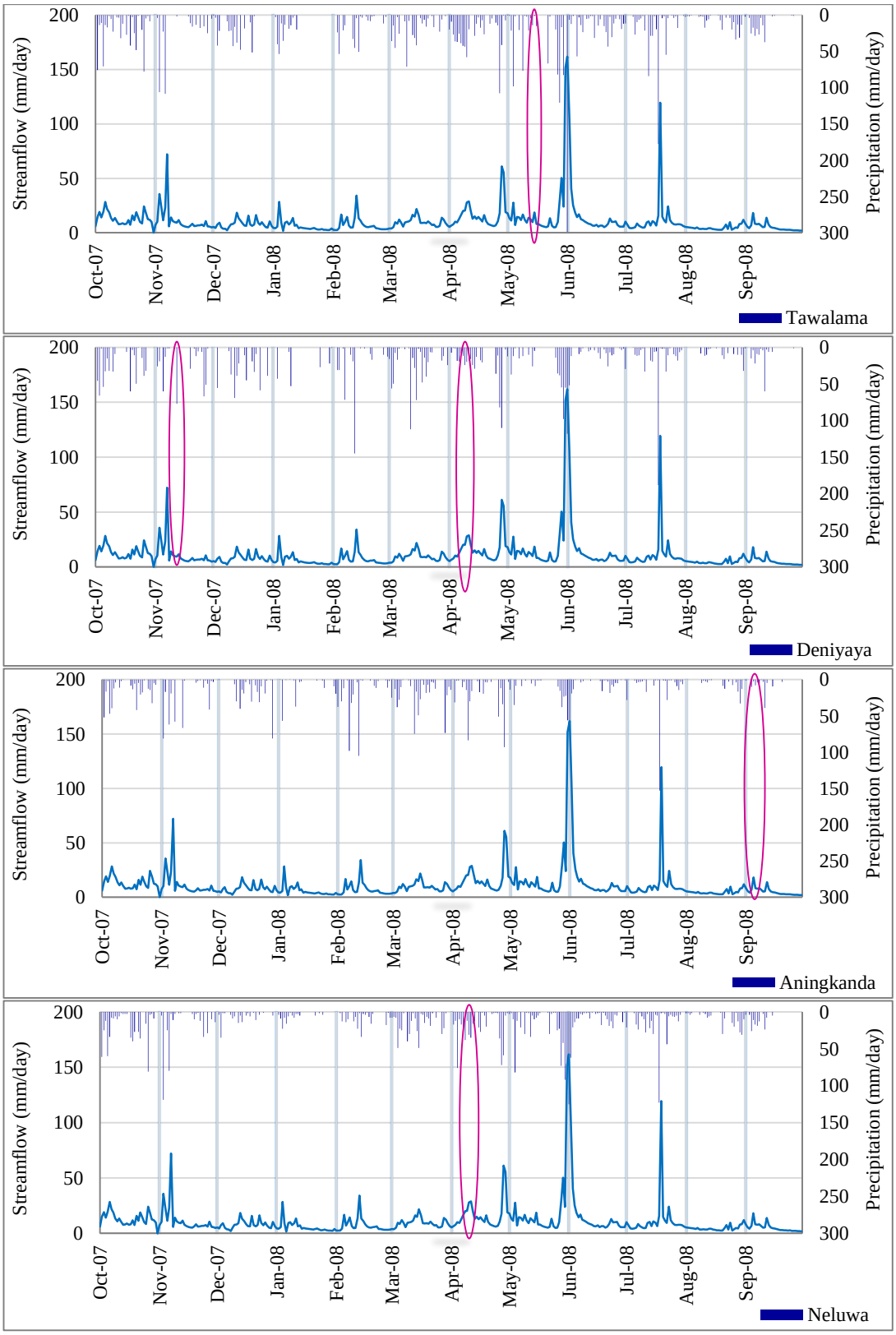

Figure C -26: Rainfall response to Tawalama Stream flow in year 2007/2008 – Normal scale

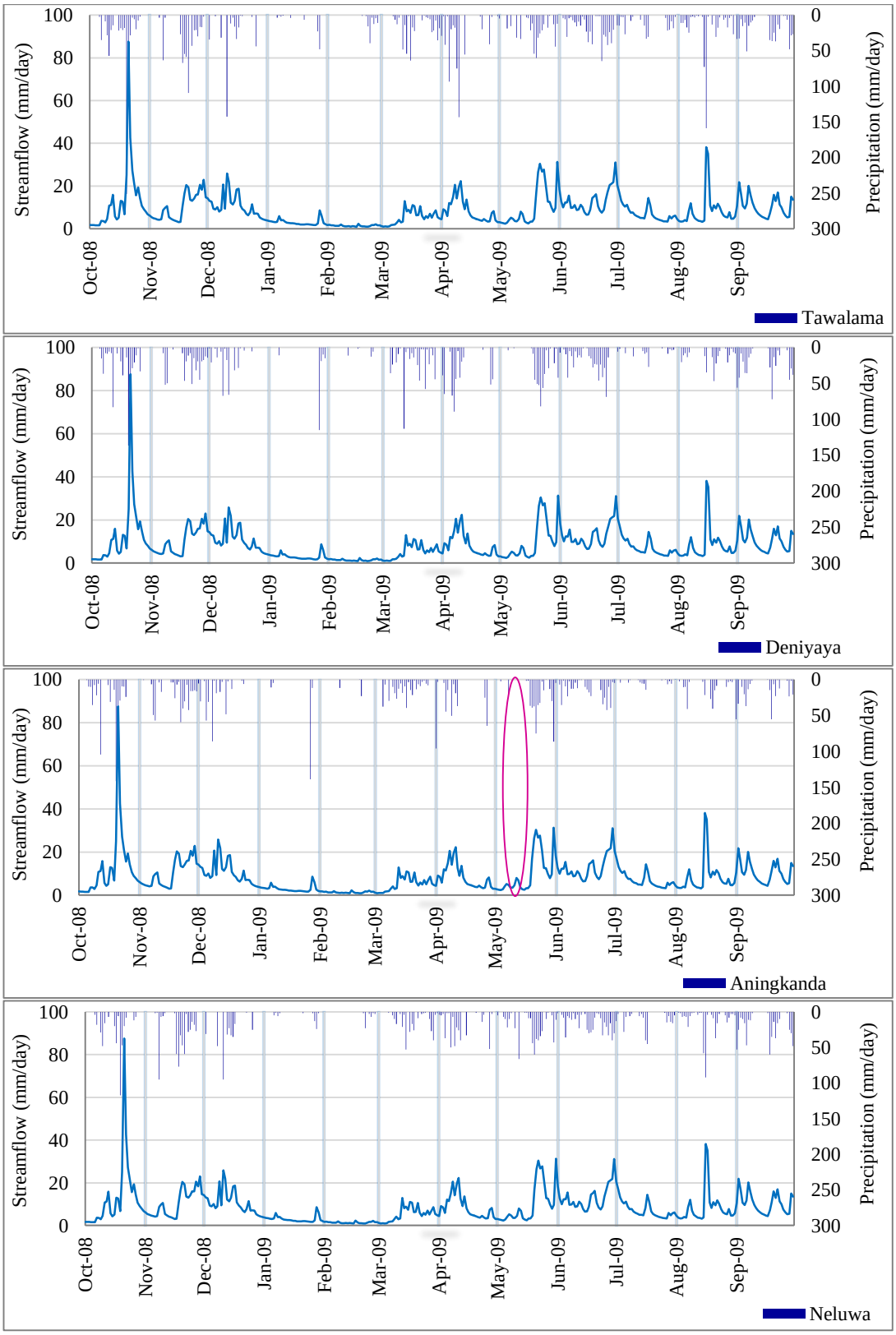

Figure C -27: Rainfall response to Tawalama Stream flow in year 2008/2009 – Normal scale

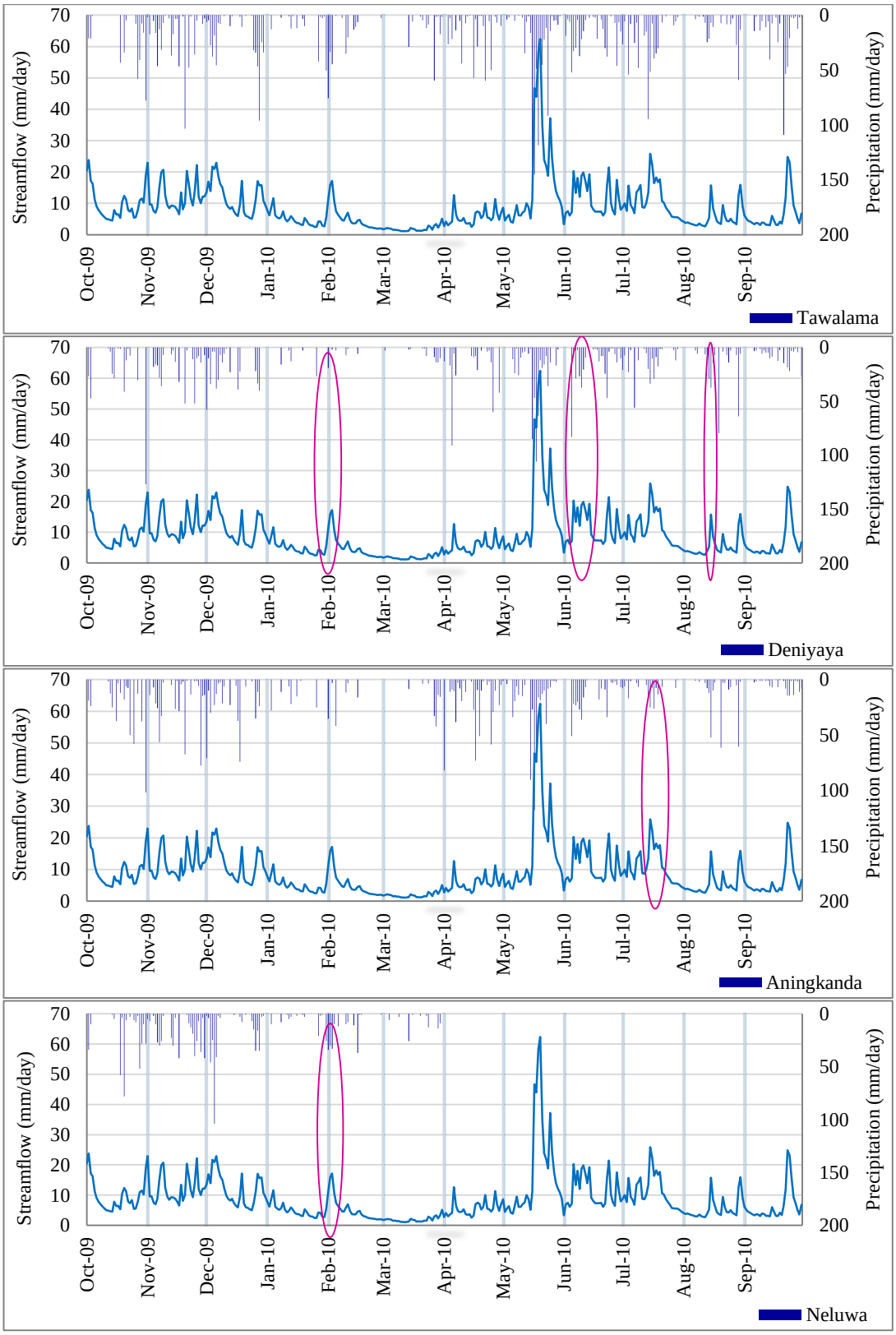

Figure C -28: Rainfall response to Tawalama Stream flow in year 2009/2010 – Normal scale

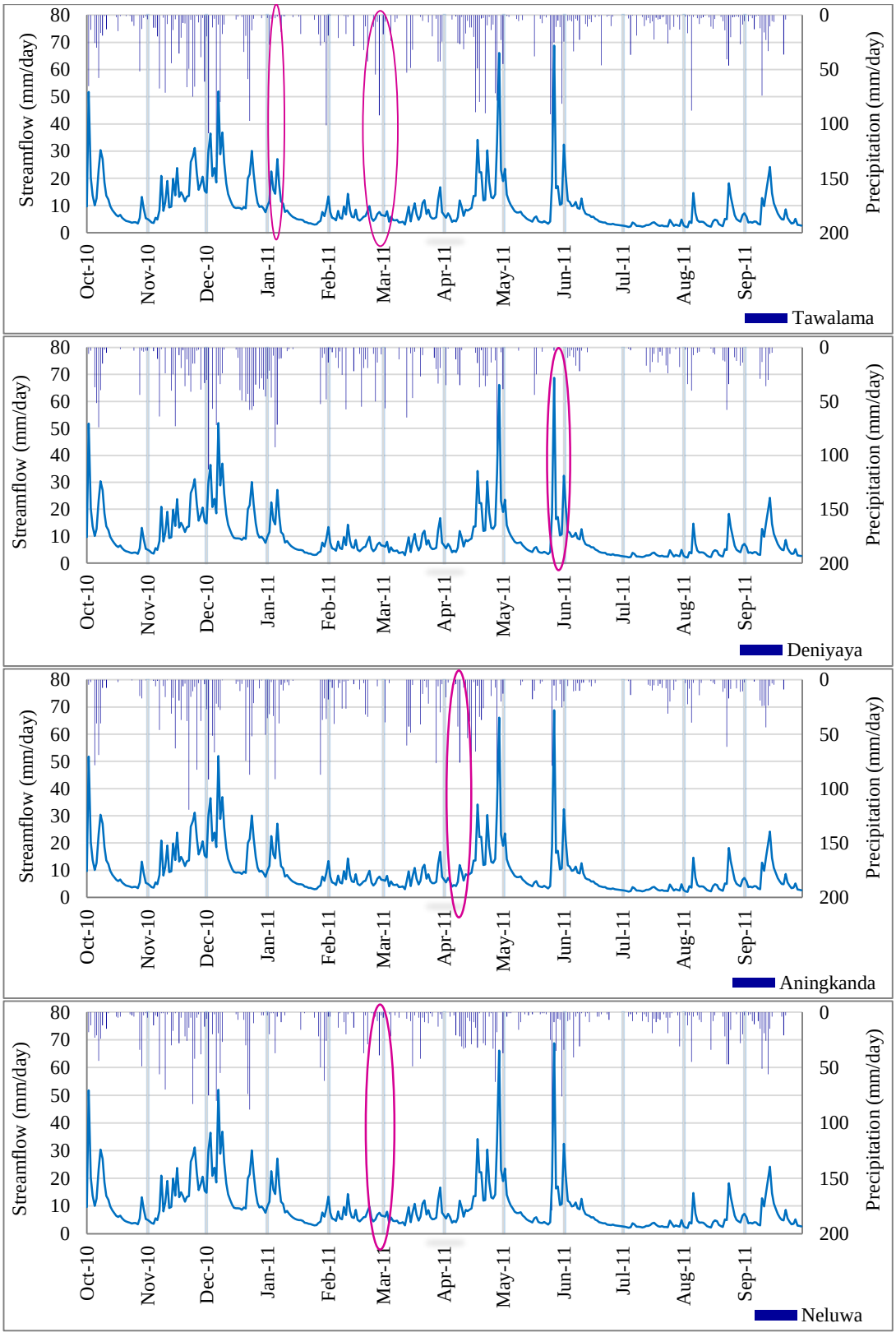

Figure C -29: Rainfall response to Tawalama Stream flow in year 2010/2011– Normal scale

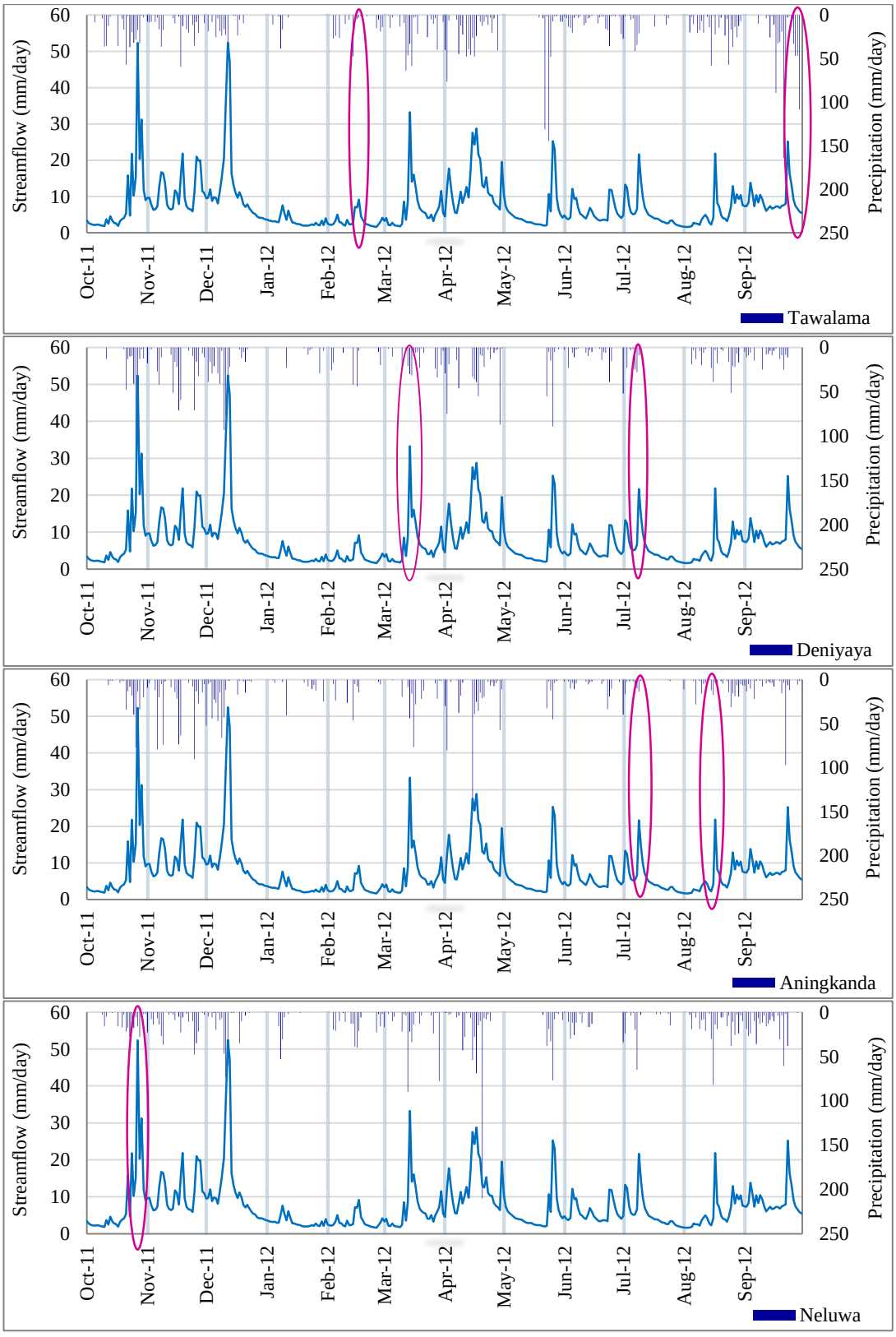

Figure C -30: Rainfall response to Tawalama Stream flow in year 2011/2012– Normal scale

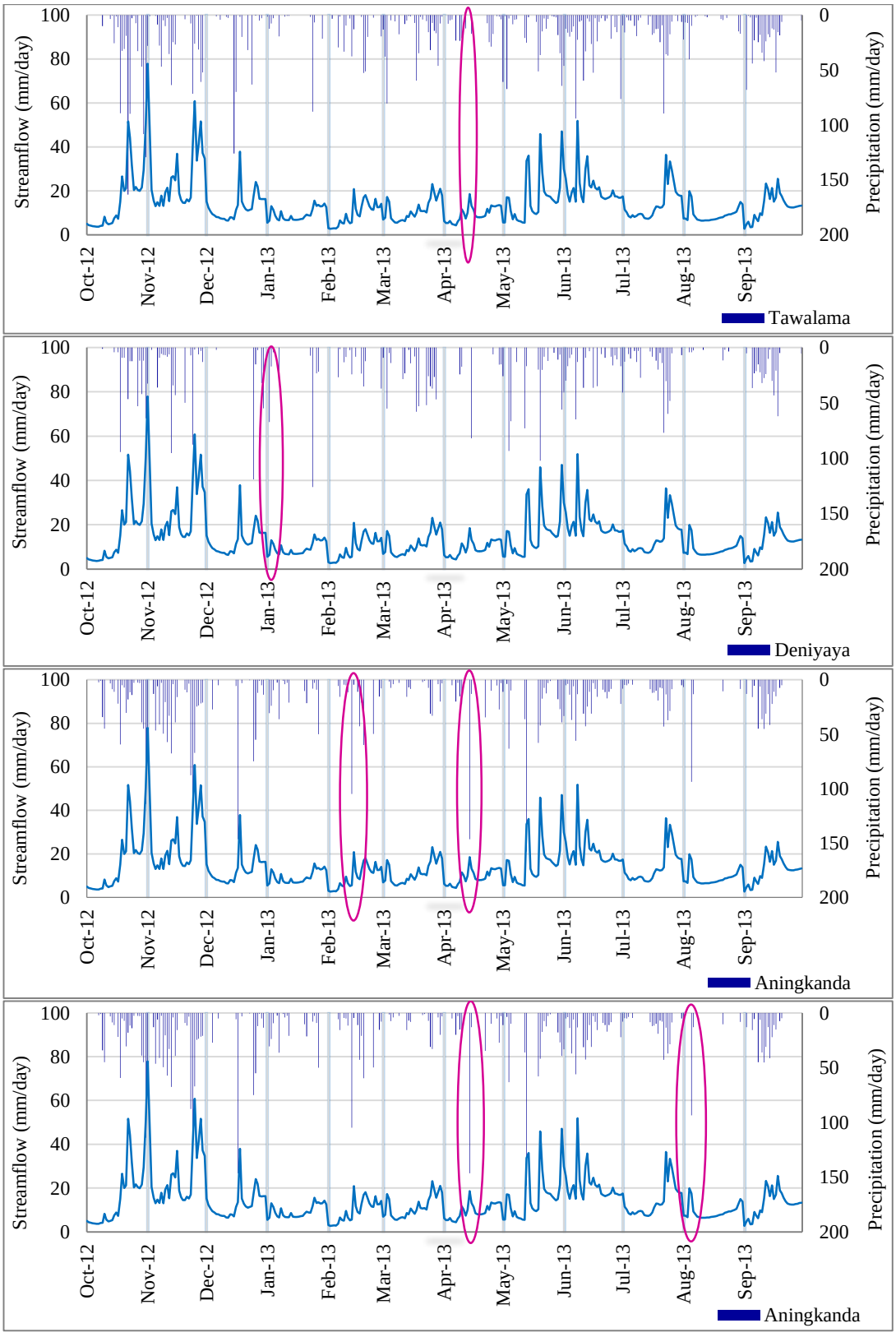

Figure C -31: Rainfall response to Tawalama Stream flow in year 2012/2013 – Normal scale

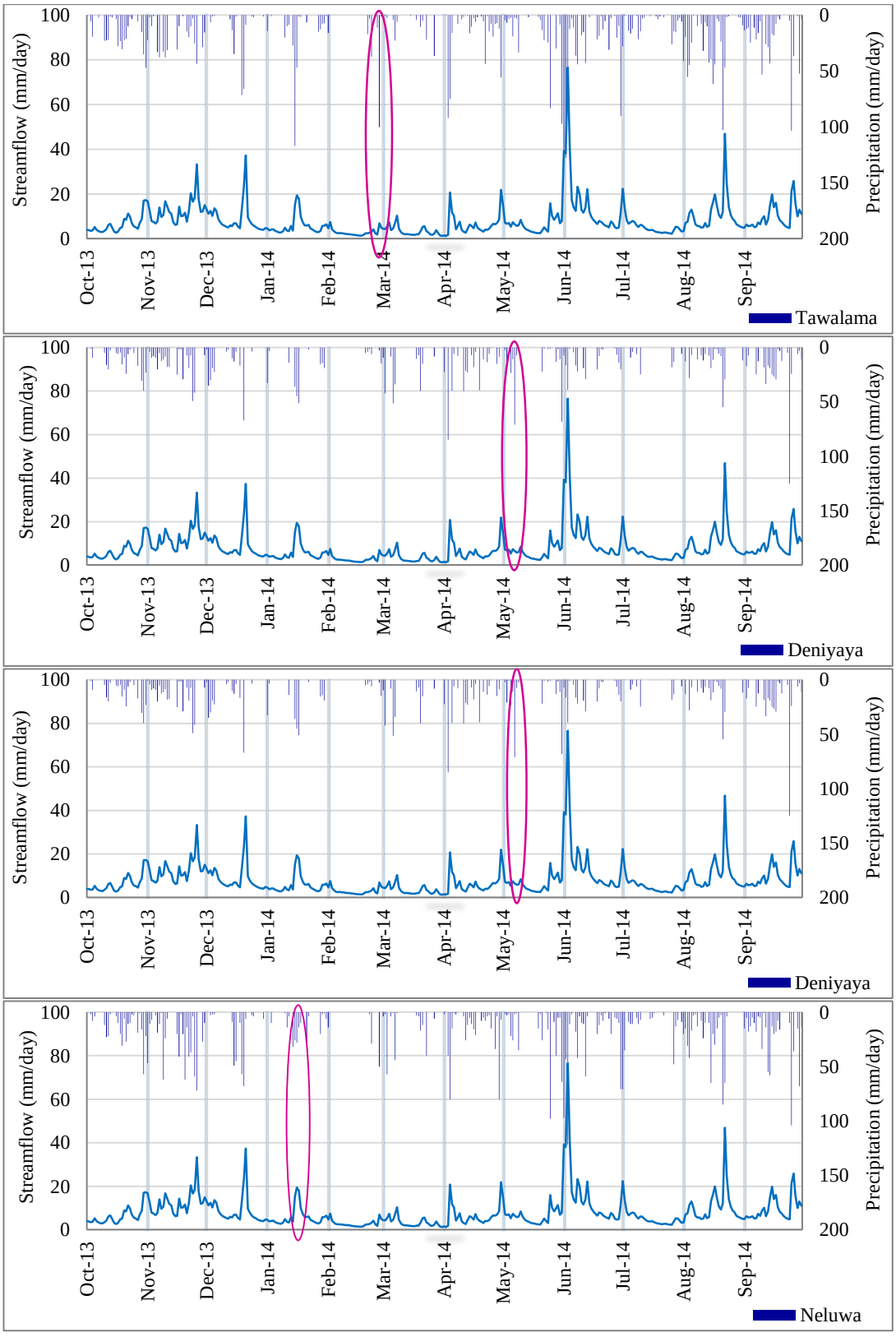

Figure C -32: Rainfall response to Tawalama Stream flow in year 2013/2014 – Normal scale

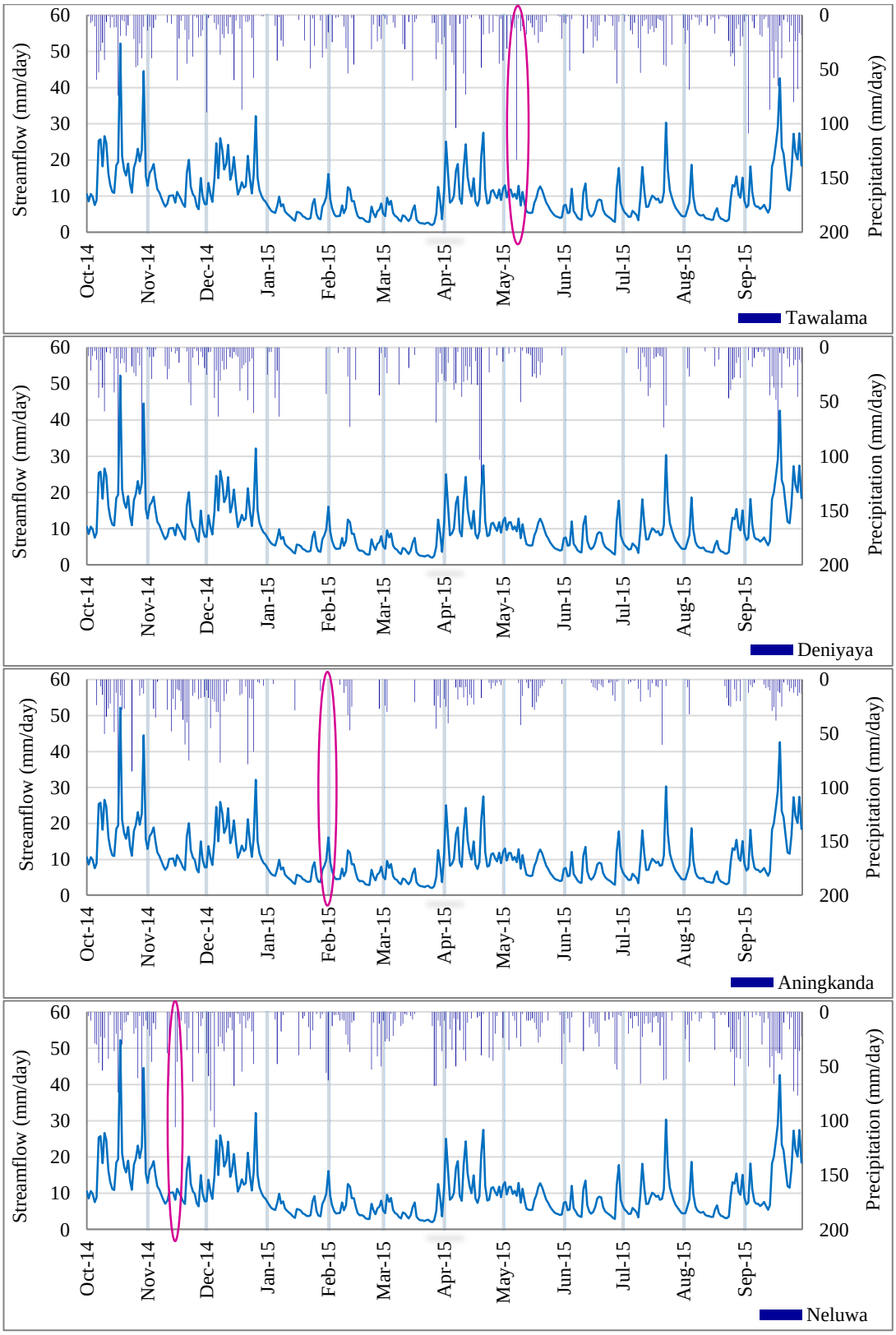

Figure C-33: Rainfall response to Tawalama Stream flow in year 2014/2015 – Normal scale

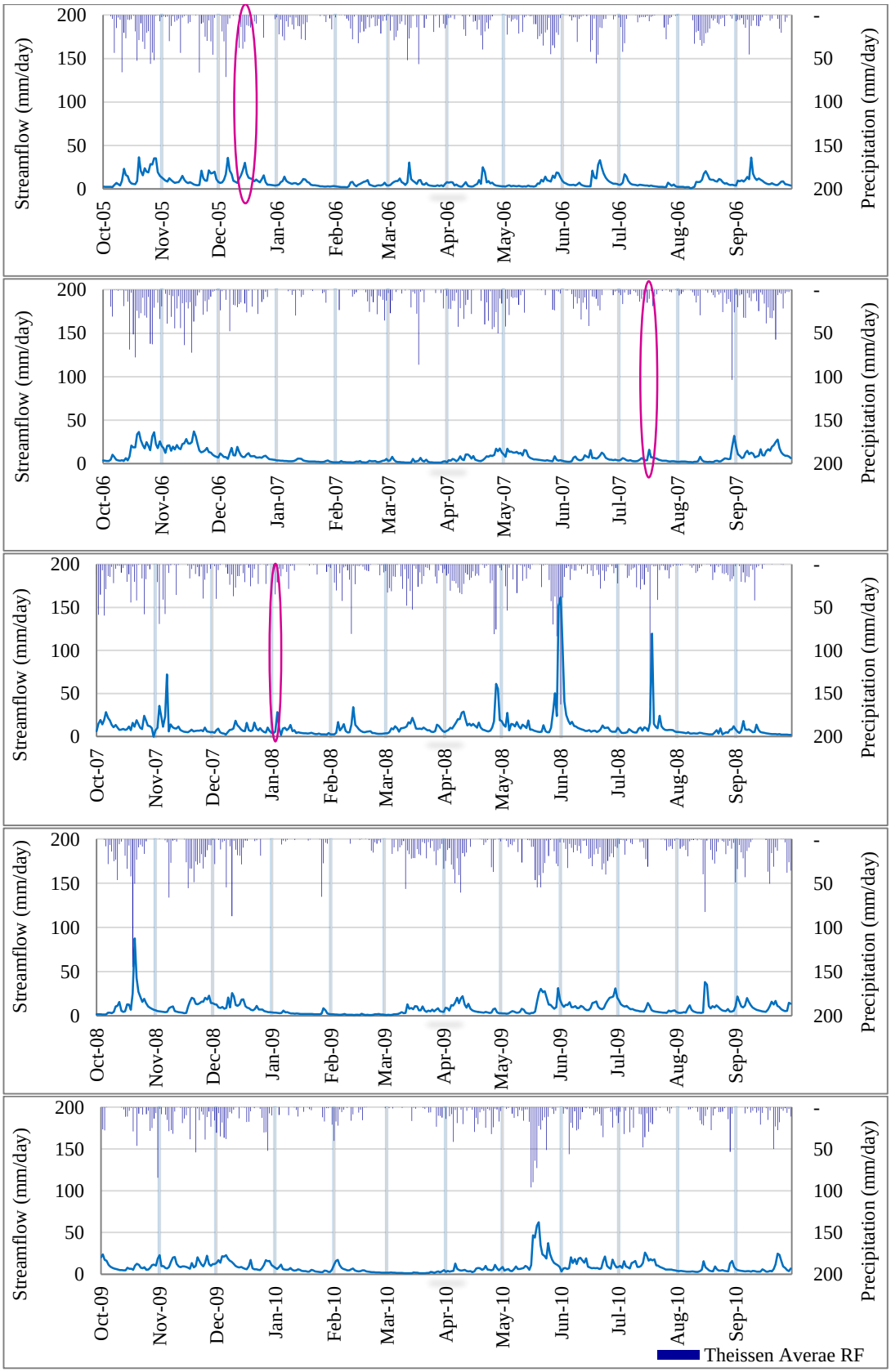

Figure C-34: Thiessen Average Rainfall response to Tawalama Stream flow 2005~2010 – Normal scale

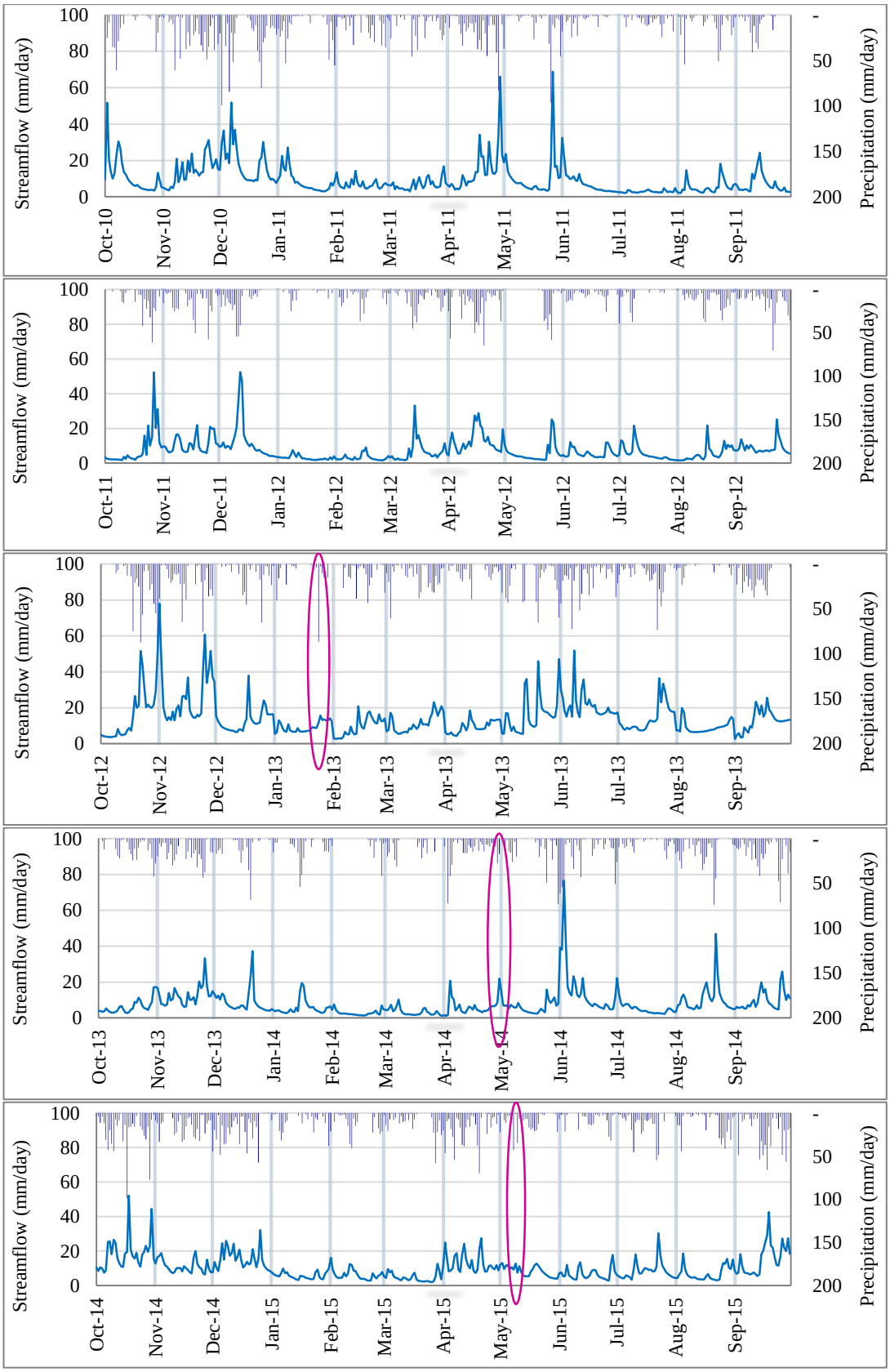

Figure C-35: Thiessen Average Rainfall response to Tawalama Stream flow 2010~2015 – Normal scale

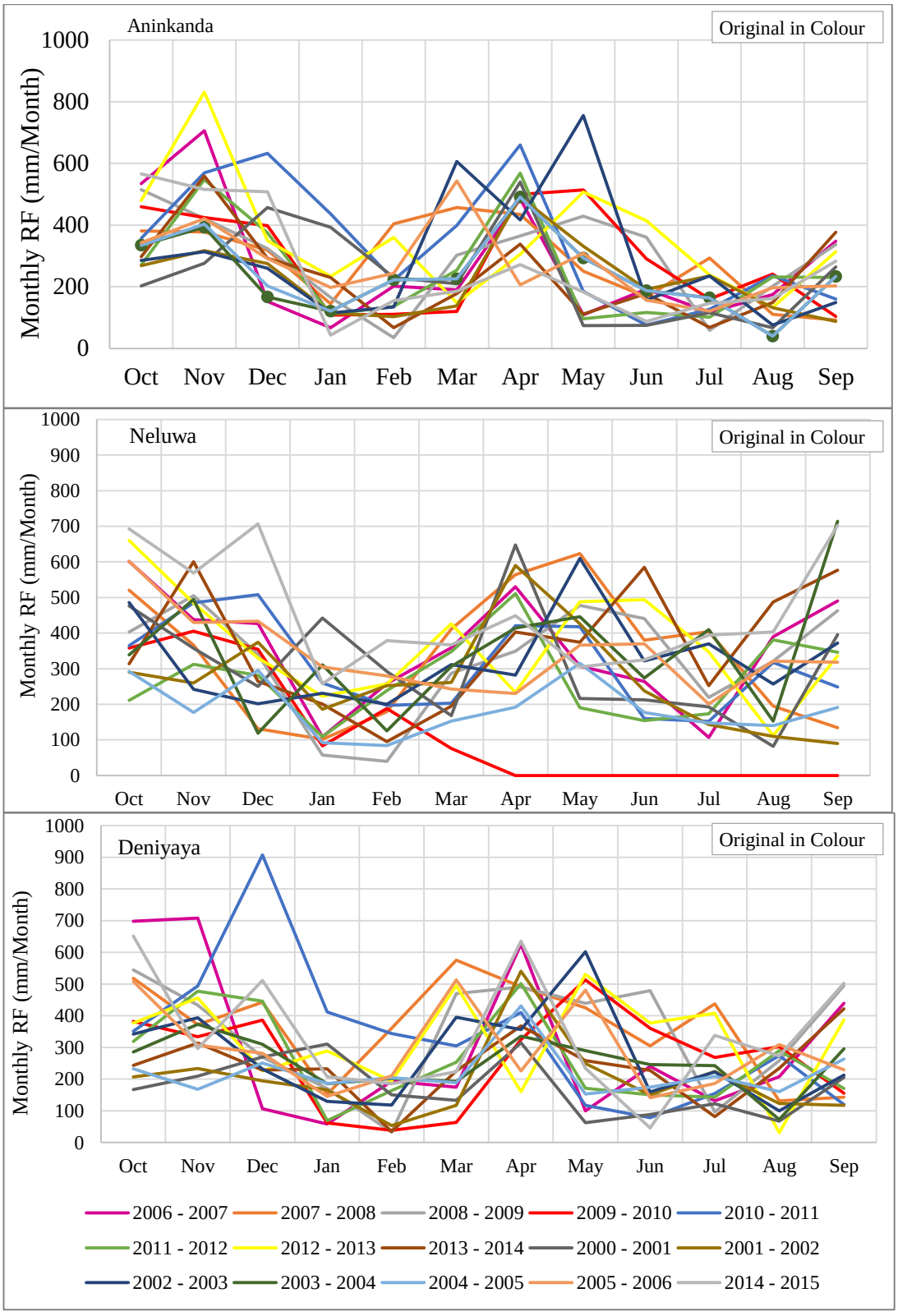

Figure C-36: Comparison of Annual Rainfall Pattern

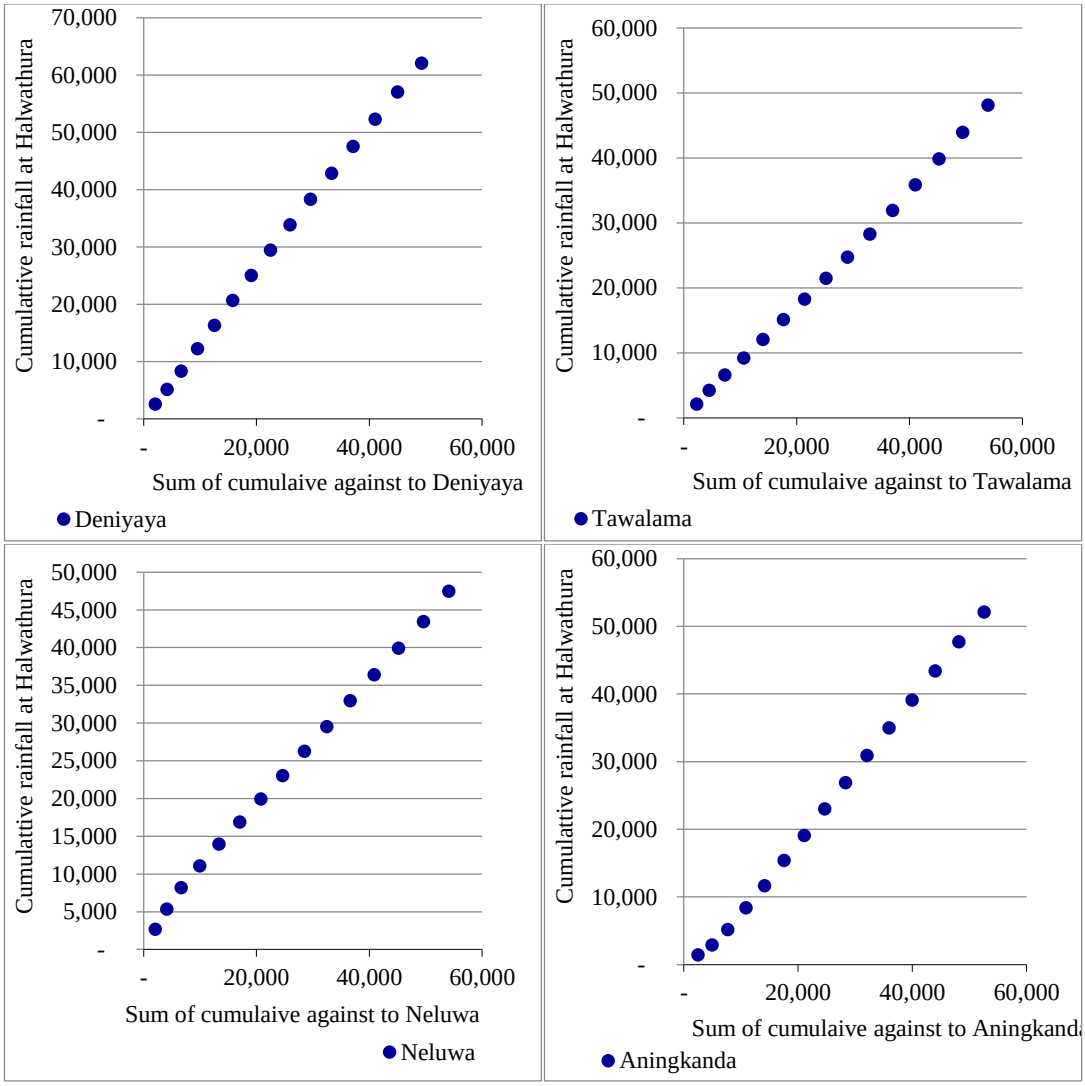

Figure C-37: Double Mass Curve for Rainfal data - Tawalama Basin

ANNEX D - ANALYSIS AND RESULTS

Specimen Calculation for Ellagawa basin

Consider 2006/Oct/04

Thiessen average rainfall P(t) = 2.07 mm/day

Daily pan Evaporation EP(t) = 3.45 mm/day

Model Parameter

Parameter c = 2.5 (Assumed)

Parameter Sc = 700 mm

Actual Evapotranspiration is given by,

$$E(t) = c \times EP(t) \times \tanh\{(P(t)/EP(t)\} \quad \text{——— (1)}$$

E(t) = 3.79 mm/day

Condition Applied,

1. Actual Evaporation should not be less than zero.
2. Actual Evaporation should not be more than pan evaporation.
3. The water content at the end of the day, S(t-1) is obtained from hydrologic cycle and next day value S(t-1) is equal to S(t) of the first day.

S(t-1) = 34 mm

Monthly runoff can be calculated by,

$$Q(t) = S(t-1) + \tanh\{(S(t-1) + P(t) - E(t)/Sc)\} \quad \text{— (2)}$$

Q(t) = 1.45 mm/day

Condition Applied,

1. Runoff should not be less than zero.
2. The water content at the t^{th} month can be computed by,

$$S(t) = S(t-1) + P(t) - E(t) - Q(t) \quad \text{——— (3)}$$

S(t) = 30.39 mm

Condition Applied,

1. Soil moisture content should not be less than zero.

Runoff coefficient can be calculated as,

C = Q(t)/P(t) ——————— (4)

= 0.89

The average runoff in the calibration period is the average value in calibration data set

C avg = 2.6

Catchment Area = 1372.4 km^2

Estimated streamflow can be calculated as

$$Q = Q(t) \times Cavg \times A \times 106/(1000 \times 24 \times 60 \times 60) \quad (5)$$

Q = 1.33 m^3/s

Error Estimation & Parameter Optimization

Mean Ratio of Absolute Error (MRAE)

$$MRAE = (1/n) \times \sum_i [Abs(Q0 - Qs)/Q0] \quad (6)$$

MRAE = 0.46

Model was developed with excel using based on literatures (Xiong, 1999). First equation of the model is as below.

E(t)/ EP(t) = c×tanh [P(t)/ EP(t)]

(19)

Where, E(t) – Model developed evaporation

EP(t) – Pan evaporation

P(t) – Rainfall

C – First parameter of the model (Pan Evaporation coefficient)

According to the basic concepts, E(t) can not be negative. Hence, condition was applied to the model as,

If E(t) < 0, then E(t) = 0

When P(t)/EP(t) is greater than 1, tanh [P(t)/ EP(t)] is approaching to 1. Then E(t) ⇒ c× EP(t)

When c is greater than to the 1, E(t) > EP(t)

But, theoretically EP(t) should be greater than the E(t). Hence, second condition incorporated as,

If, E(t) > EP(t), then E(t) = EP(t)

Second equation of the model is,

$$Q(t)=S(t-1)+\tanh\{(S(t-1)+P(t)-E(t)/Sc)\} \quad (20)$$

According to the basic concepts, Q(t) can not be negative. Hence, condition incorporated to the model as,

If, Q(t) < 0, then Q(t) = 0

The third equation of the model was used the continuity equation and modified equation is as below.

$$S(t) = S(t-1)+P(t)-E(t)-Q(t) \quad (21)$$

The condition incorporated to the model as,

If, S(t)<0, then S(t) = 0

Finally, model developed with while incorporating those conditions and then optimization done.

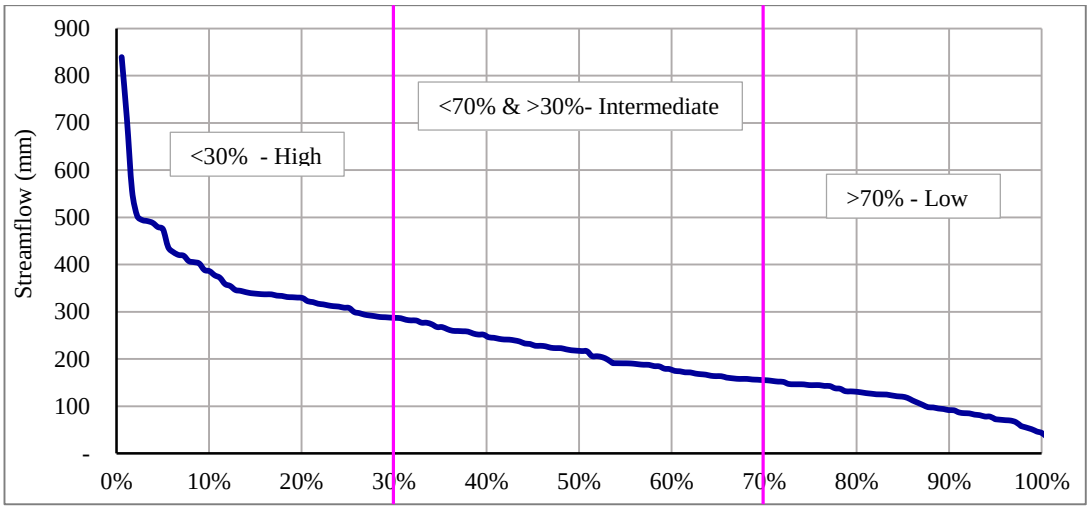

Figure D-1: Flow Duration Curve – Monthly Scale - Tawalama Watershed (Normal Scale)

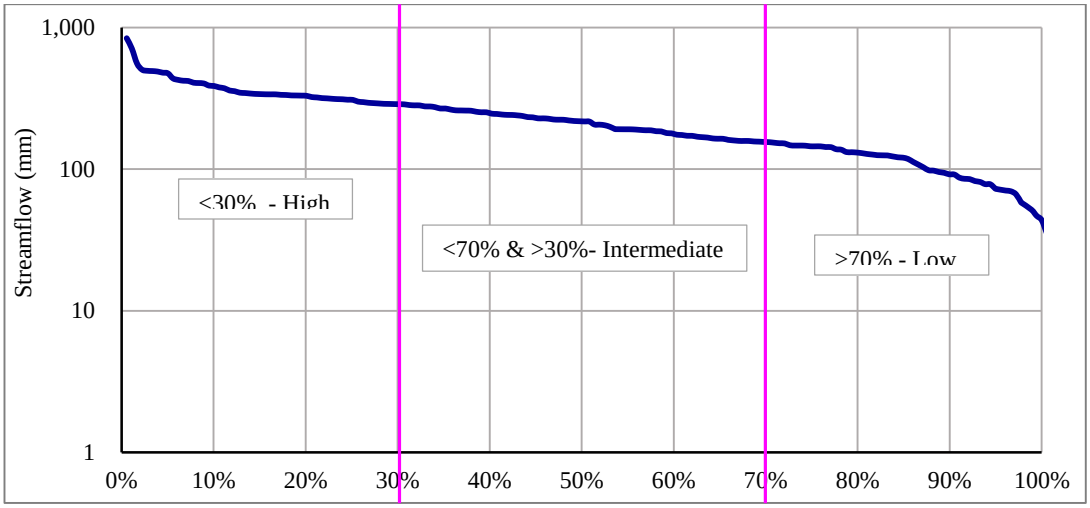

Figure D-2: Flow Duration Curve – Monthly Scale - Tawalama Watershed (Log Scale)

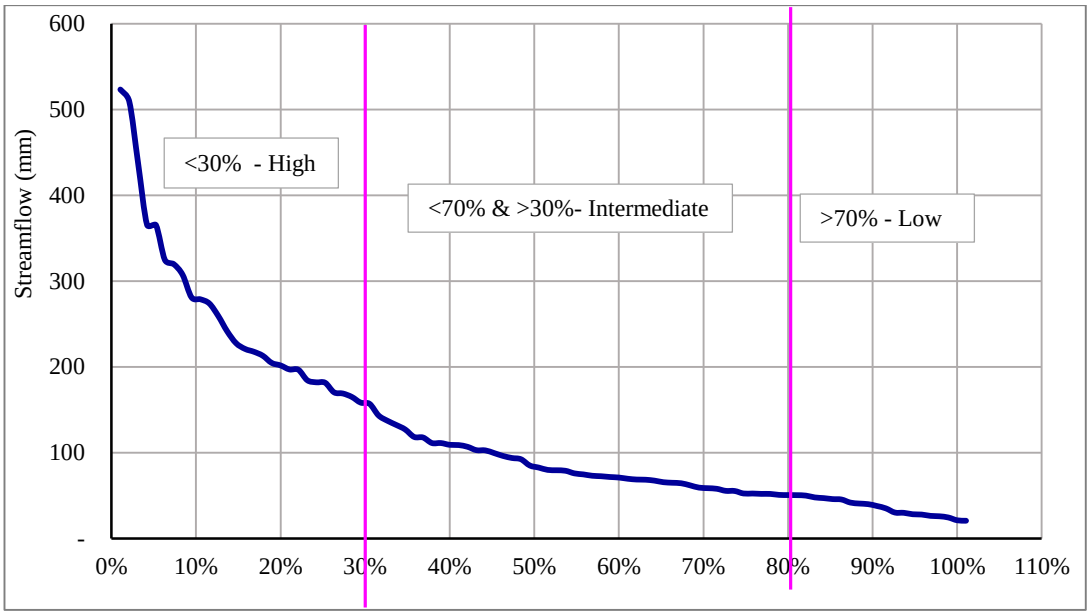

Figure D-3: Flow Duration Curve – Monthly Scale - Ellagawa Watershed (Normal Scale)

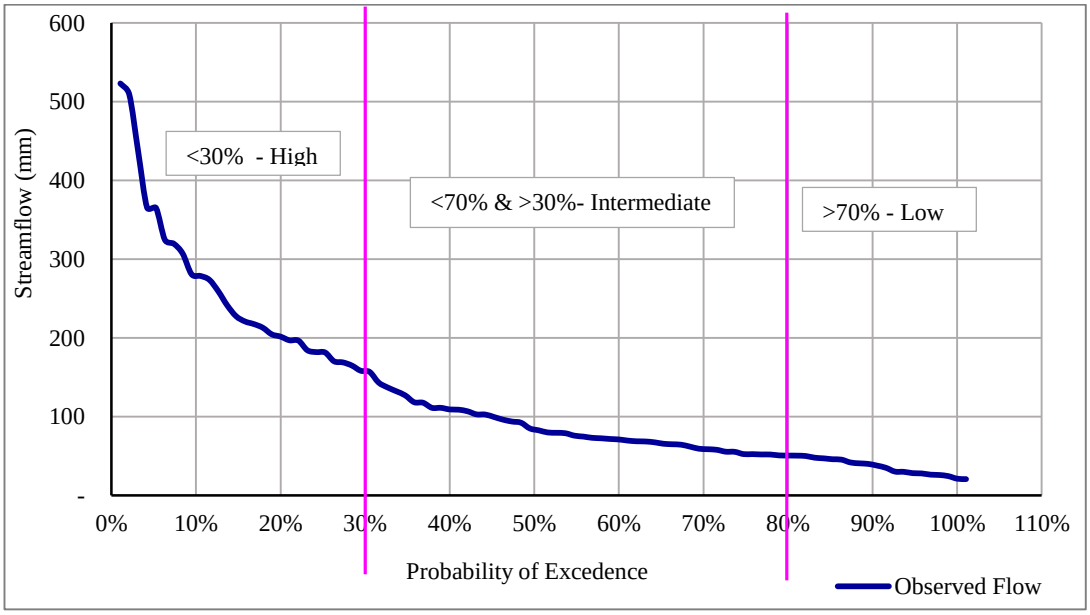

Figure D-4: Flow Duration Curve – Monthly Scale - Ellagawa Watershed (Log Scale)

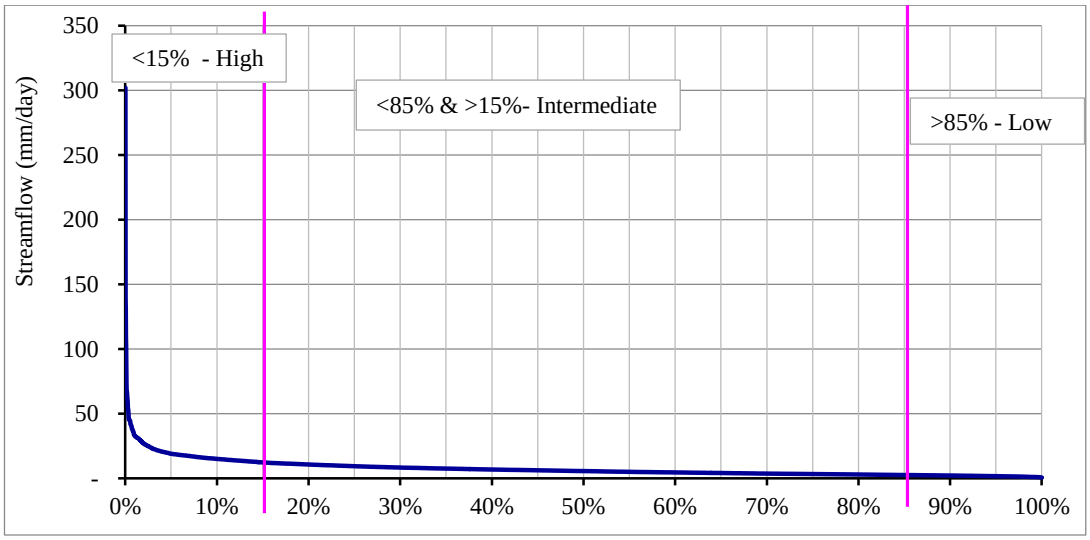

Figure D-5: Flow Duration Curve – Daily Scale - Tawalama Watershed (Normal Scale)

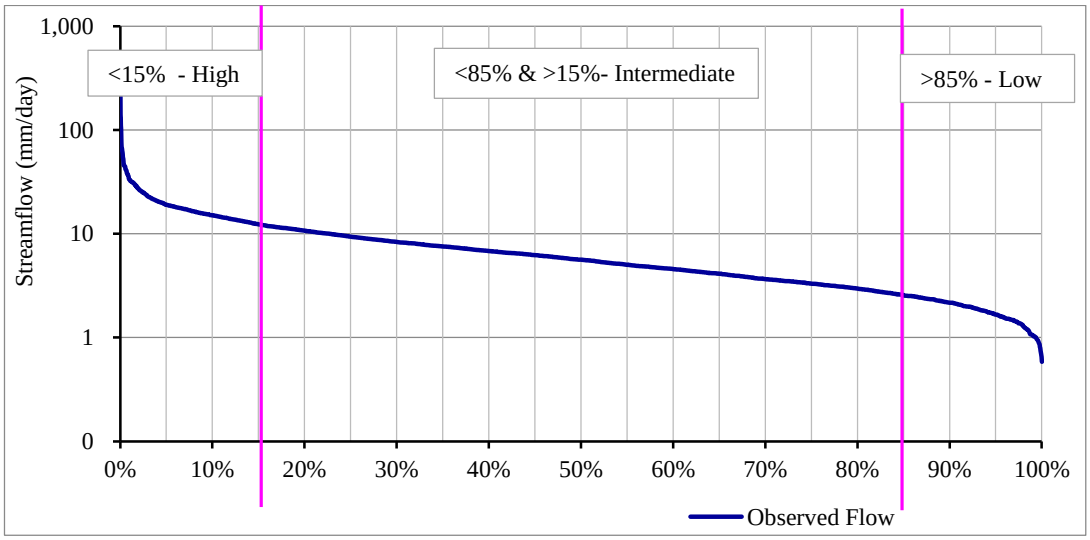

Figure D-6: Flow Duration Curve – Daily Scale - Tawalama Watershed (Log Scale)

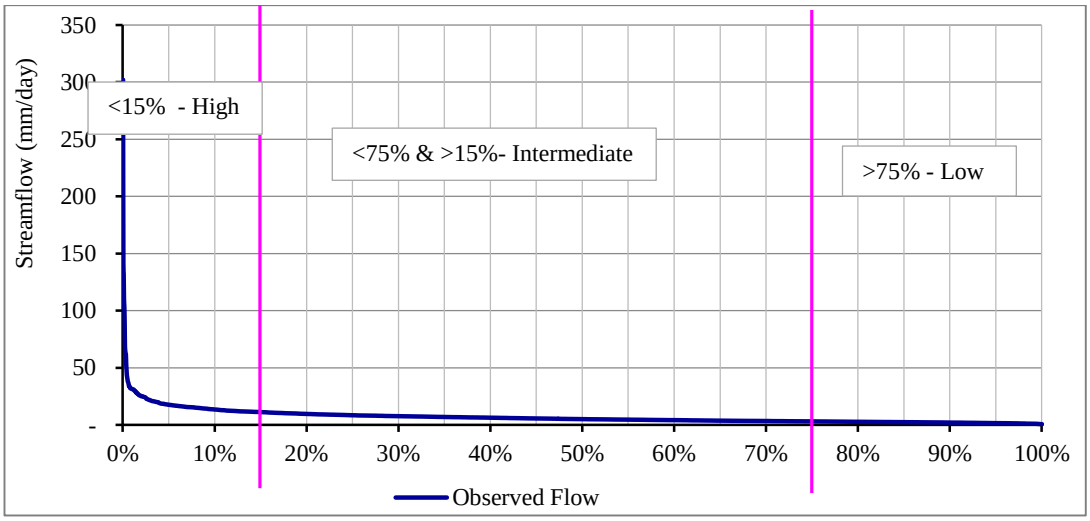

Figure D-7: Flow Duration Curve – Daily Scale - Ellagawa Watershed (Normal Scale)

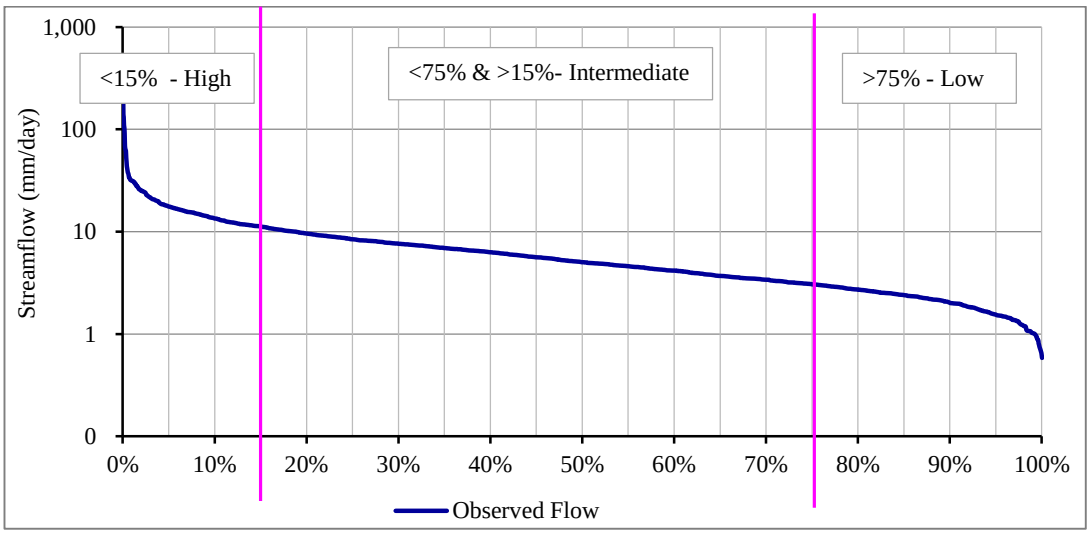

Figure D-8: Flow Duration Curve – Daily Scale - Ellagawa Watershed (Log Scale)

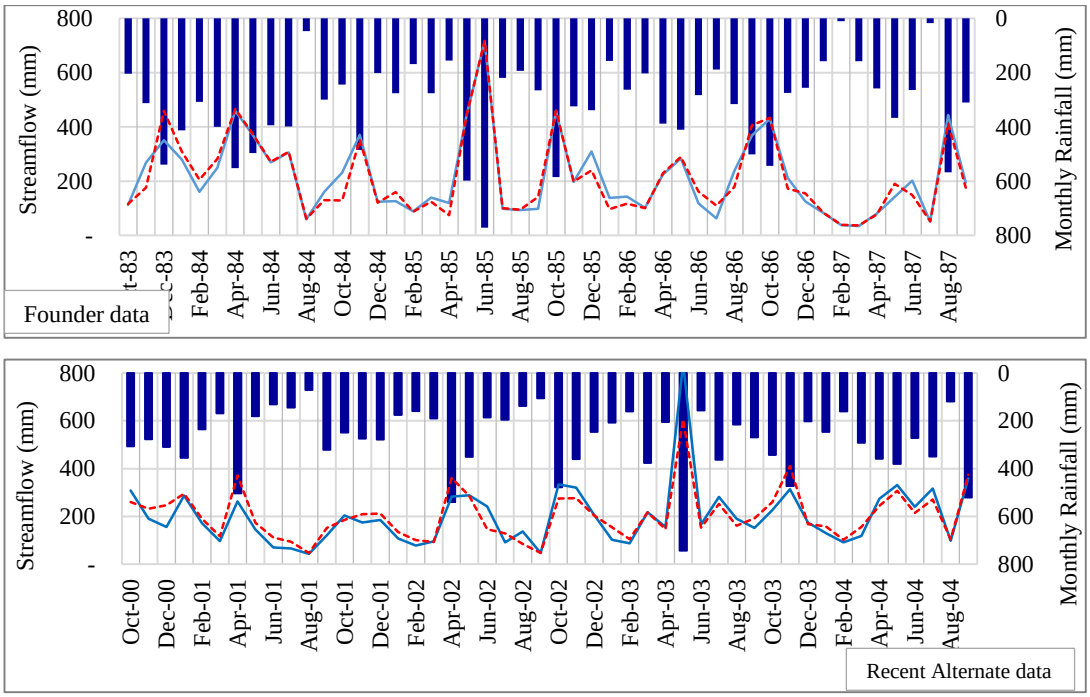

Figure D-9: Streamflow Comparison with Kandu.D.,(2016,unpuble) Model– Tawalama watershed – Founder and Alternate Data (Normal Scale)

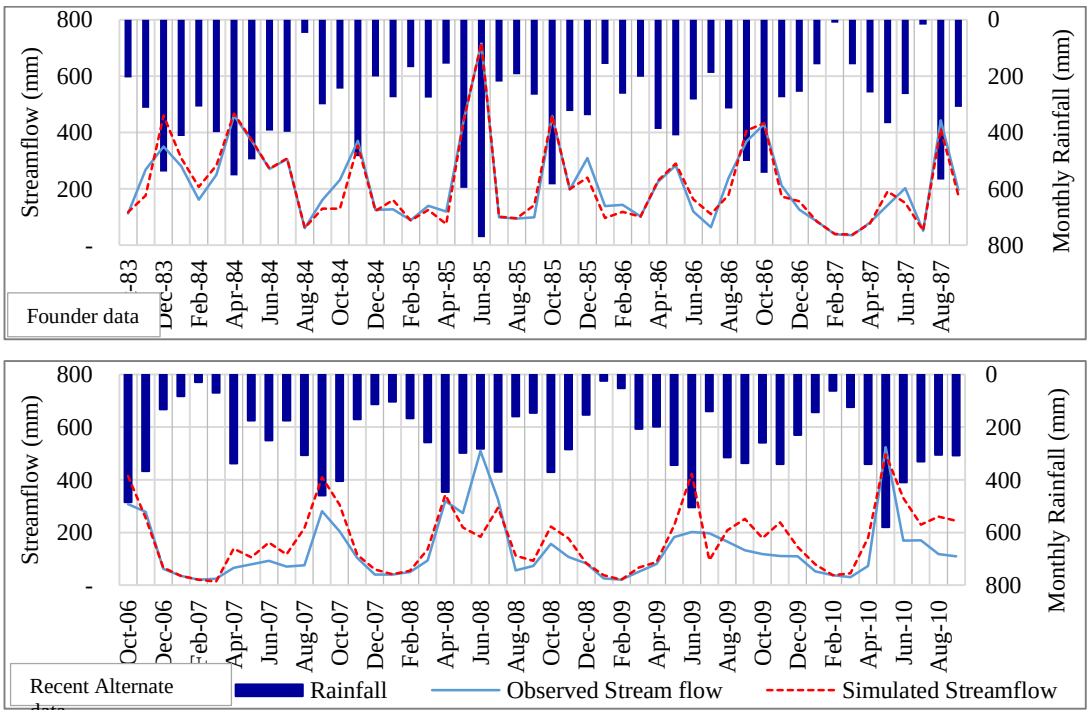

Figure D-10: Streamflow Comparison with Sariffi.M.B.,(2016,unpuble) Model– Ellagawa watershed – Founder and Alternate Data (Normal Scale)

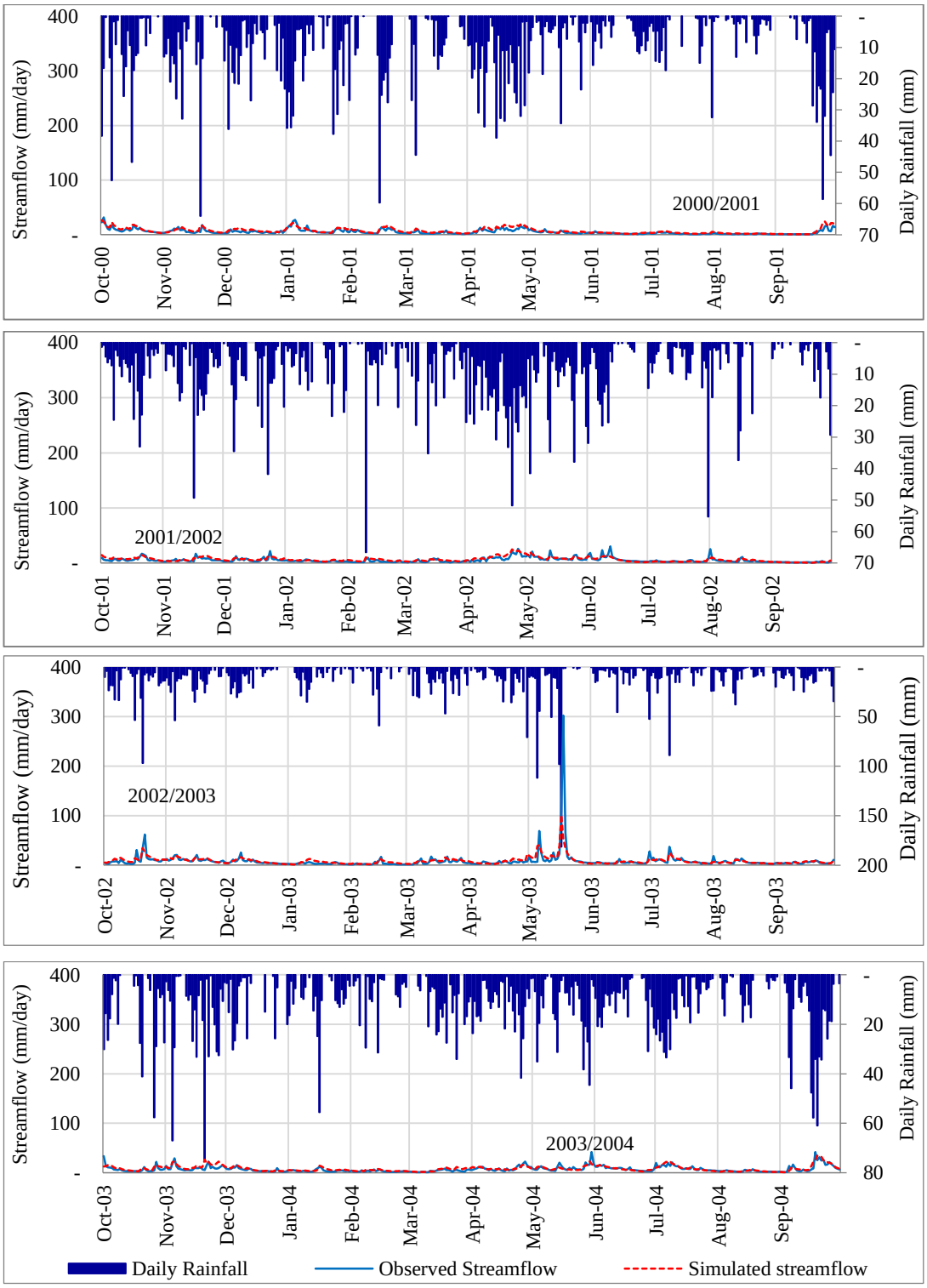

Figure D-11: Output hydrographs from 2PM (Daily) – with calibrated parameters – Calibration - Tawalama watershed (Normal Scale Plot)

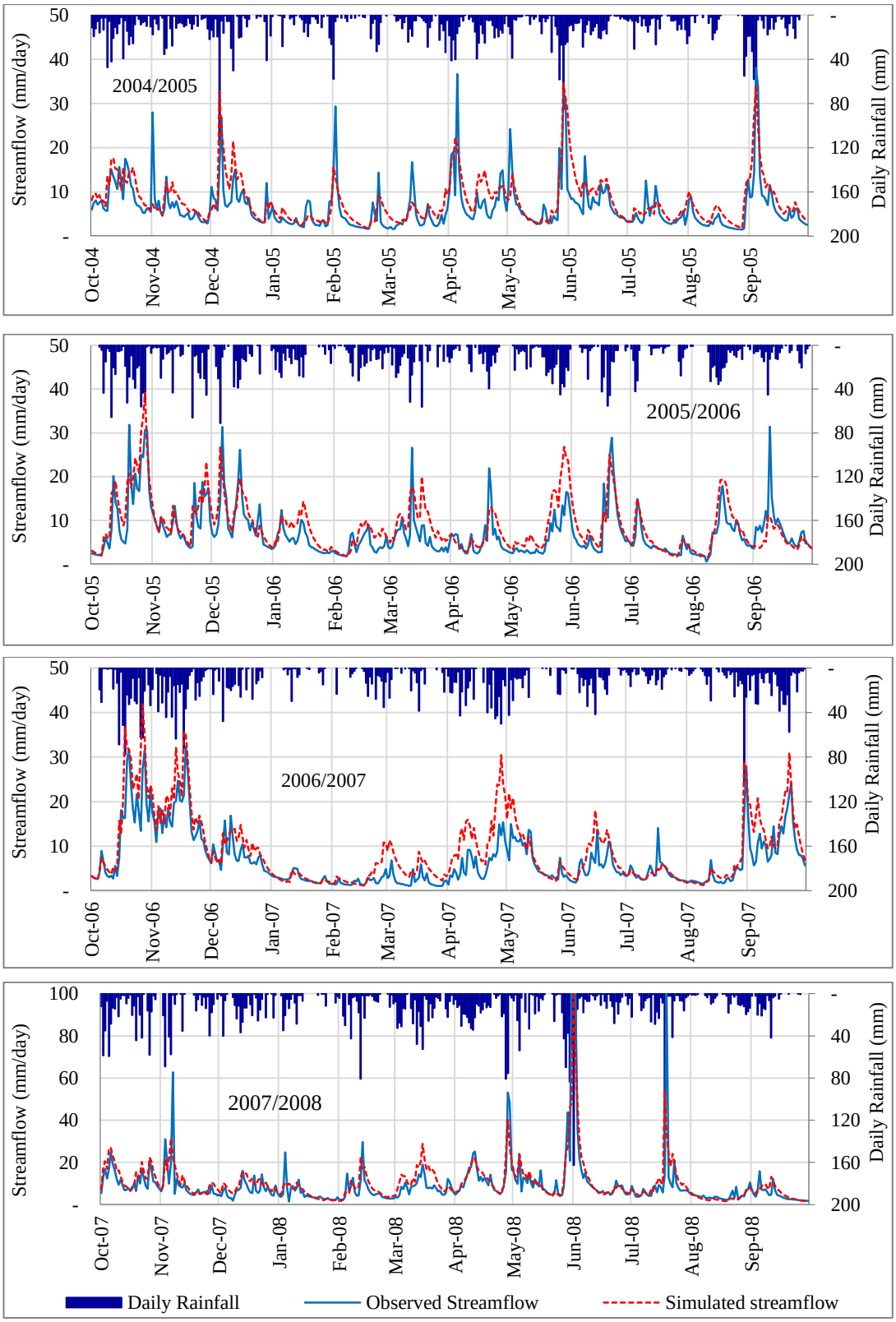

Figure D-12: Output hydrographs from 2PM (Daily) – with calibrated parameters – Calibration - Tawalama watershed (Normal Scale Plot)

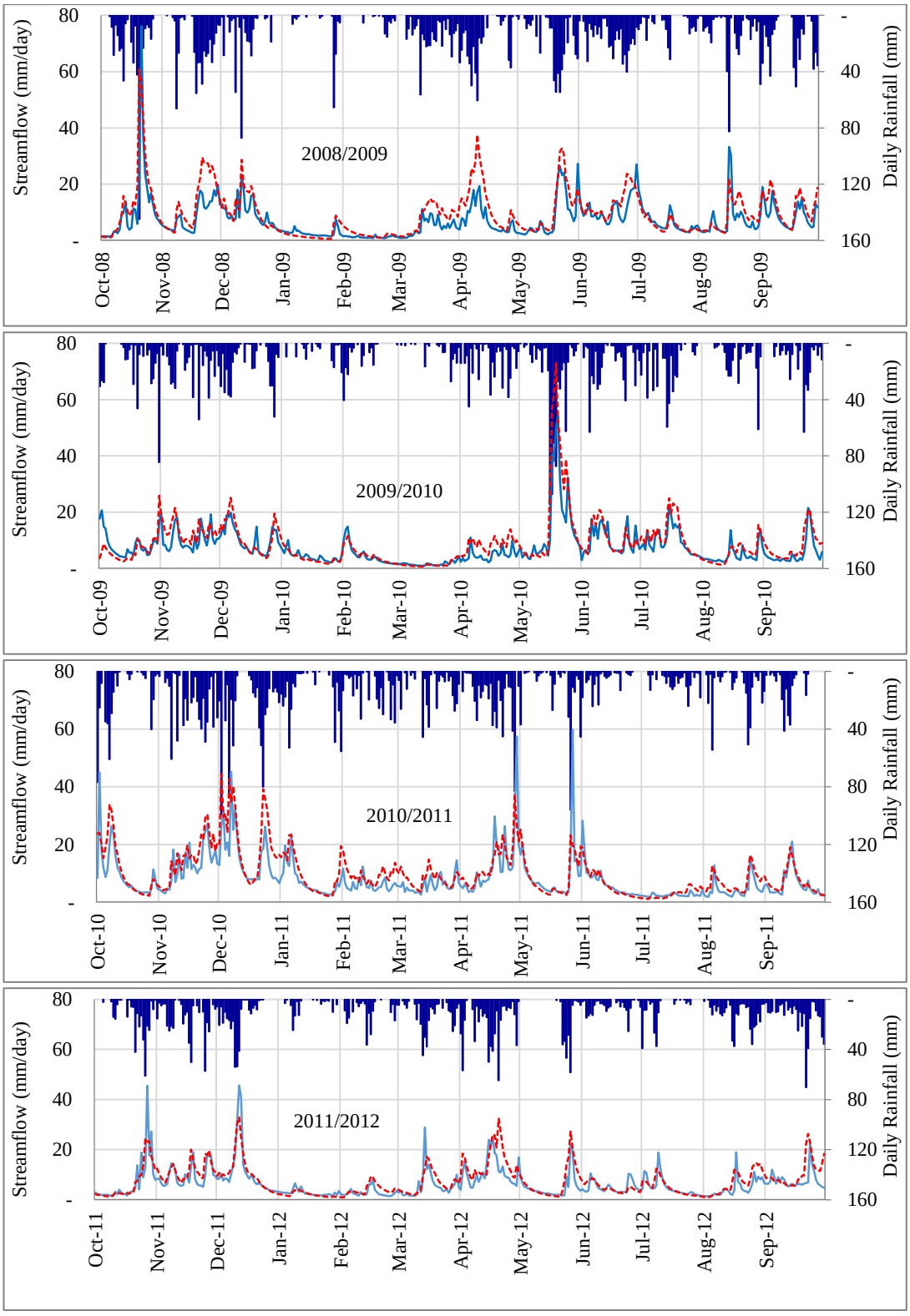

Figure D-13: Output hydrographs from 2PM (Daily) –Verification - Tawalama watershed (Normal Scale Plot)

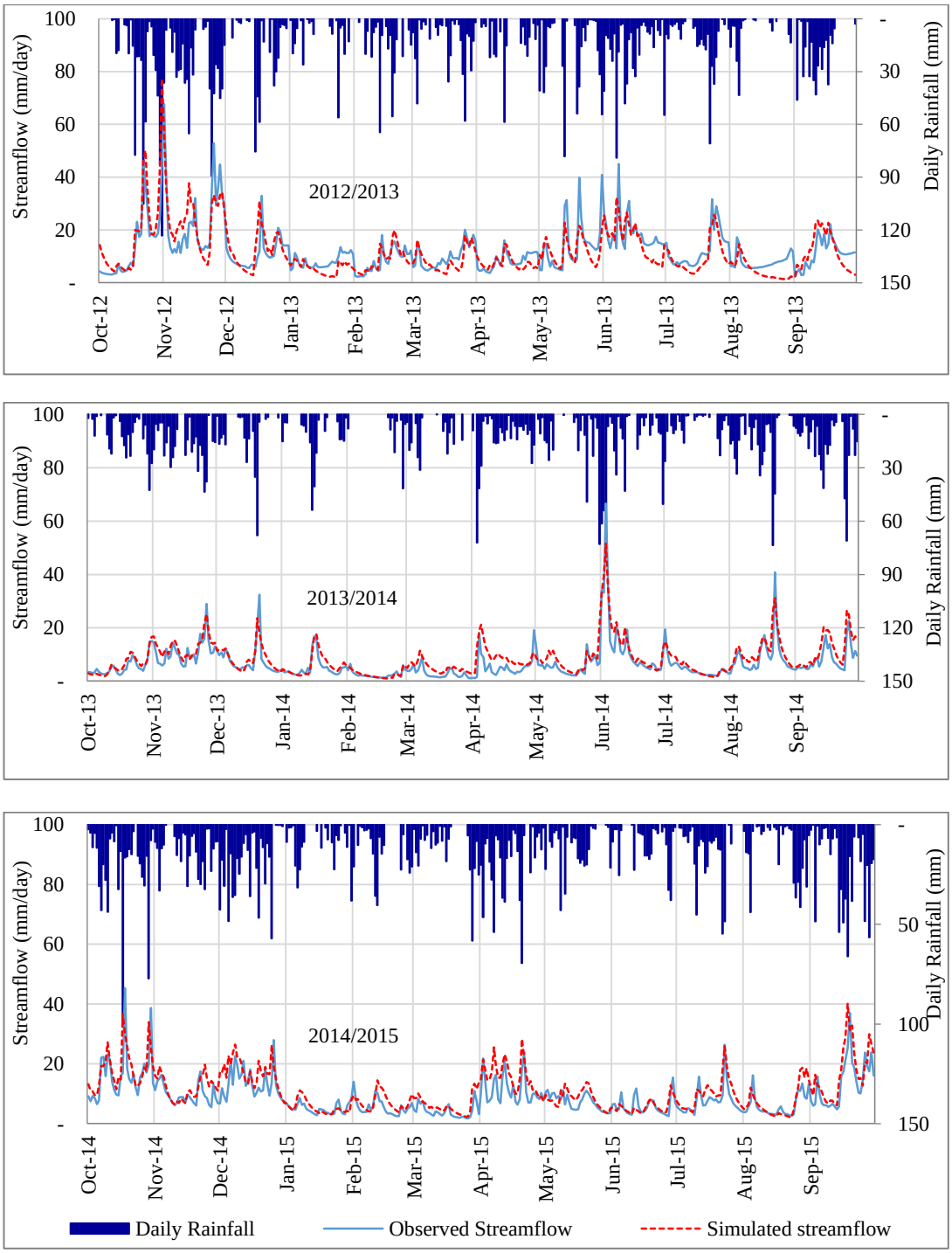

Figure D-14: Output hydrographs from 2PM (Daily) –Verification - Tawalama watershed (Normal Scale Plot)

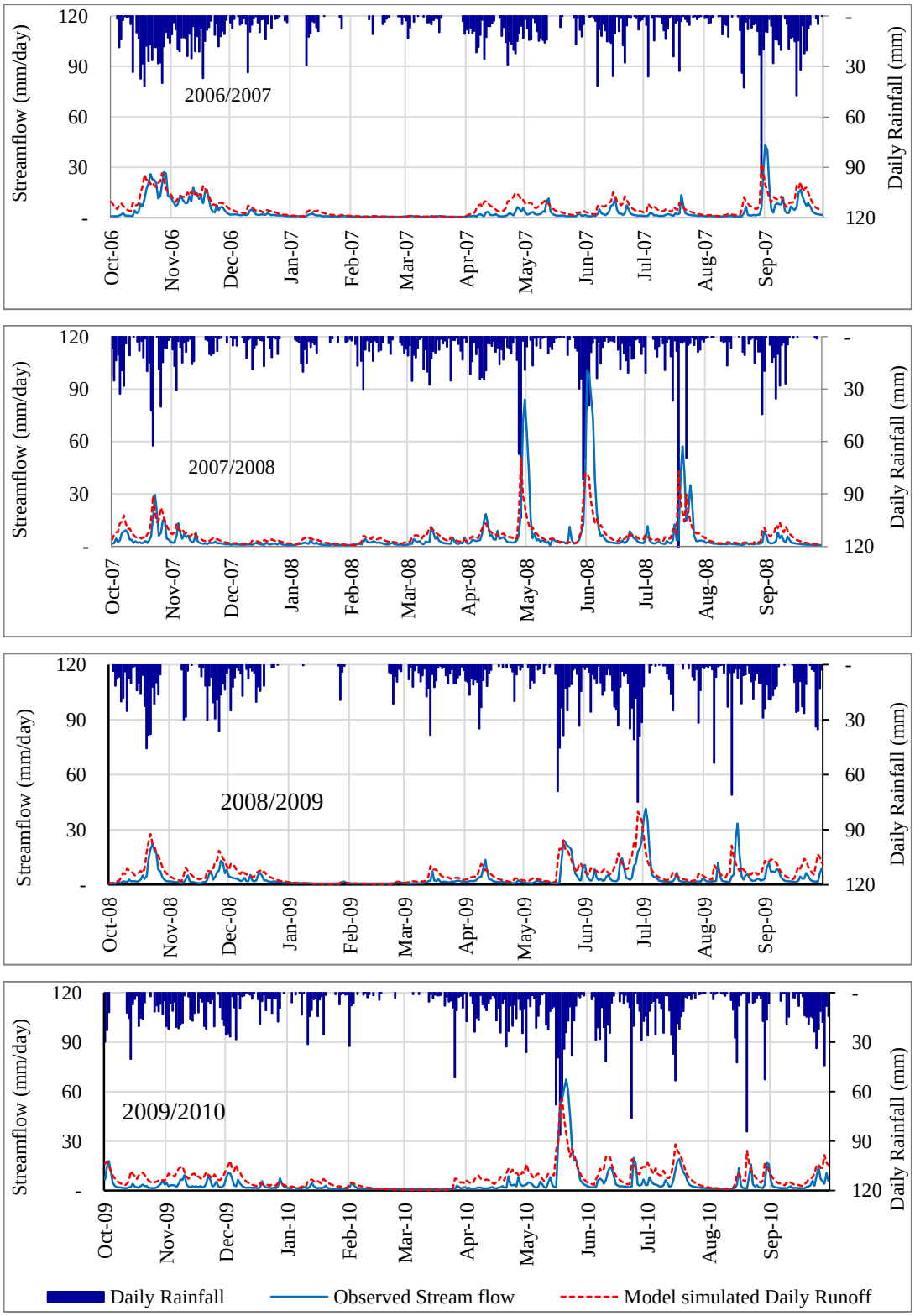

Figure D-15: Output hydrographs from 2PM (Daily) – with calibrated parameters – Calibration - Ellagawa watershed (Normal Scale Plot)

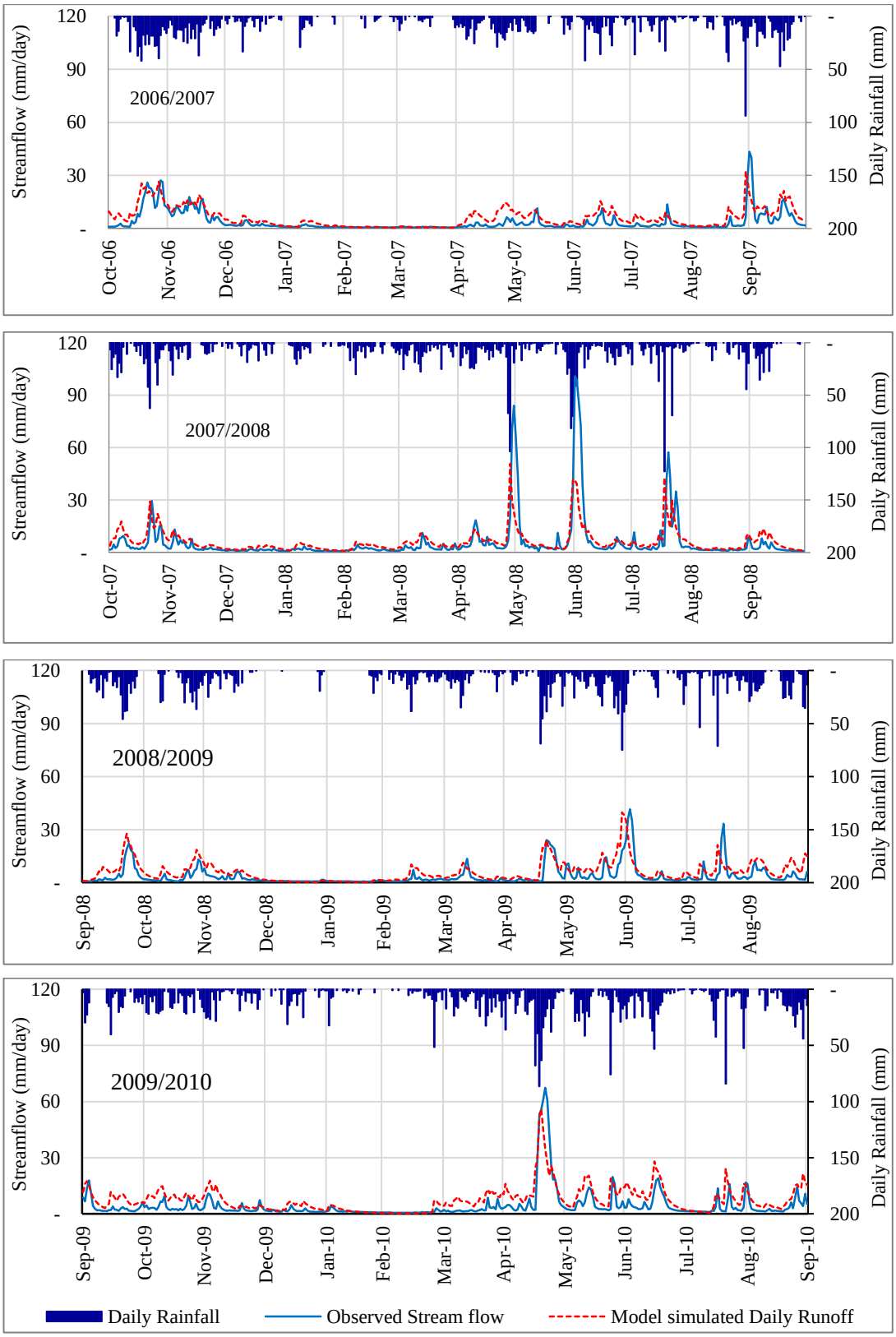

Figure D-16: Output hydrographs from 2PM (Daily) – Calibration - Ellagawa watershed (Normal Scale Plot)

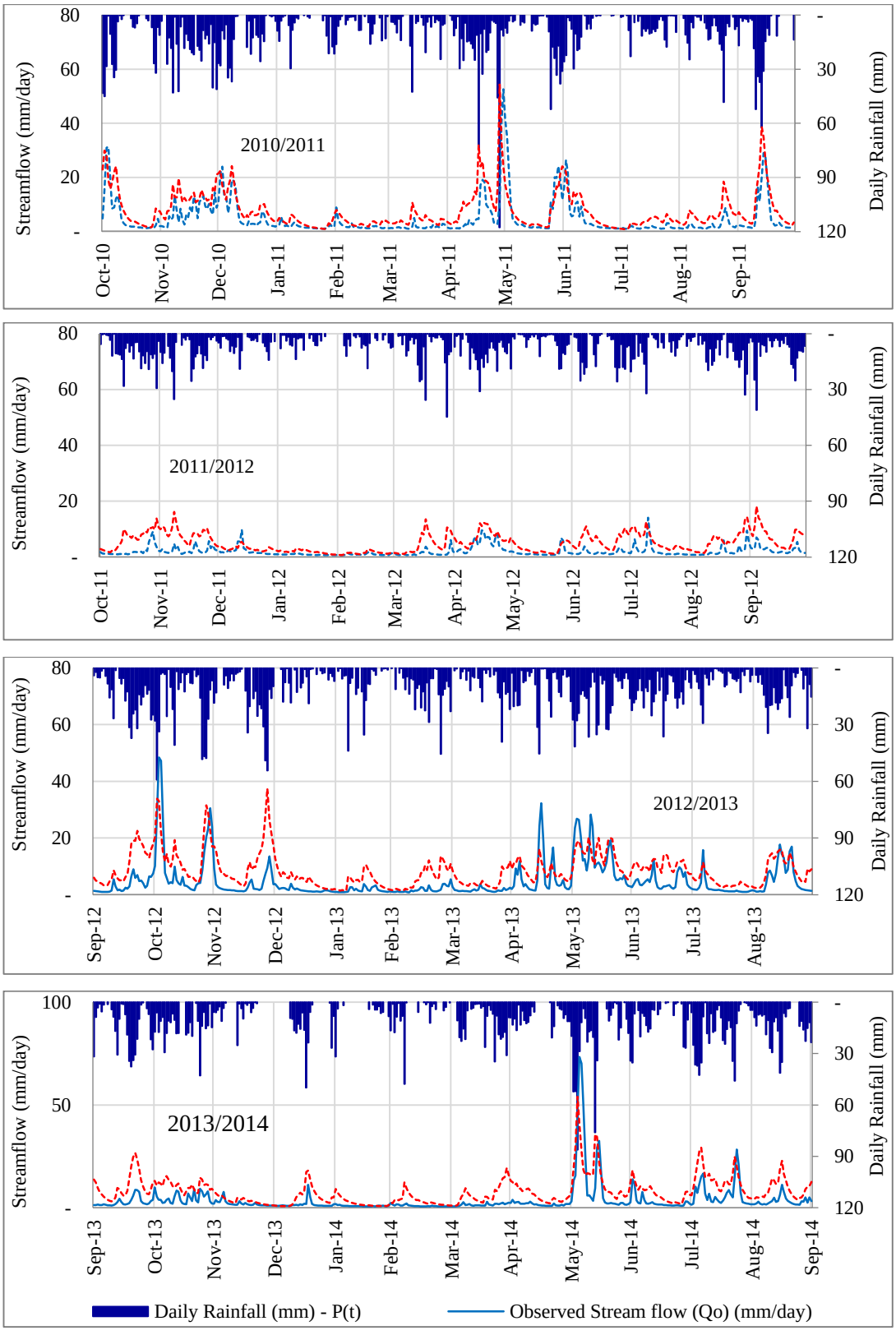

Figure D-17: Output hydrographs from 2PM (Daily) – with calibrated parameters – Validation - Ellagawa watershed (Normal Scale Plot)

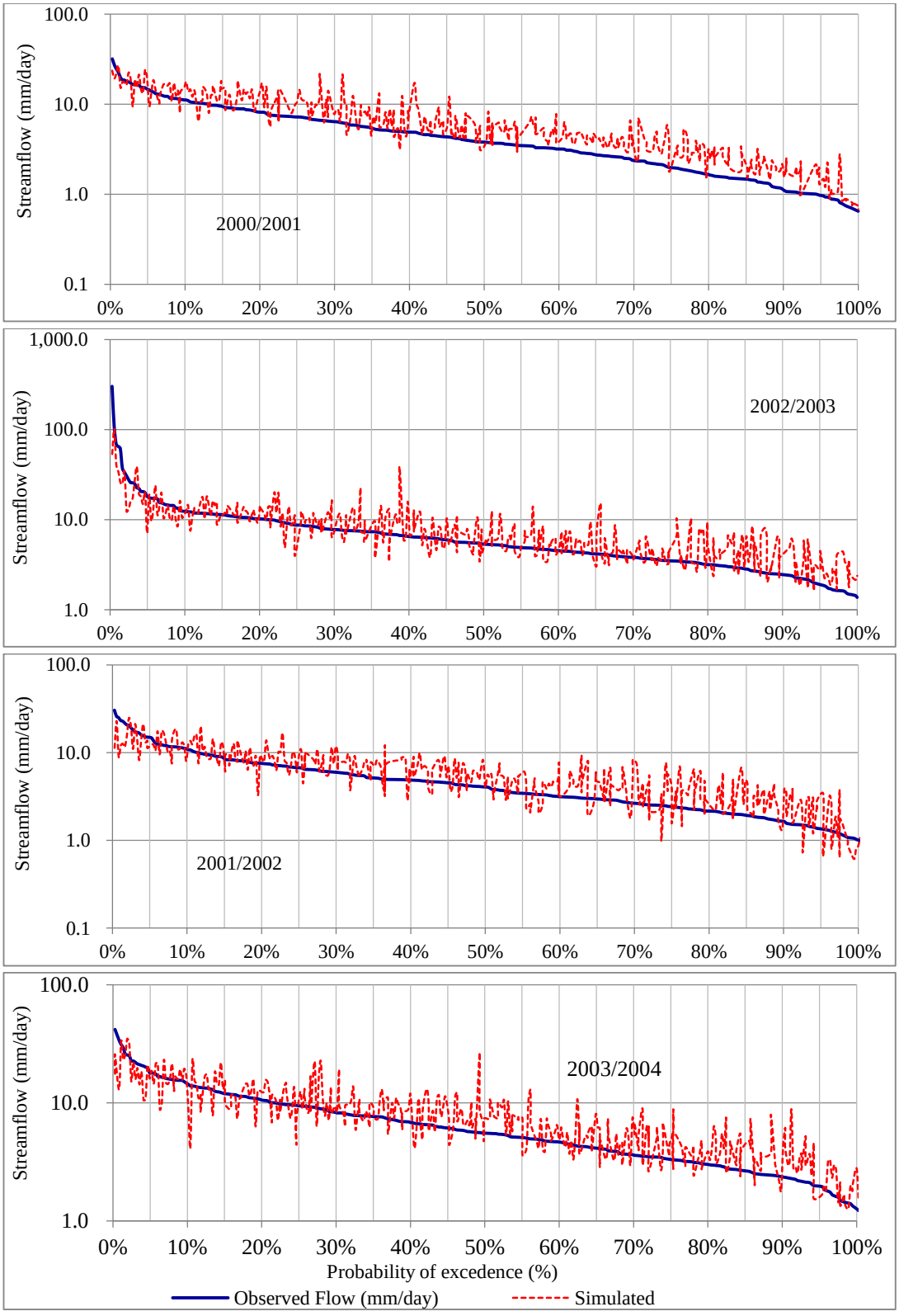

Figure D-18: Flow duration curves for 2PM (Daily) – with calibrated parameters – Calibration - Tawalama watershed (Log Scale Plot)

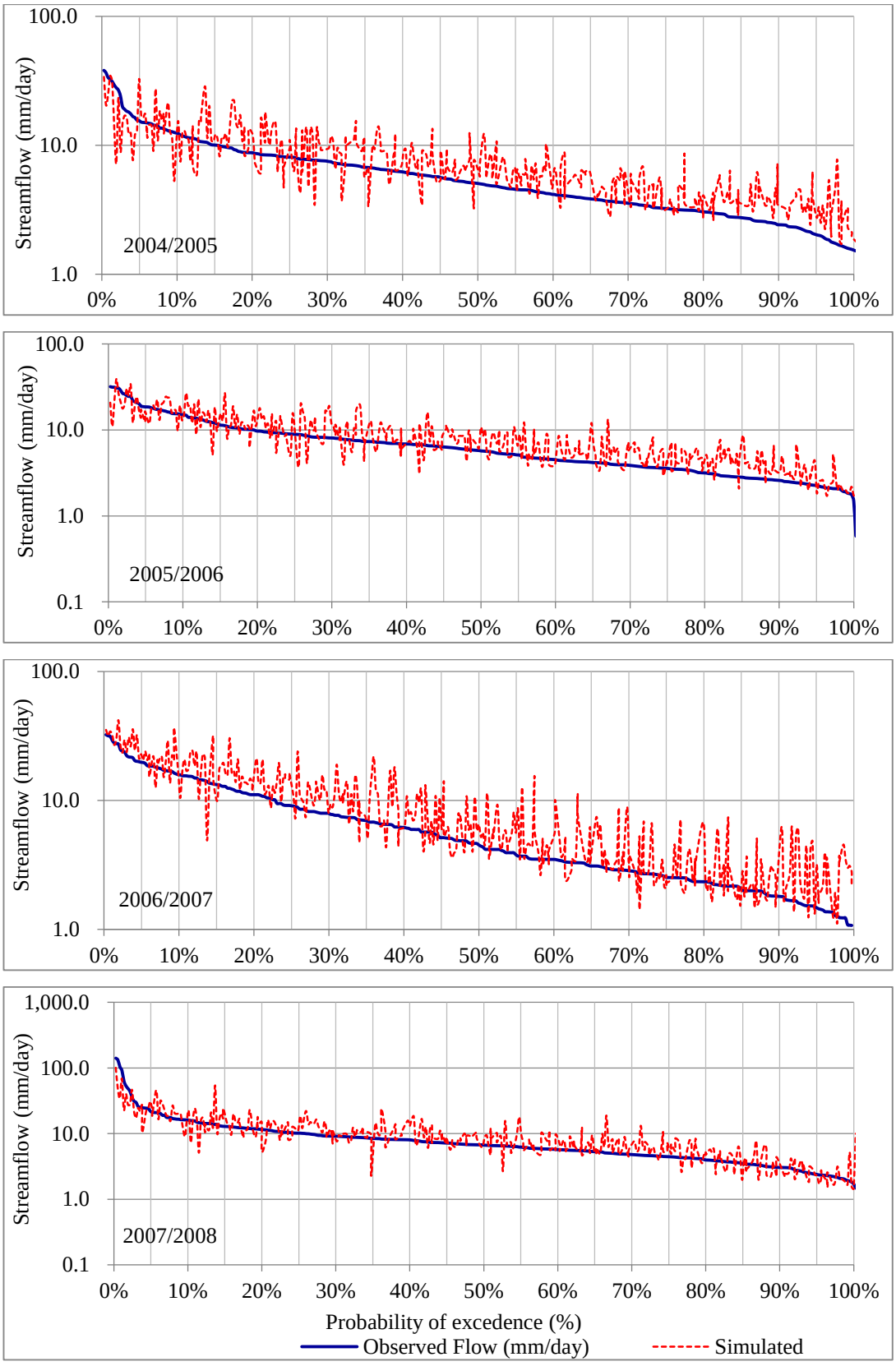

Figure D-19: Flow Duration Curves for 2PM (Daily) – with calibrated parameters – Calibration - Tawalama watershed (Log Scale Plot)

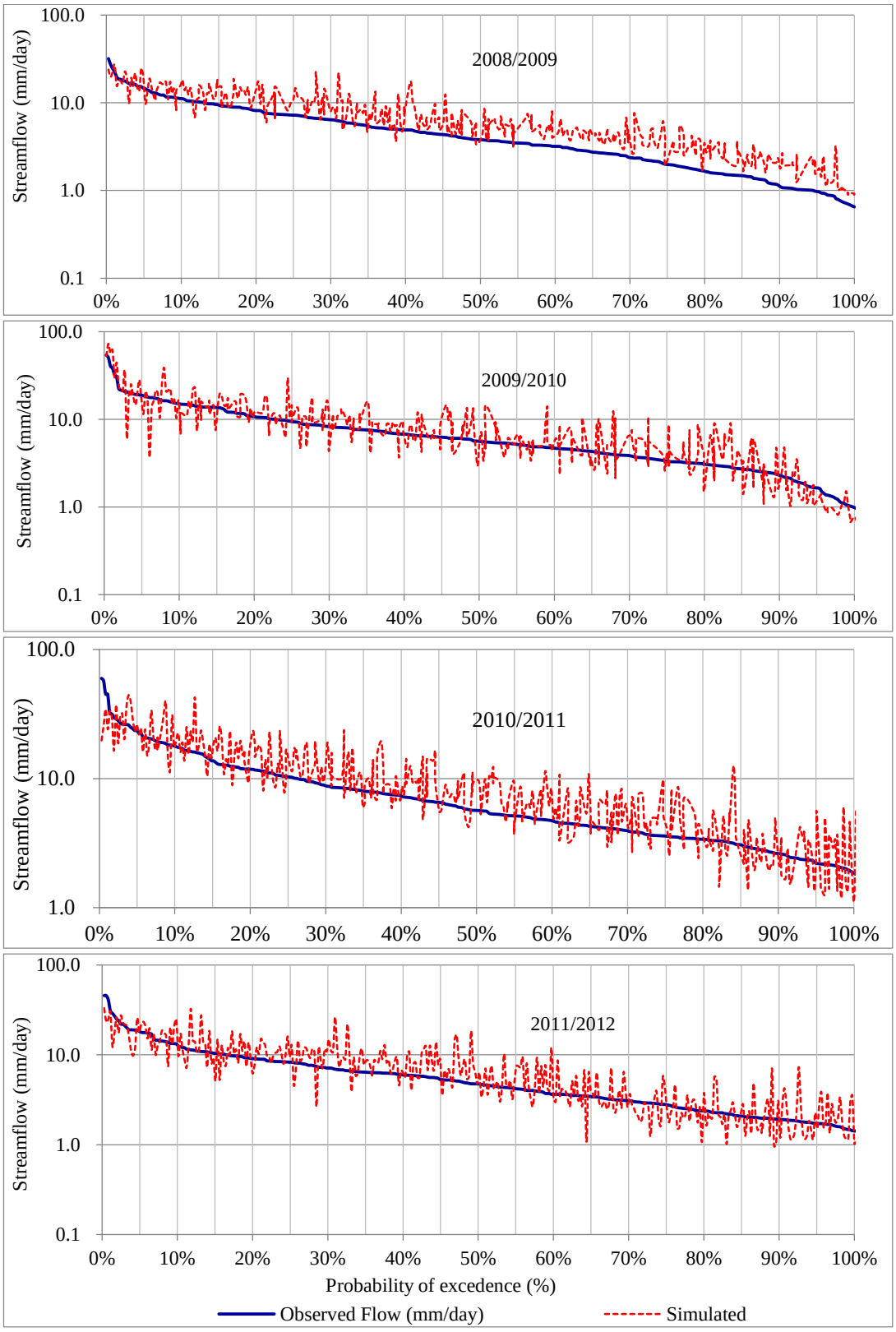

Figure D-20: Flow Duration Curves for 2PM (Daily) – with calibrated parameters – Validation - Tawalama watershed (Log Scale Plot)

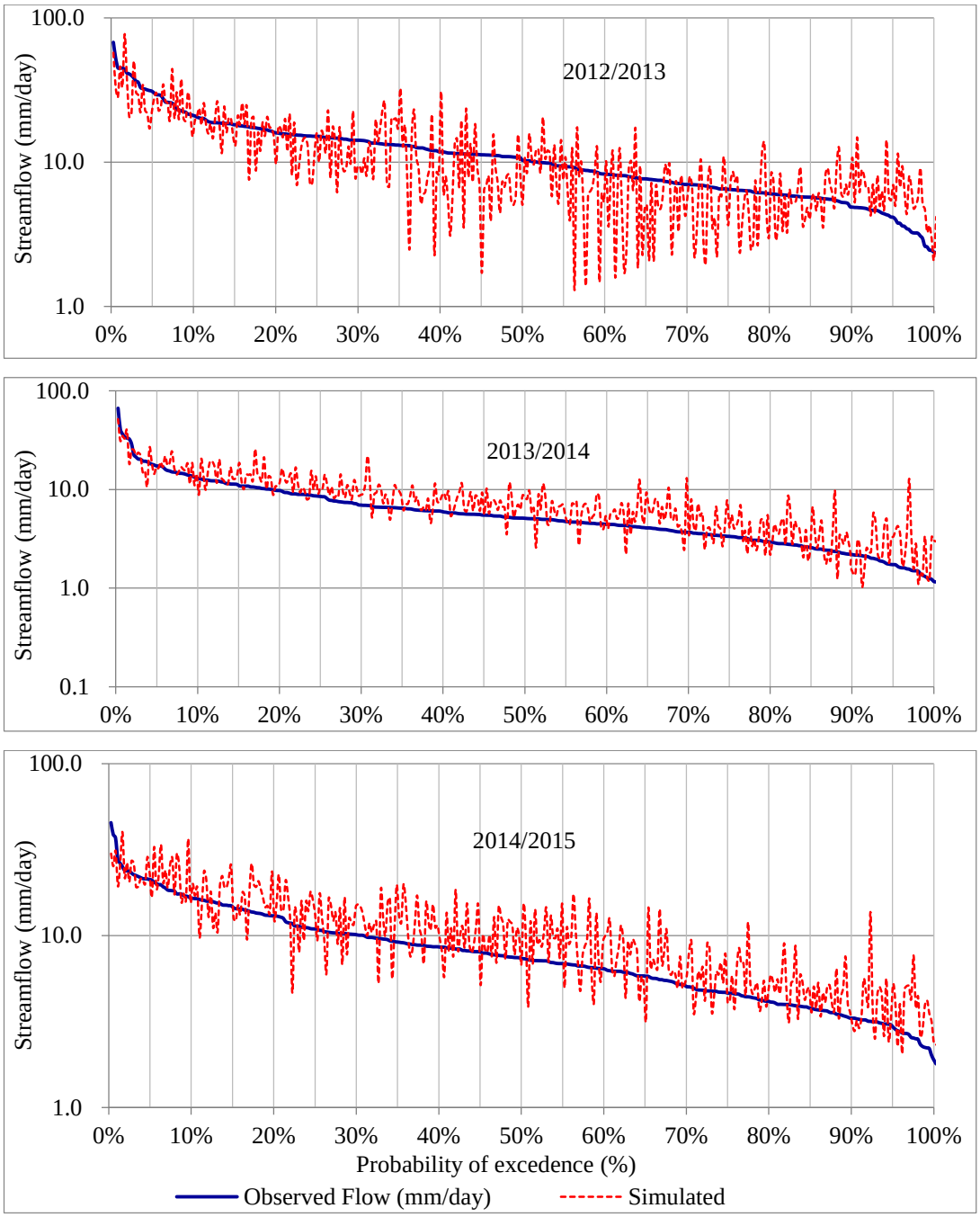

Figure D-21: Flow Duration Curves for 2PM (Daily) – with calibrated parameters – Validation - Tawalama watershed (Log Scale Plot)

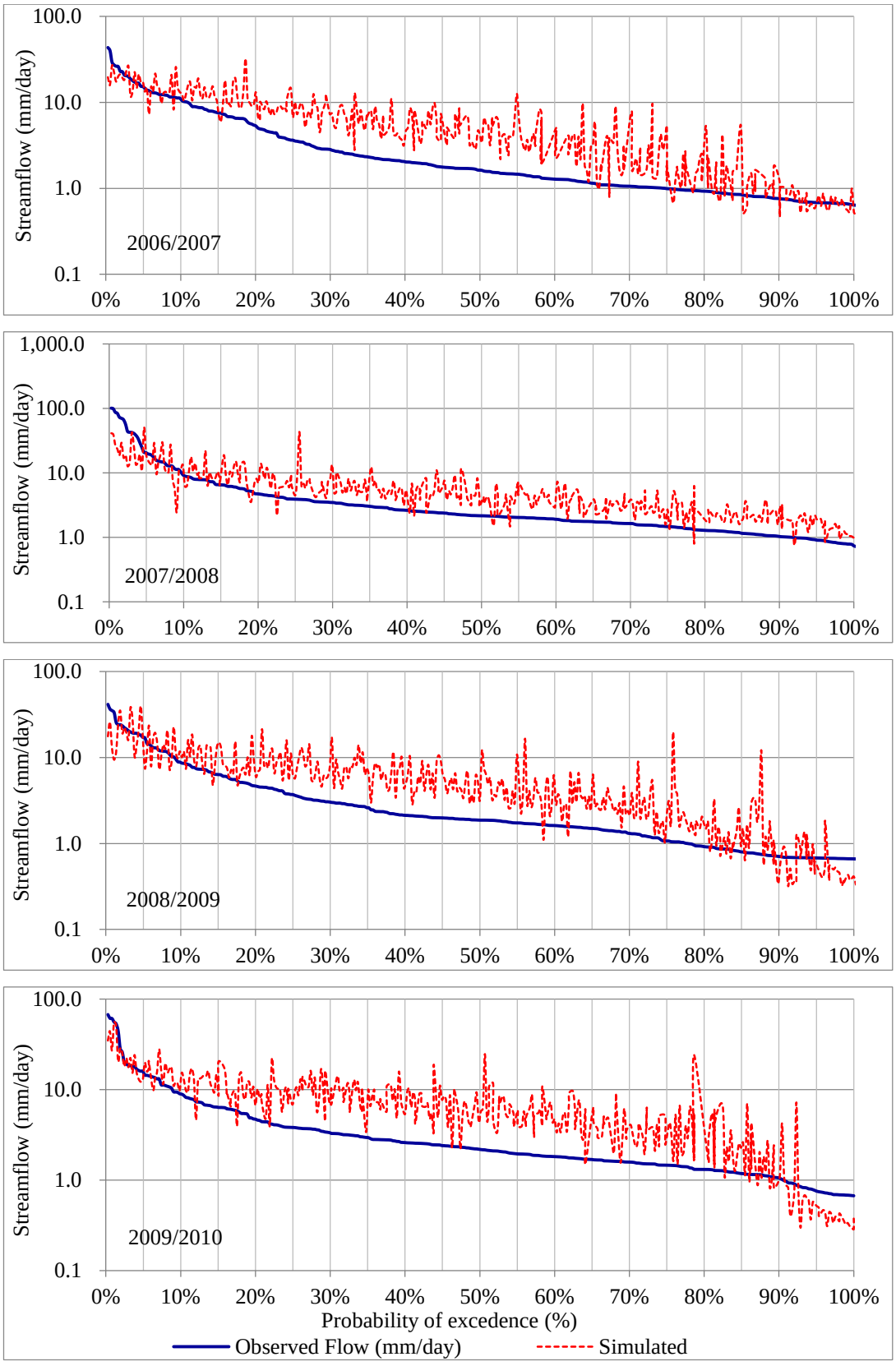

Figure D-22: Flow Duration Curves for 2PM (Daily) – with calibrated parameters – Calibration - Ellagawa watershed (Log Scale Plot)

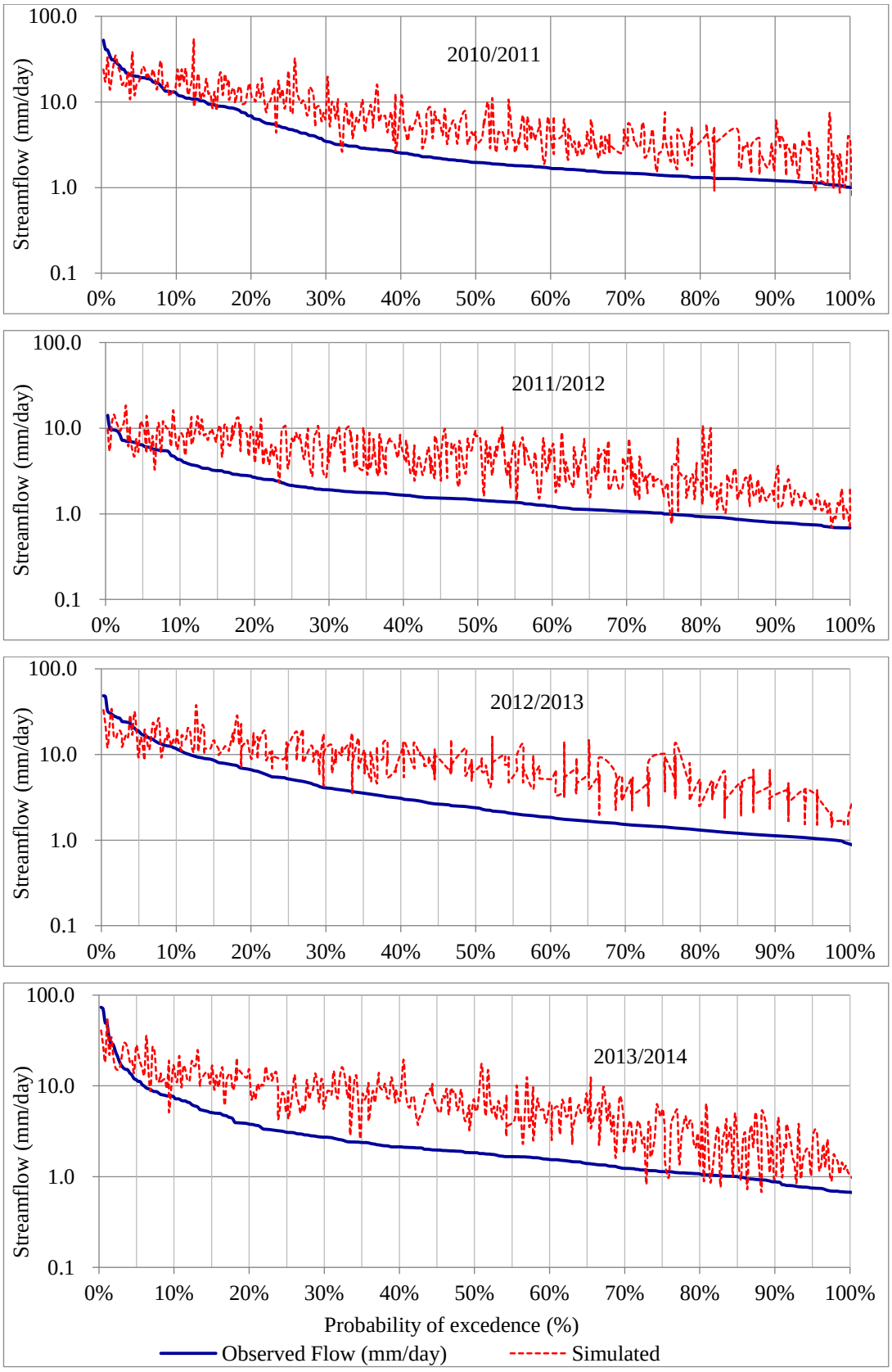

Figure D-23: Flow Duration Curves for 2PM (Daily) – with calibrated parameters – Validation - Ellagawa watershed (Log Scale Plot)

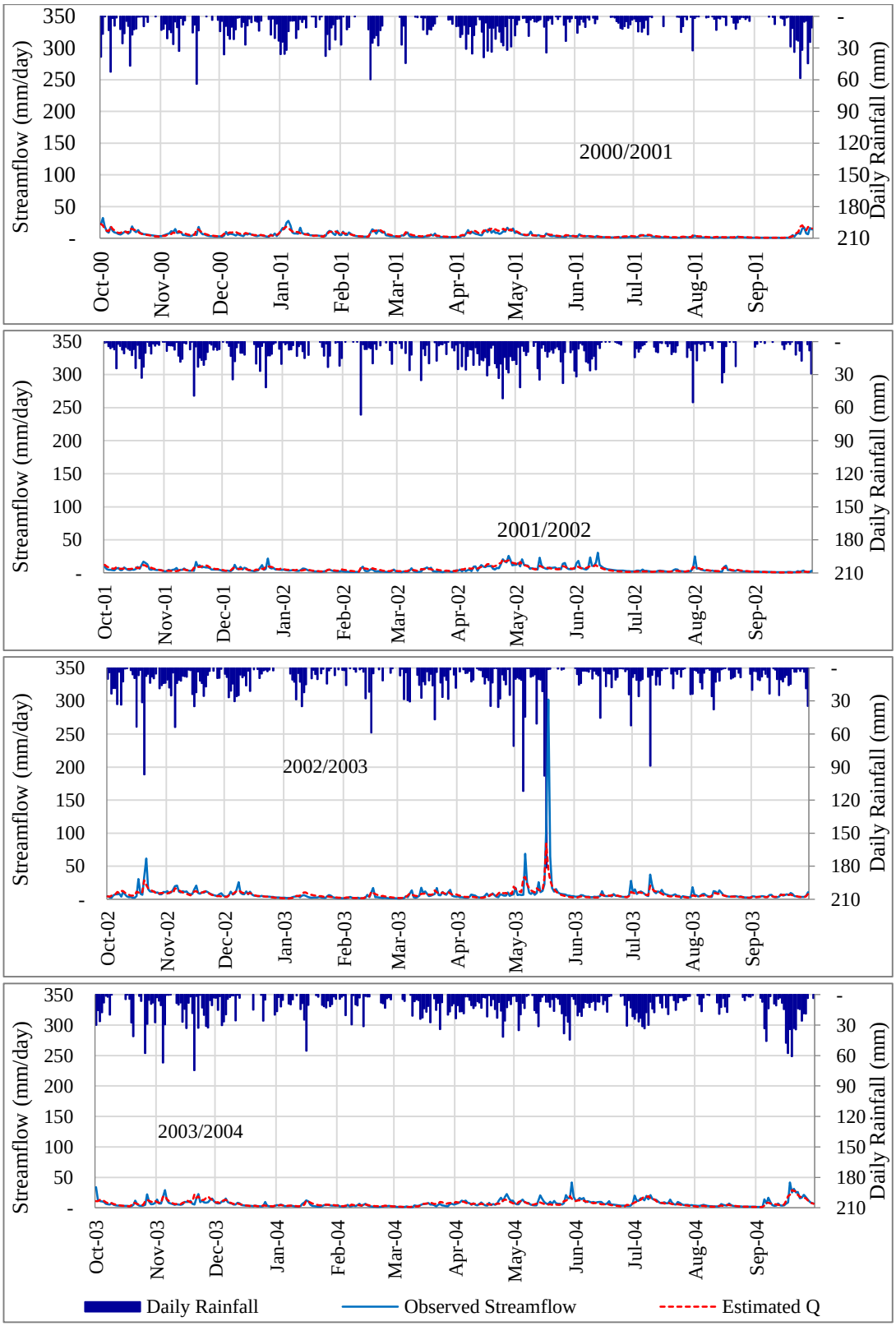

Figure D-24: Output hydrographs for 3PM (Daily) – Calibration - Tawalama watershed (Log Scale Plot)

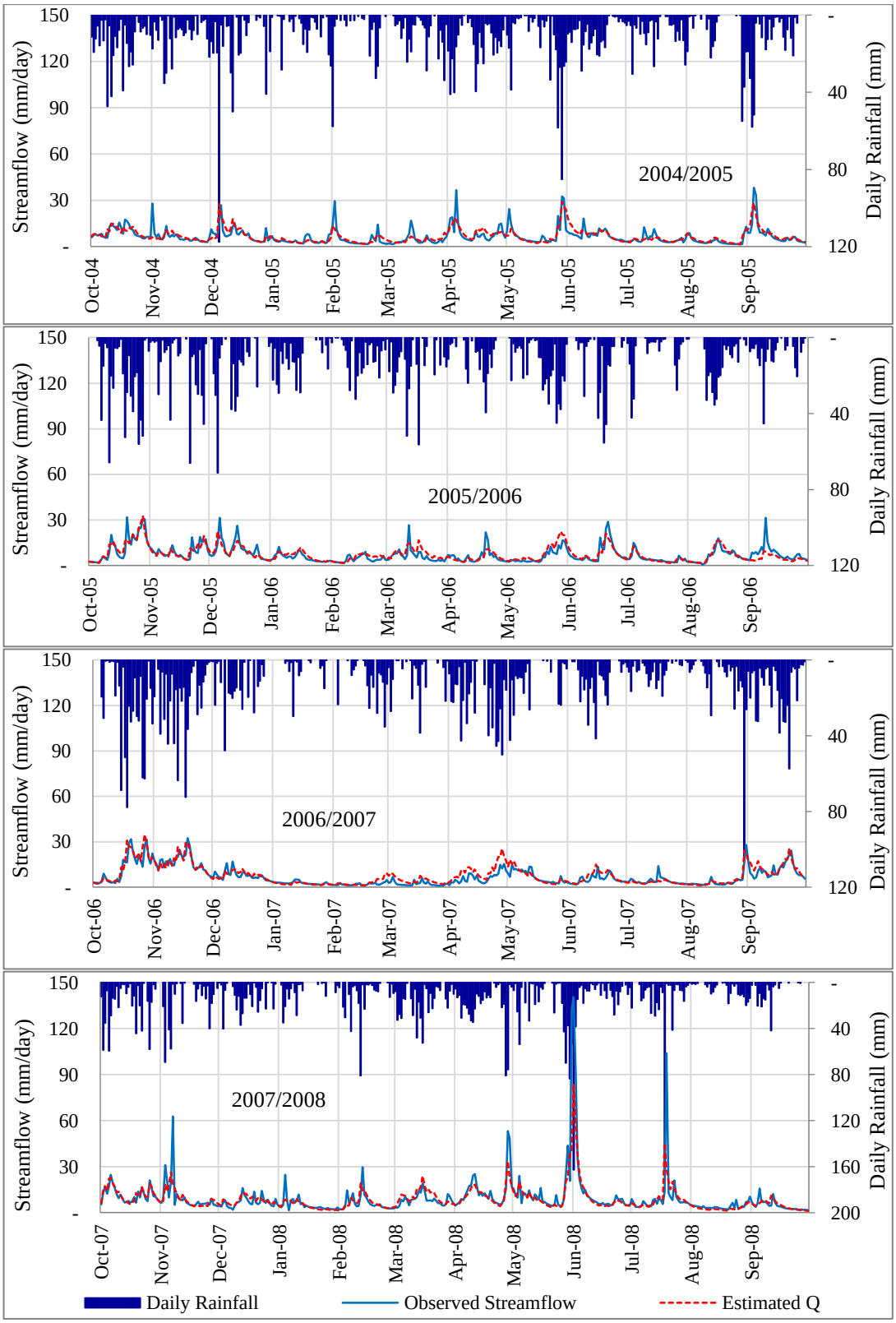

Figure D-25: Output hydrographs for 3PM (Daily) – Calibration - Tawalama watershed (Log Scale Plot)

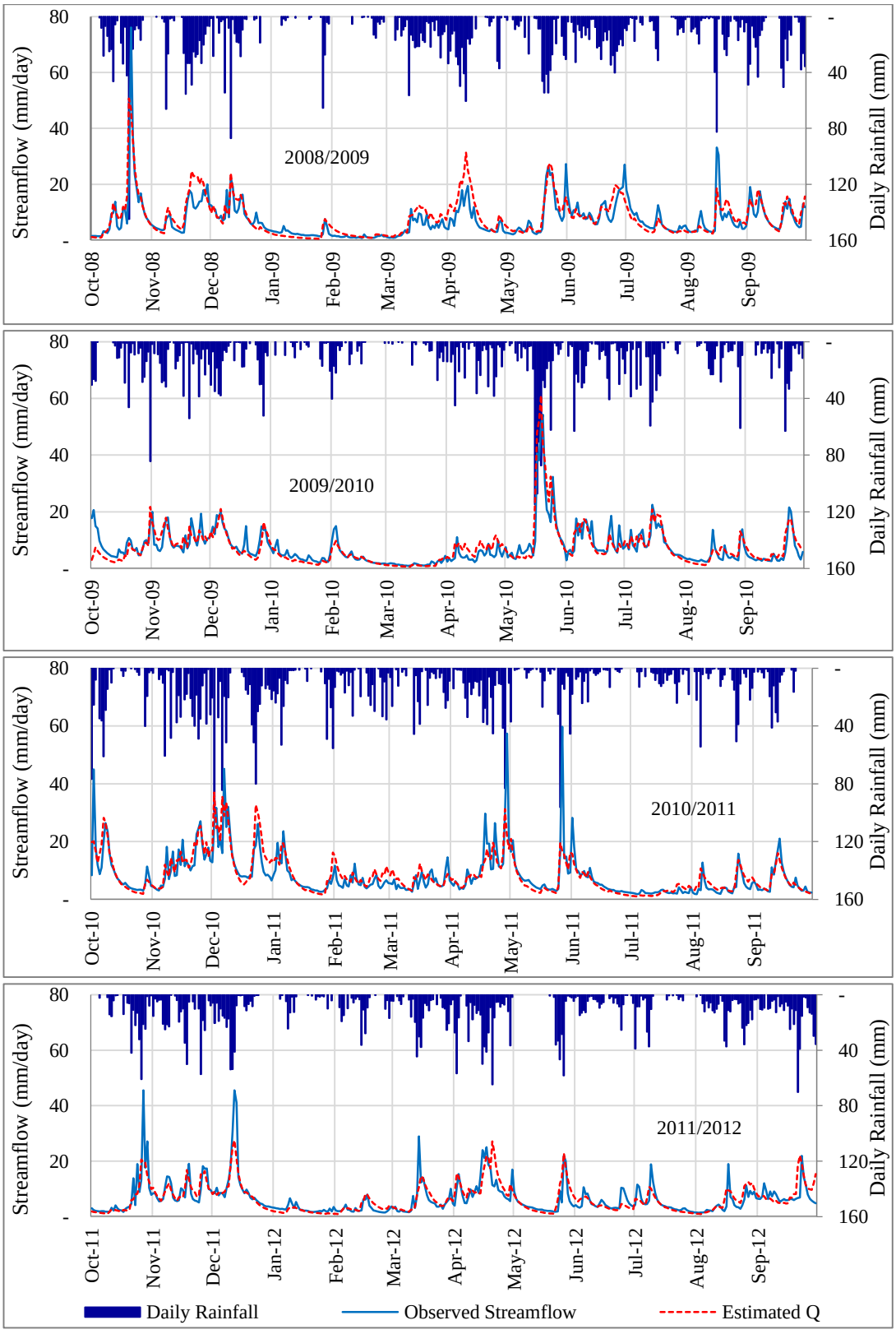

Figure D-26: Output hydrographs for 3PM (Daily) – Verification - Tawalama watershed (Normal Scale Plot)

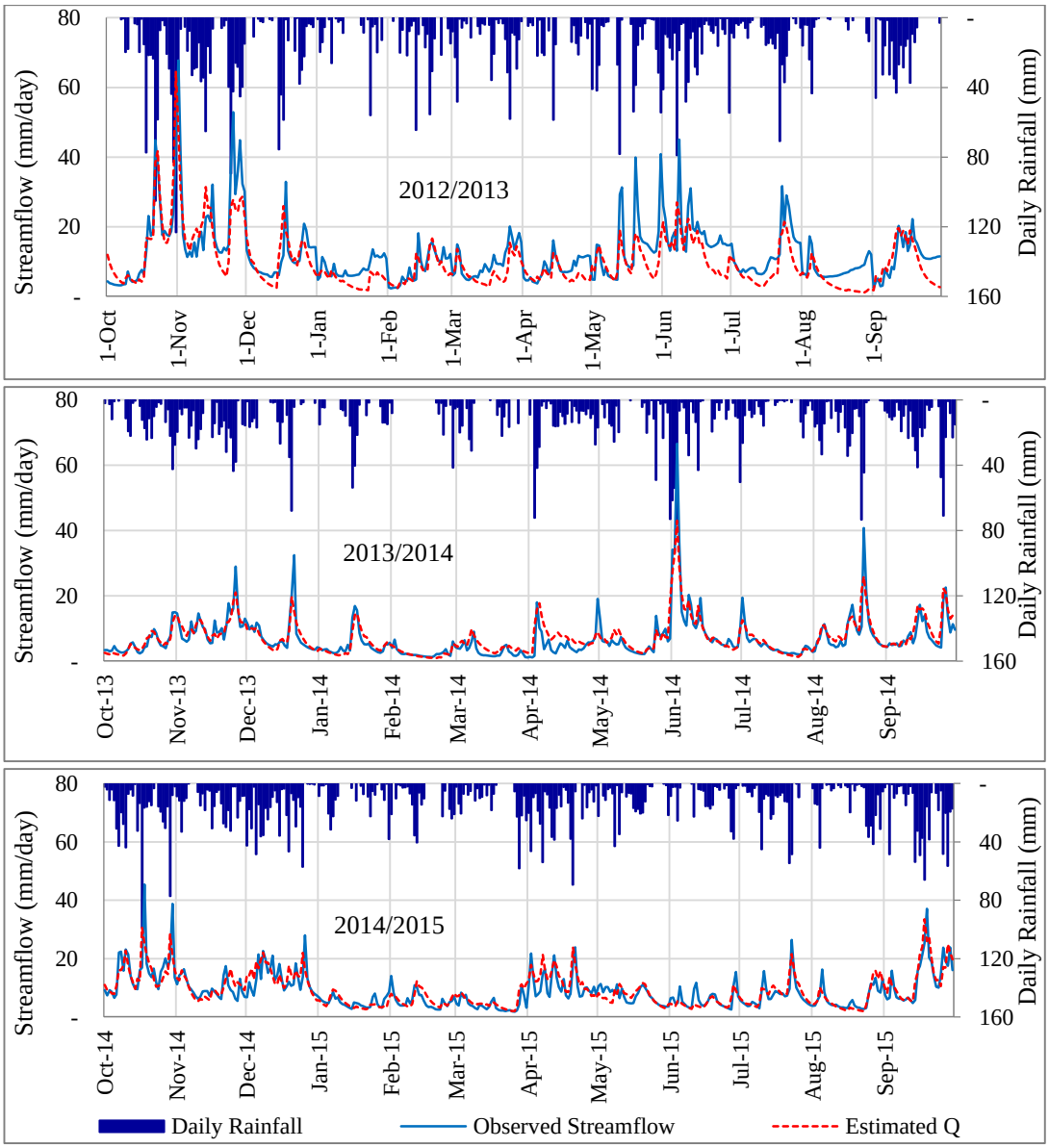

Figure D-27: Output hydrographs for 3PM (Daily) – Verification - Tawalama watershed (Normal Scale Plot)

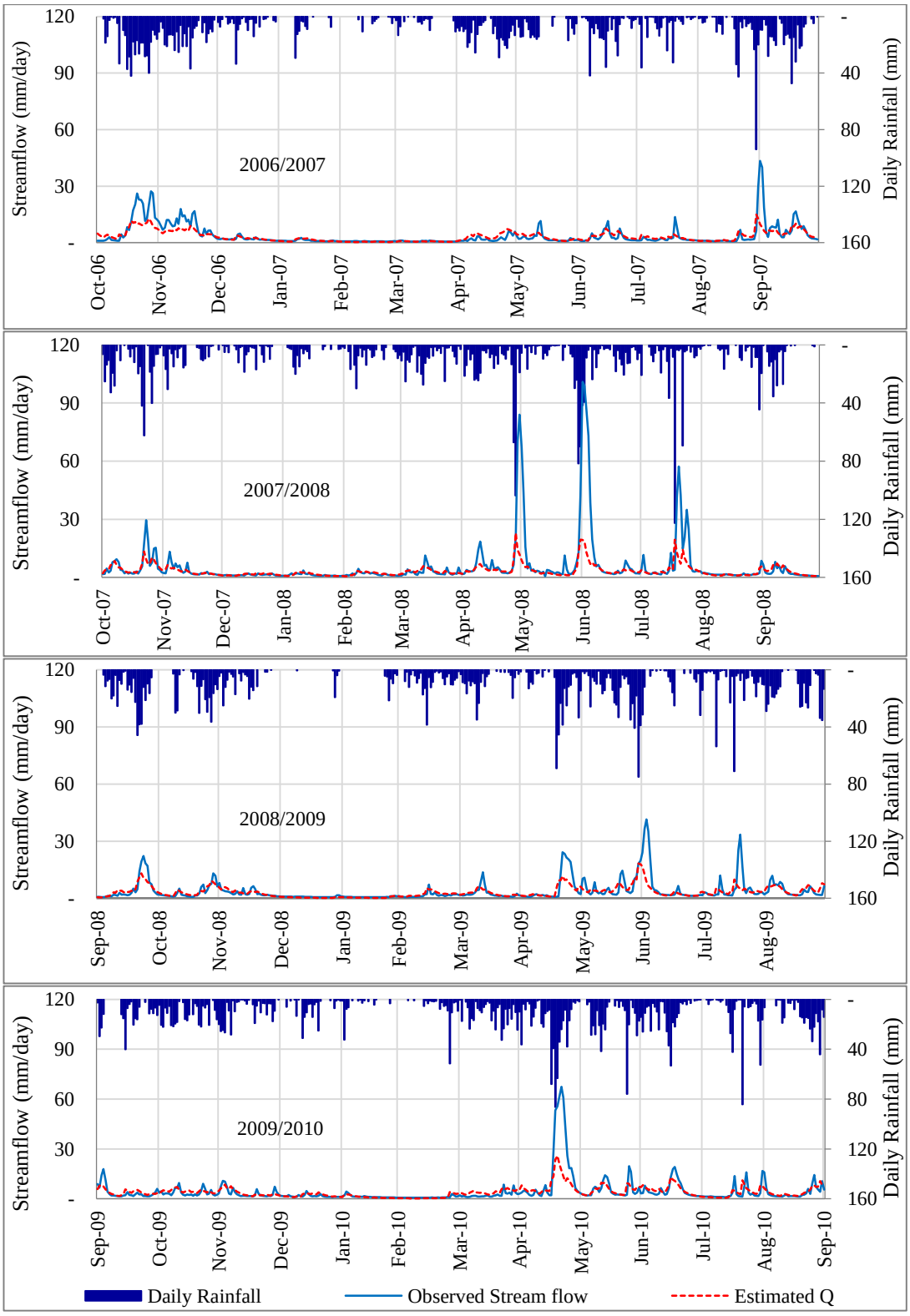

Figure D-28: Output hydrographs for 3PM (Daily) – Calibration - Ellagawa watershed (Normal Scale Plot)

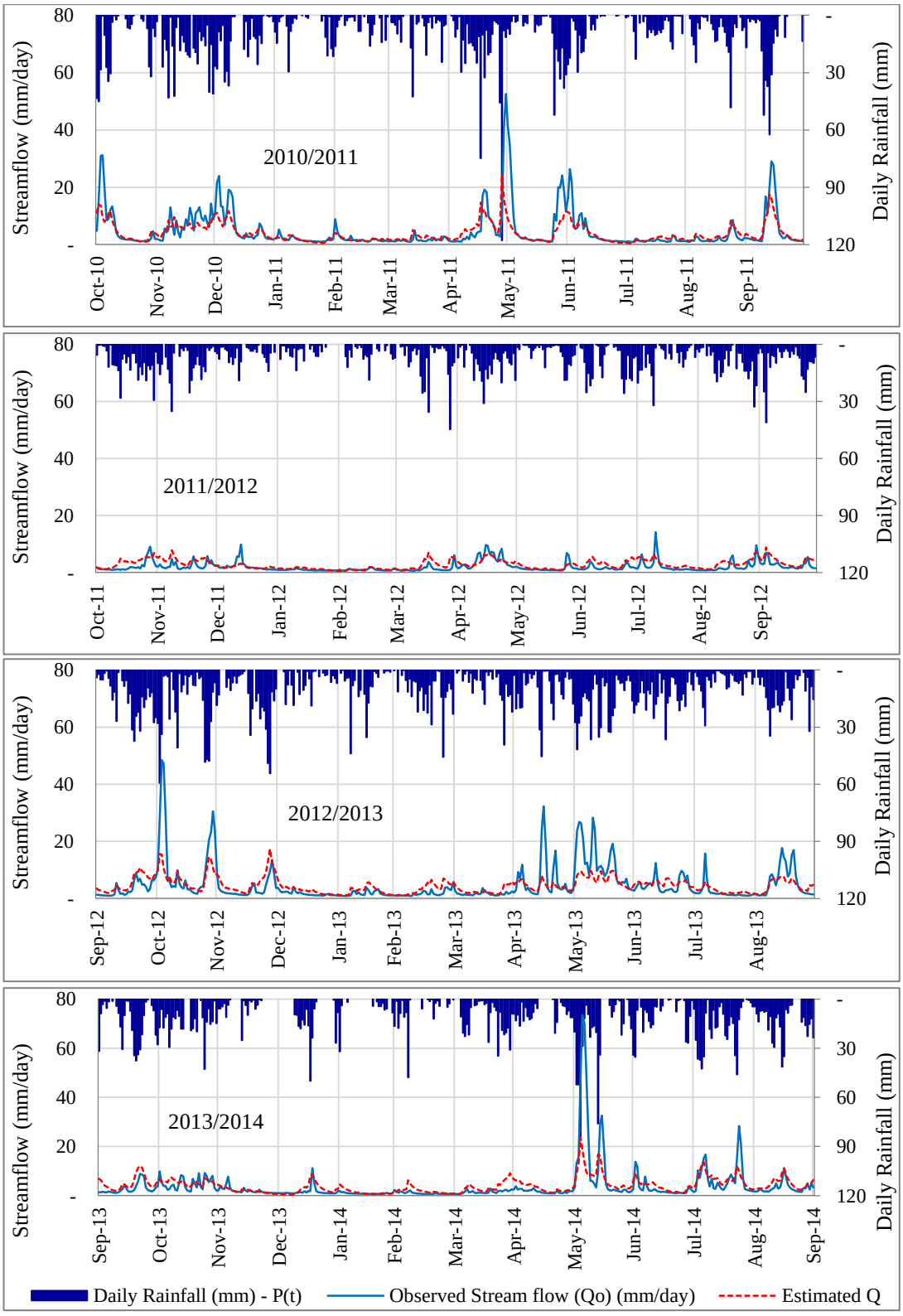

Figure D-29: Output hydrographs for 3PM (Daily) – Verification - Ellagawa watershed (Normal Scale Plot)

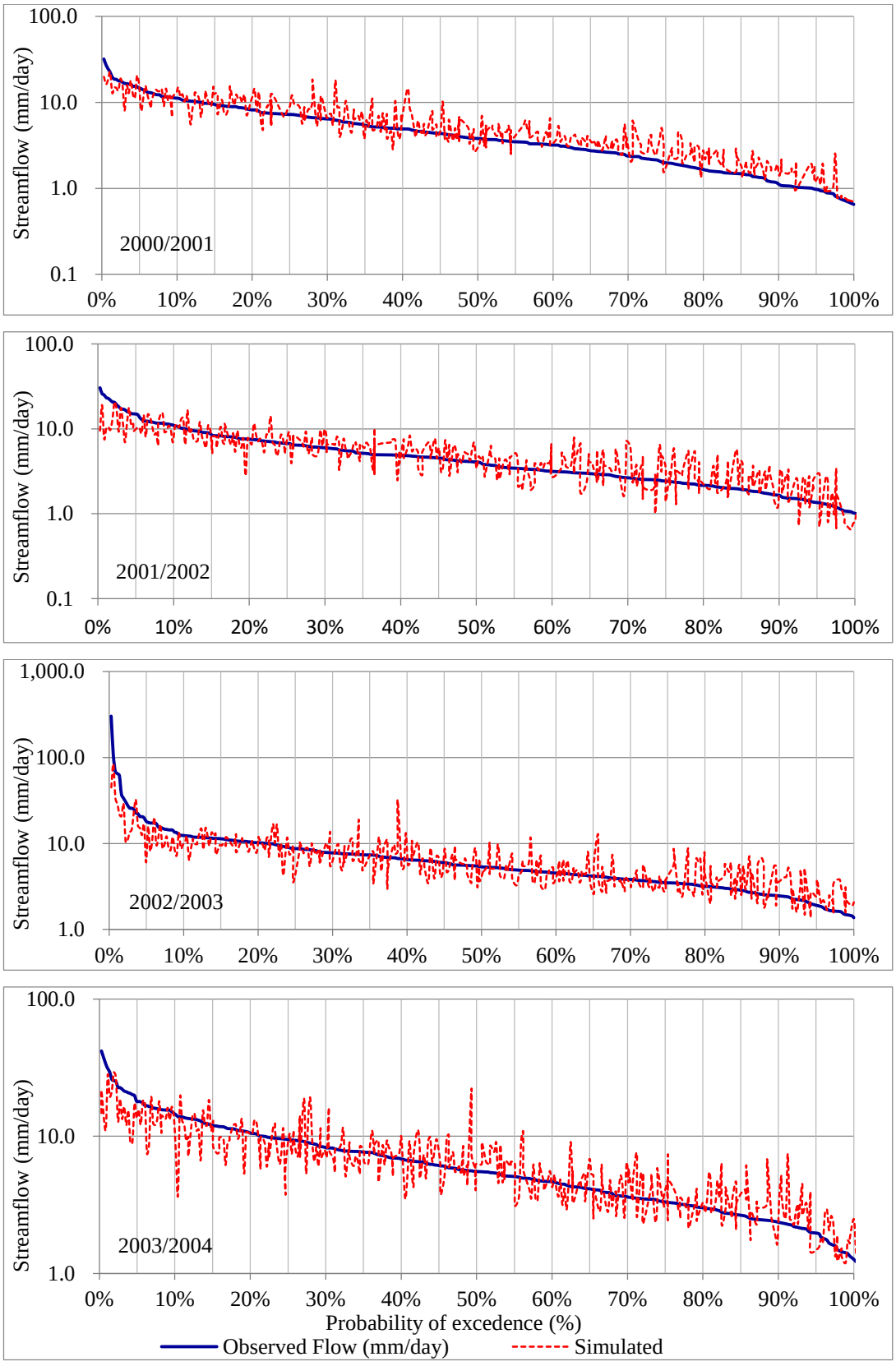

Figure D-30: Flow duration curves for 3PM (Daily) – Calibration - Tawalama watershed (Log Scale Plot)

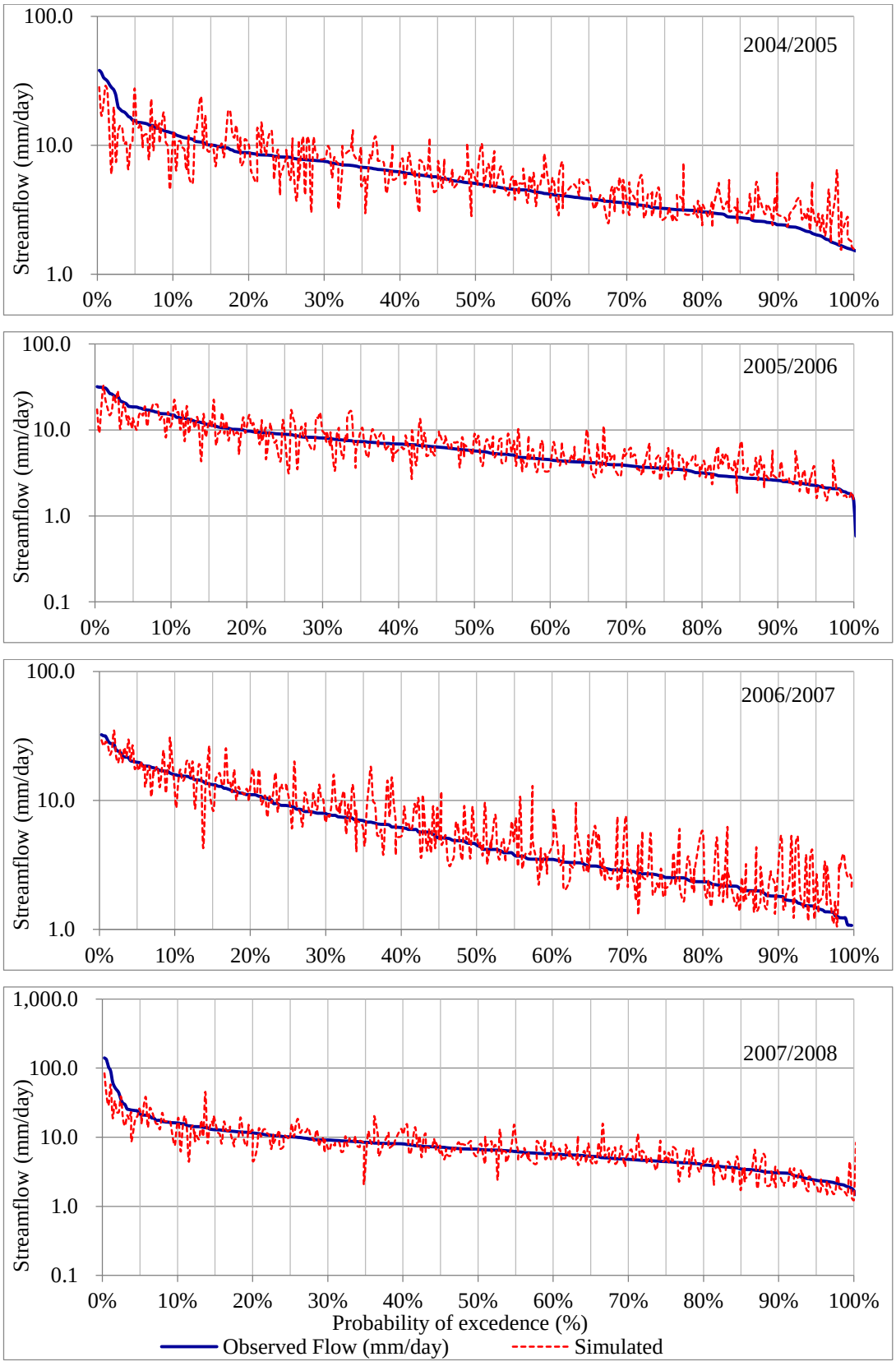

Figure D-31: Flow duration curves for 3PM (Daily) – Calibration - Tawalama watershed (Log Scale Plot)

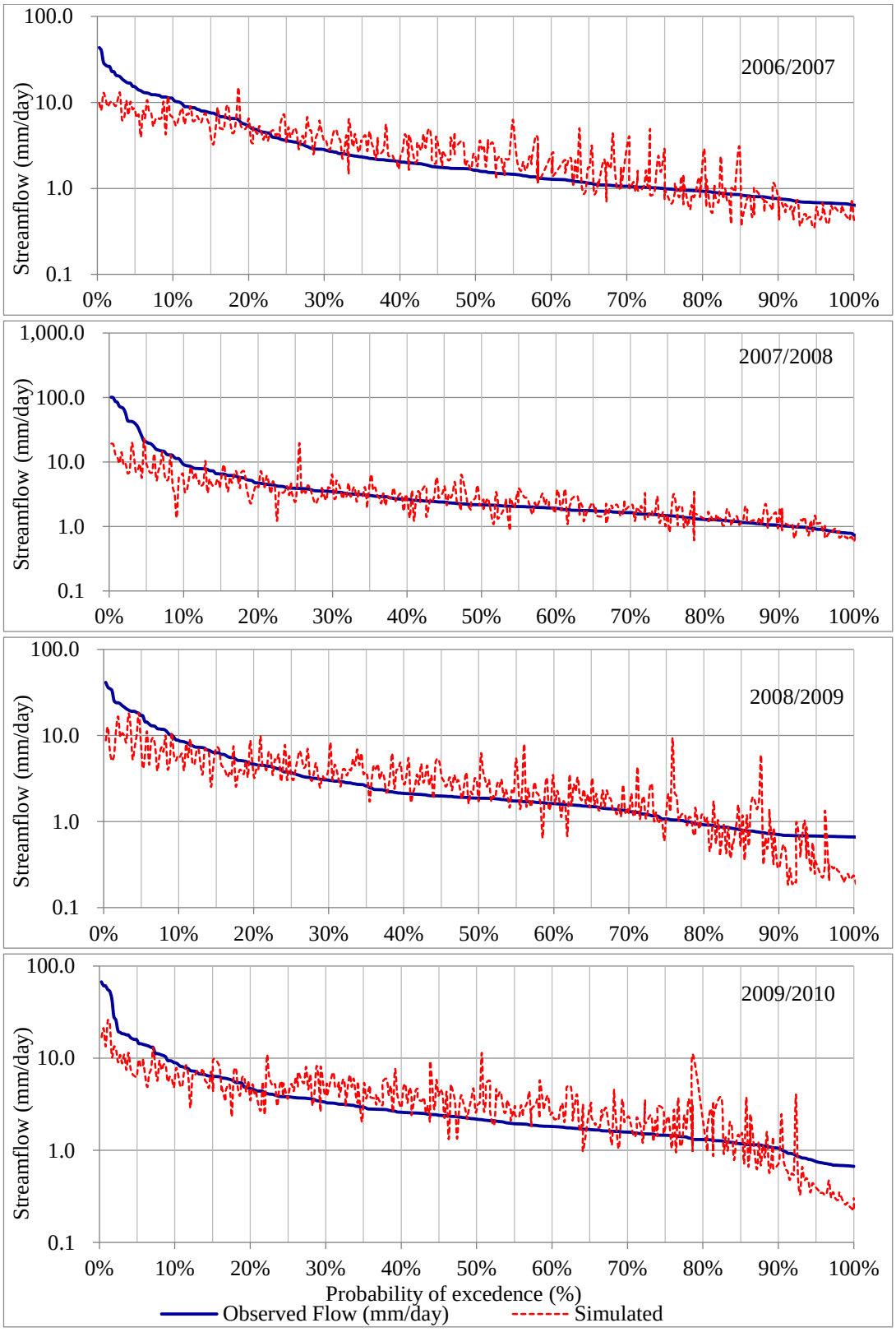

Figure D-32: Flow duration curves for 3PM (Daily) – Calibration – Ellagawa watershed (Log Scale Plot)

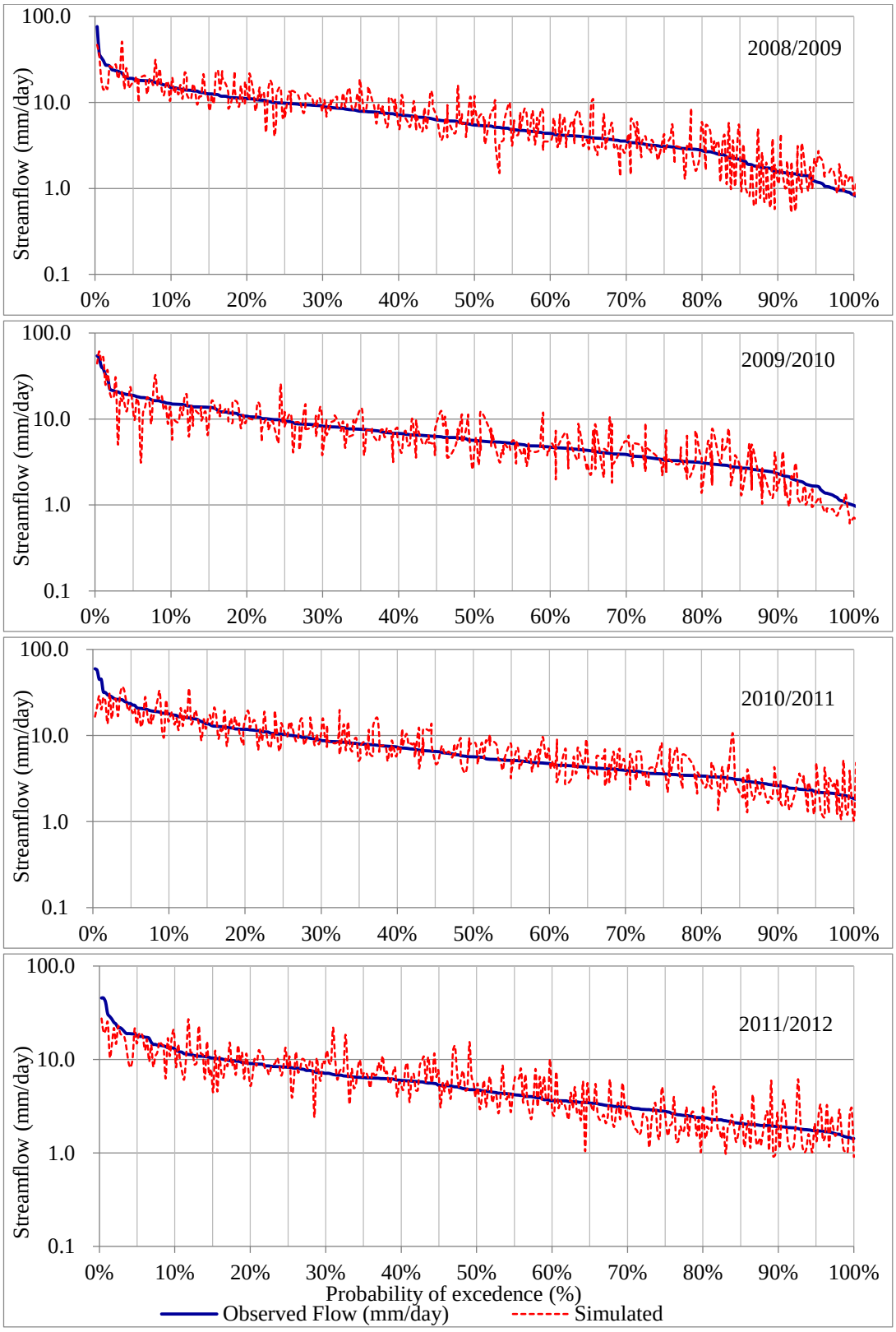

Figure D-33: Flow duration curves for 3PM (Daily) – Validation – Tawalama watershed (Log Scale Plot)

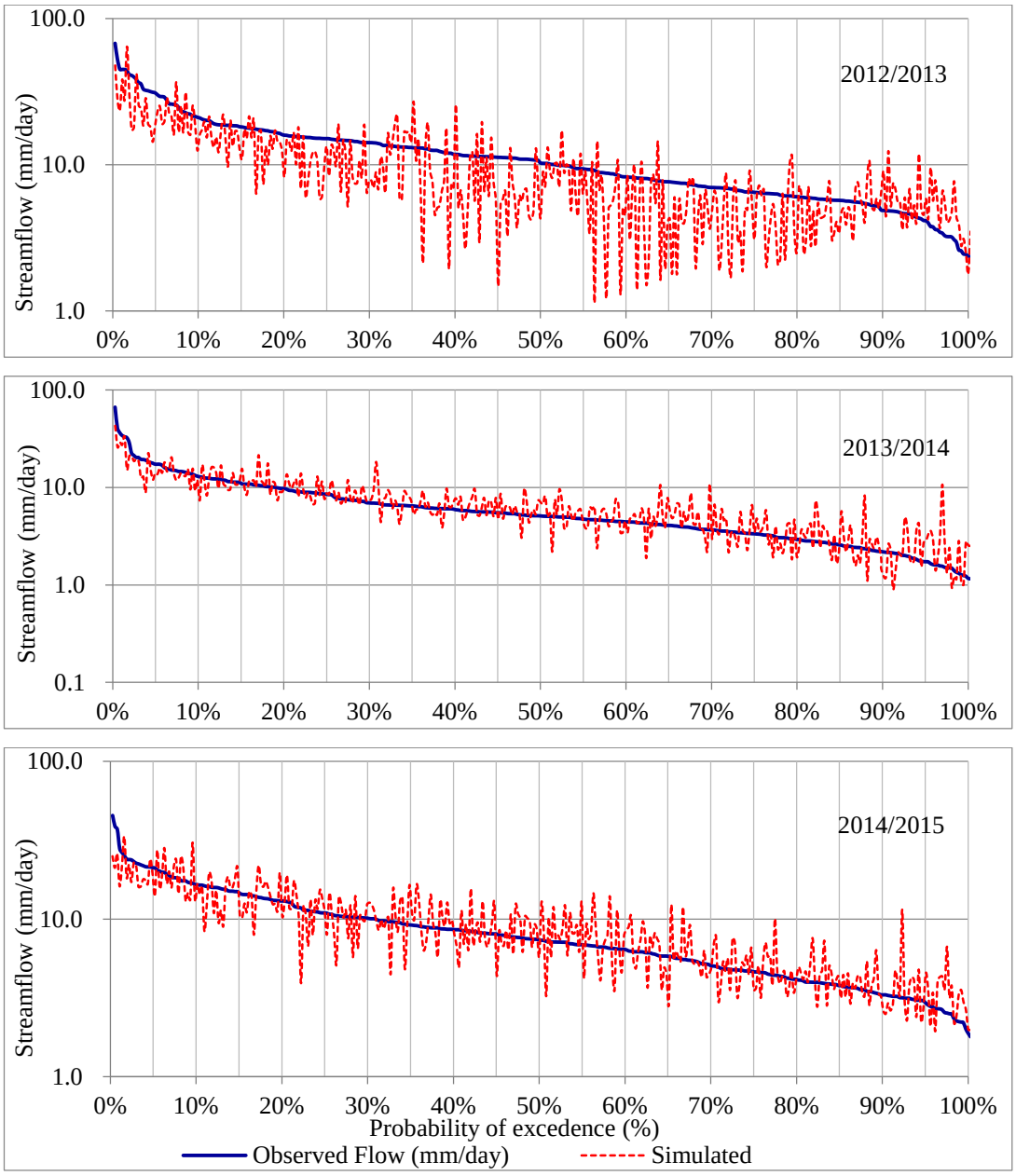

Figure D-34: Flow duration curves for 3PM (Daily) – Validation – Tawalama watershed (Log Scale Plot)

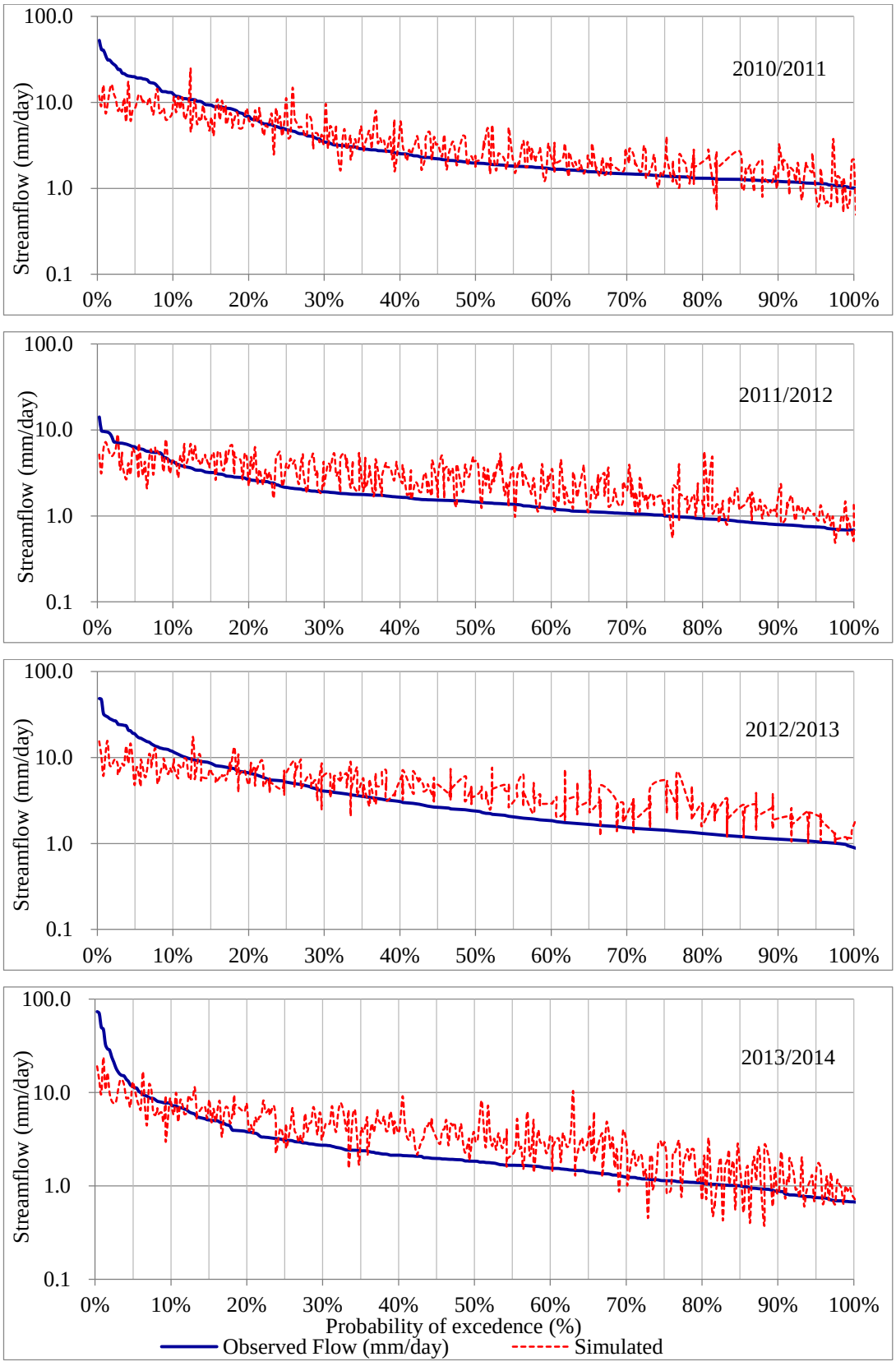

Figure D-35: Flow duration curves for 3PM (Daily) – Validation – Ellagawa watershed (Log Scale Plot)

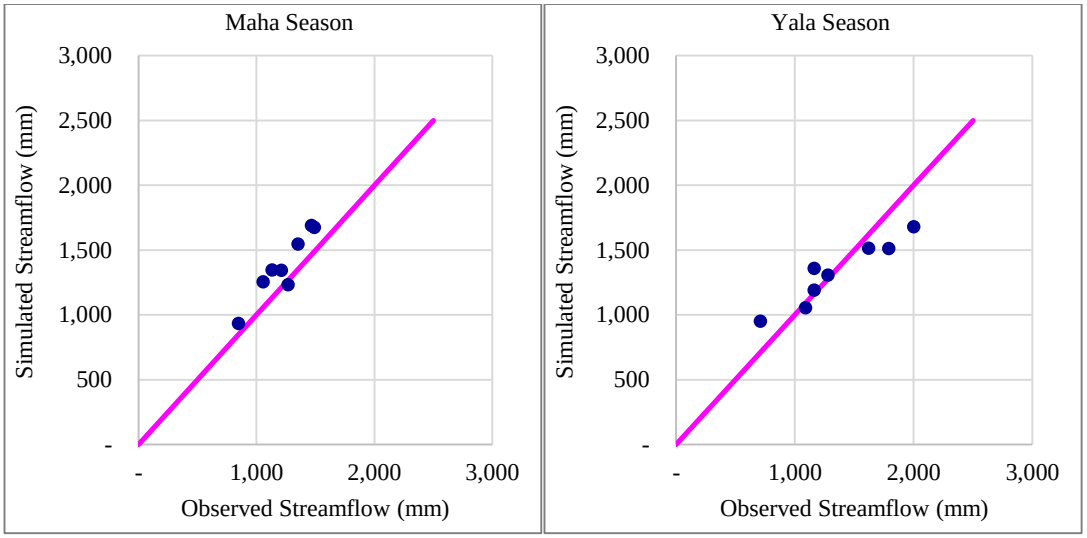

Figure D-36: 2PM (Monthly) – Seasonal Comparison (Calibration) - Tawalama

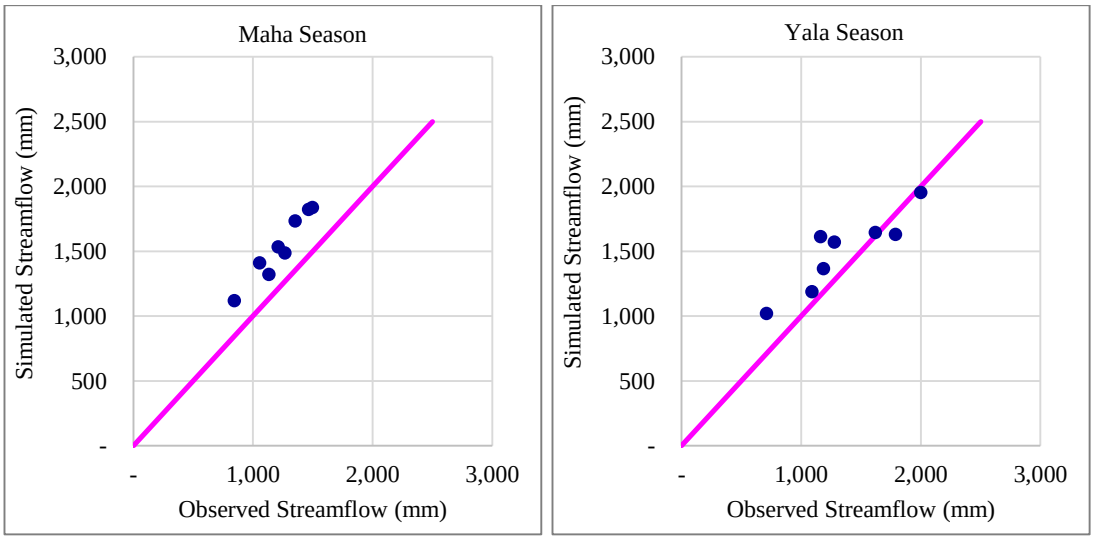

Figure C-37: 2PM (Daily) – Seasonal Comparison (Calibration) – Tawalama

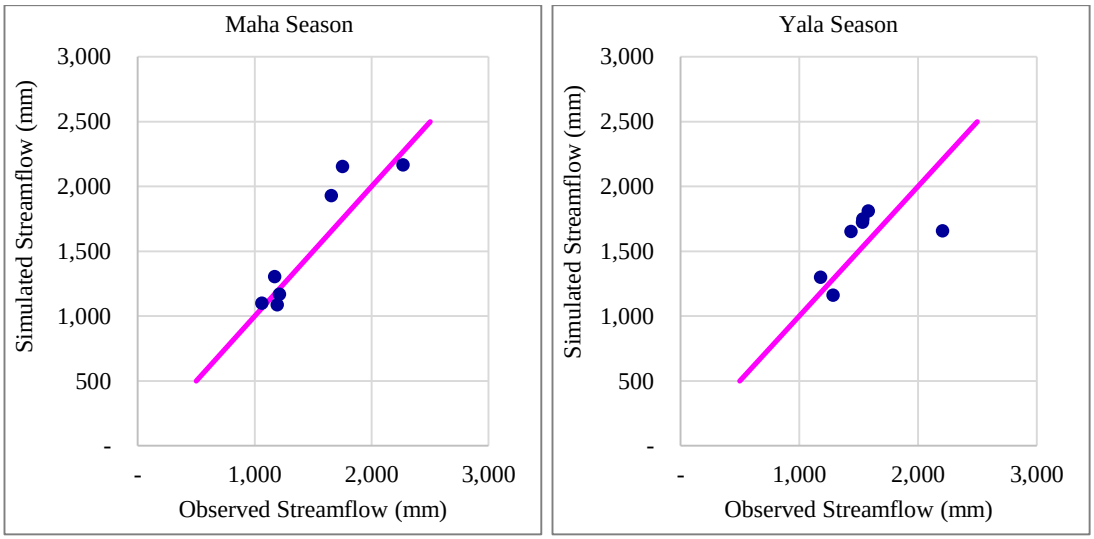

Figure D-38: 2PM (Monthly) – Seasonal Comparison (Validation) - Tawalama

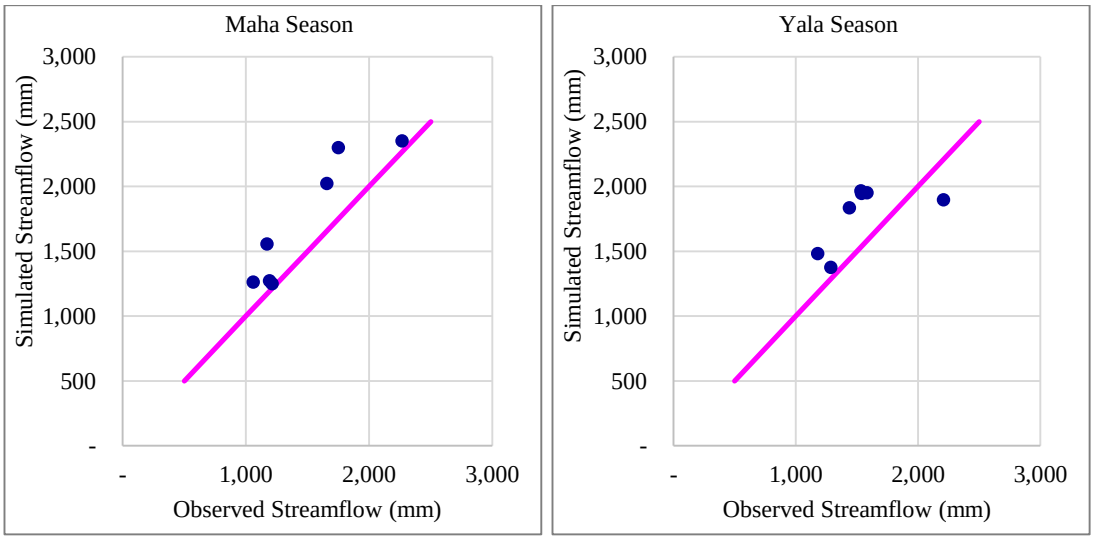

Figure D-39: 2PM (Daily) – Seasonal Comparison (Validation) - Tawalama

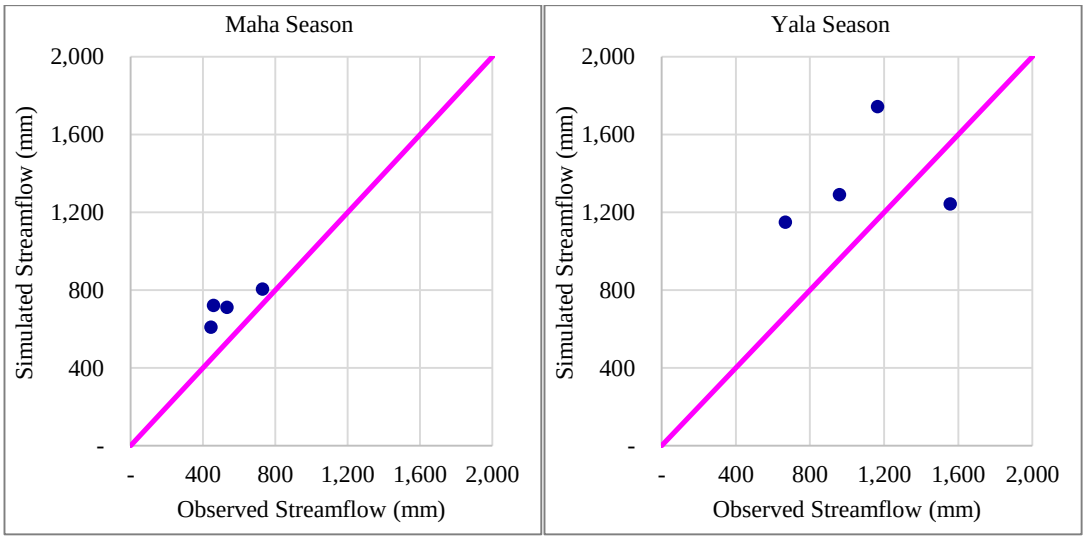

Figure D-40: 2PM (Monthly) – Seasonal Comparison (Calibration) – Ellagawa

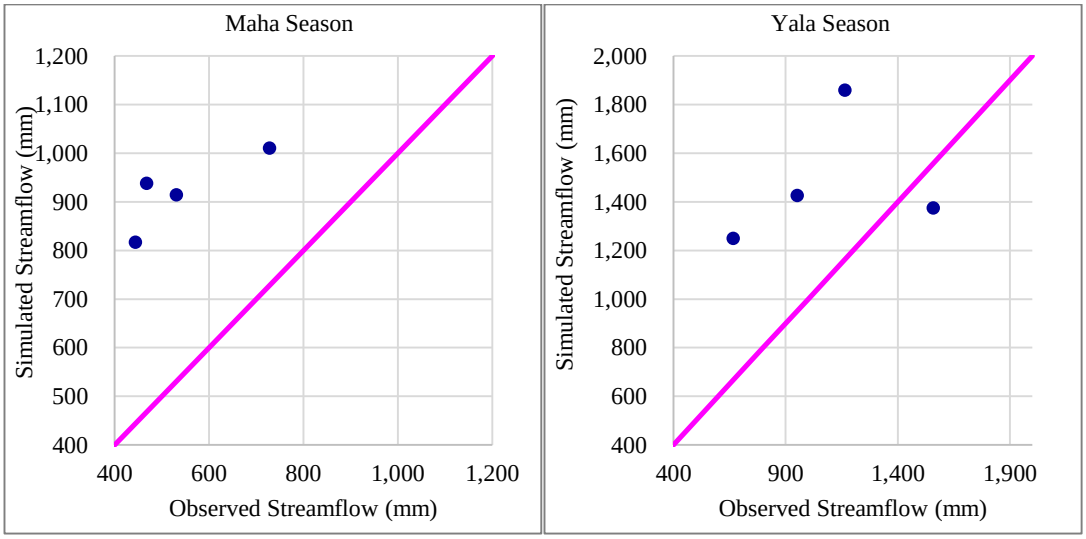

Figure D-41: 2PM (Daily) – Seasonal Comparison (Calibration) – Ellagawa

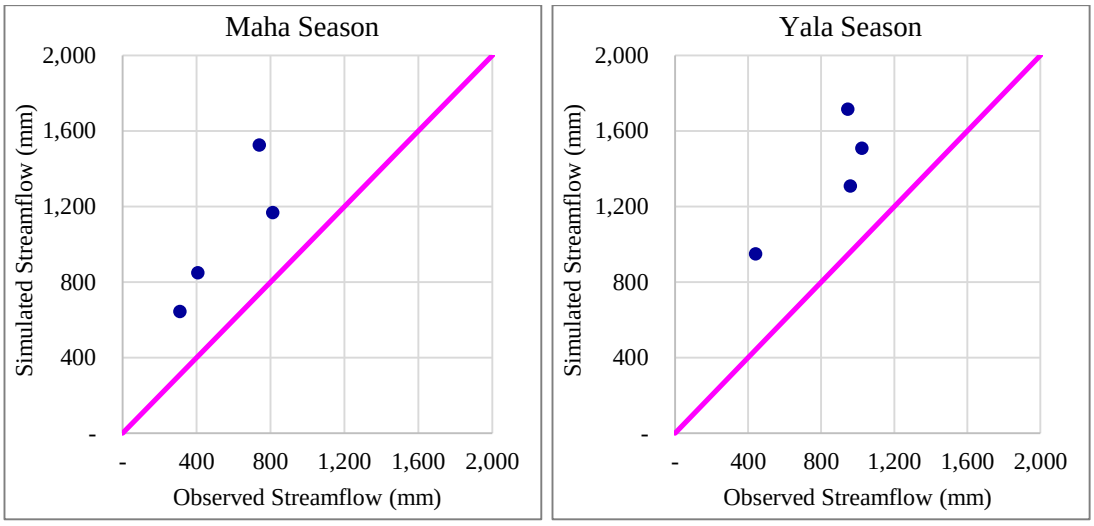

Figure D-42: 2PM (Monthly) – Seasonal Comparison (Validation) – Ellagawa

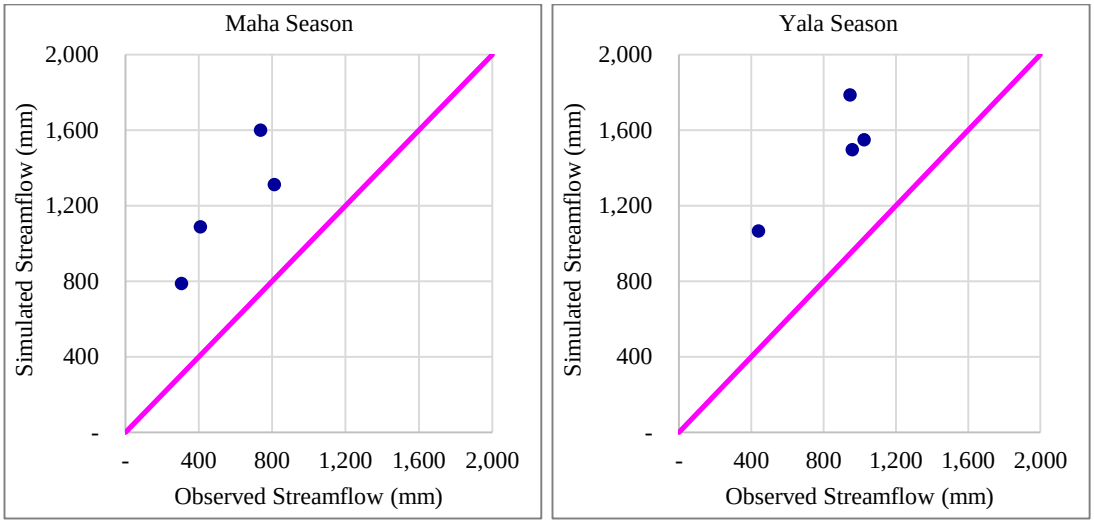

Figure D-43: 2PM (Daily) – Seasonal Comparison (Validation) – Ellagawa

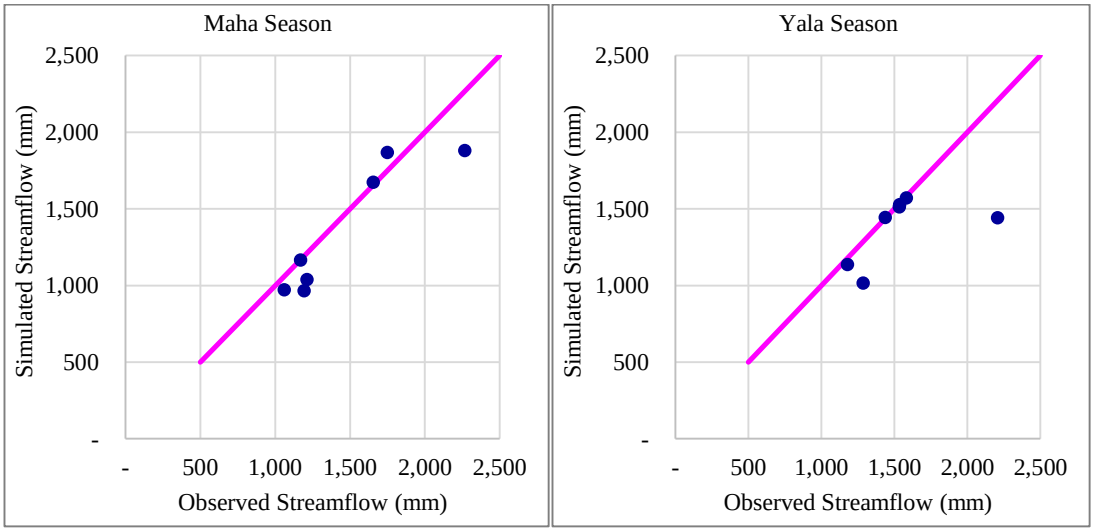

Figure D-44: Seasonal comparison – 3PM (Monthly) – Validation – Tawalama

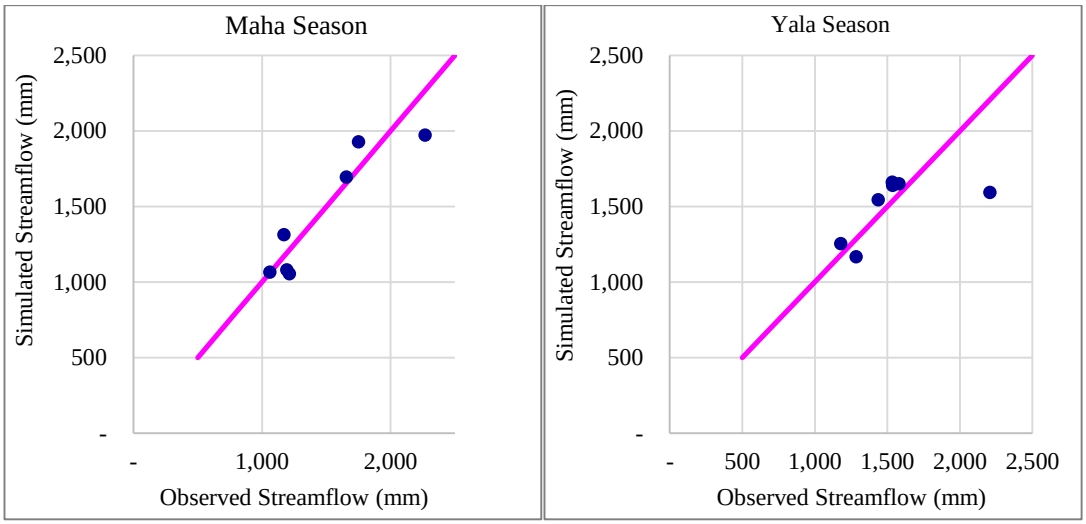

Figure D-45: Seasonal comparison – 3PM (Daily) – Validation – Tawalama

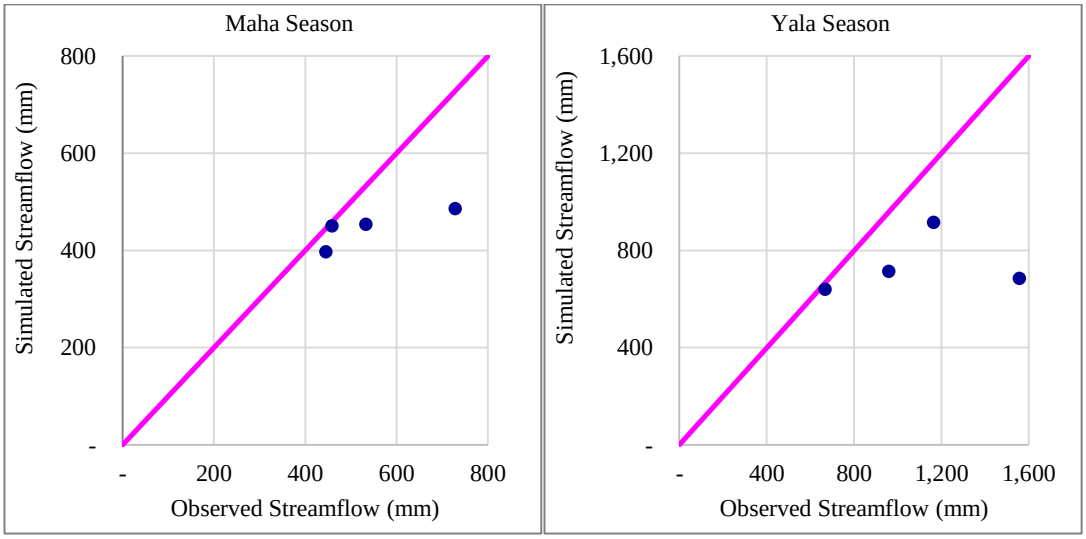

Figure D-46: Seasonal comparison – 3PM (Monthly) – Calibration – Ellagawa

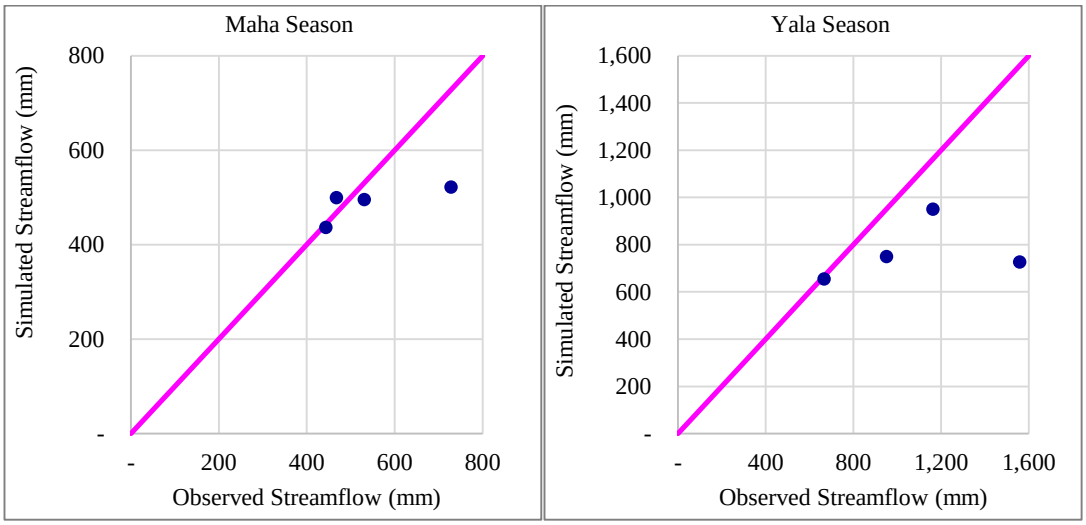

Figure D-47: Seasonal comparison – 3PM (Daily) – Calibration – Ellagawa

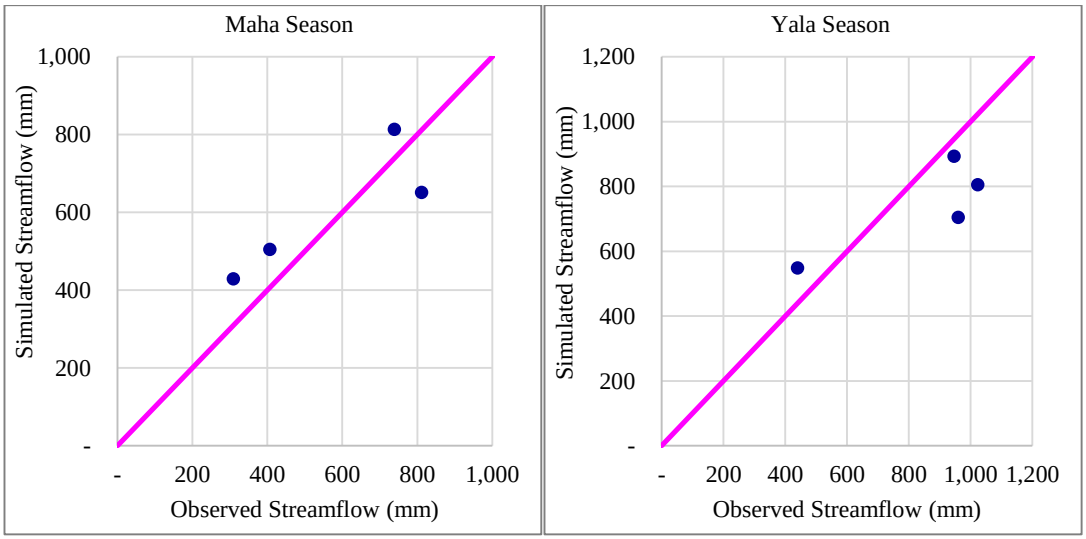

Figure D-48: Seasonal comparison – 3PM (Monthly) – Validation – Ellagawa

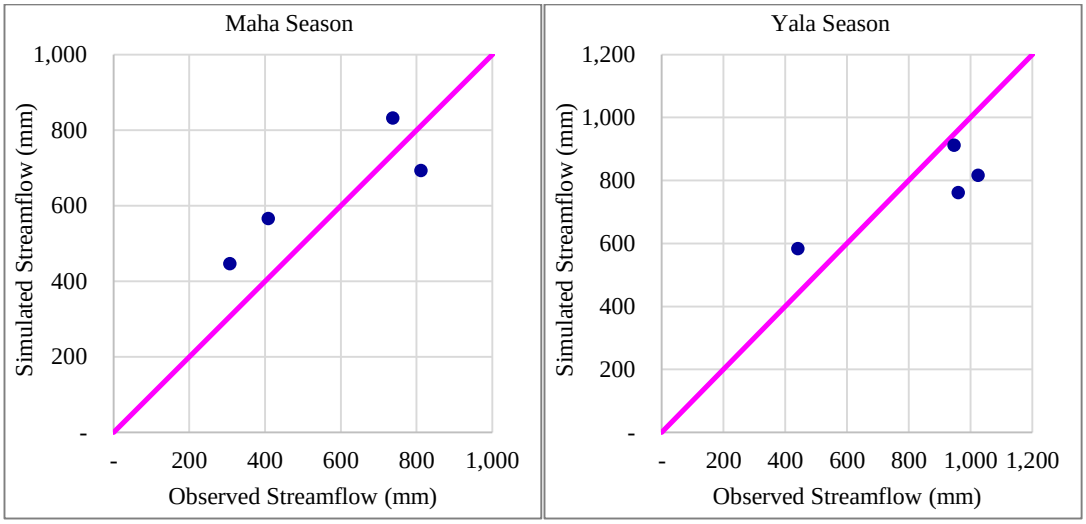

Figure D-49: Seasonal comparison – 3PM (Daily) – Validation – Ellagawa

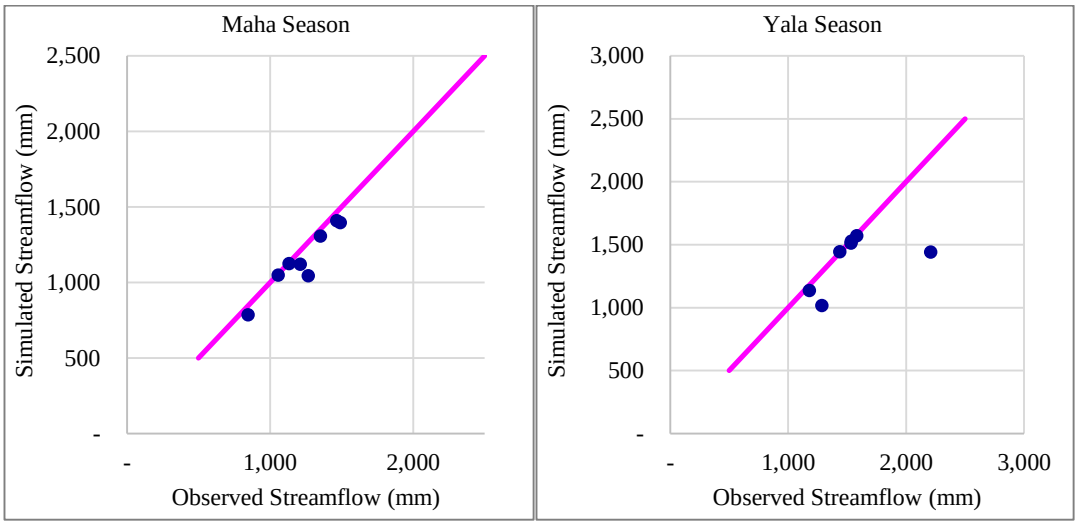

Figure D-50: Seasonal comparison – 3PM (Monthly) – Calibration – Tawalama

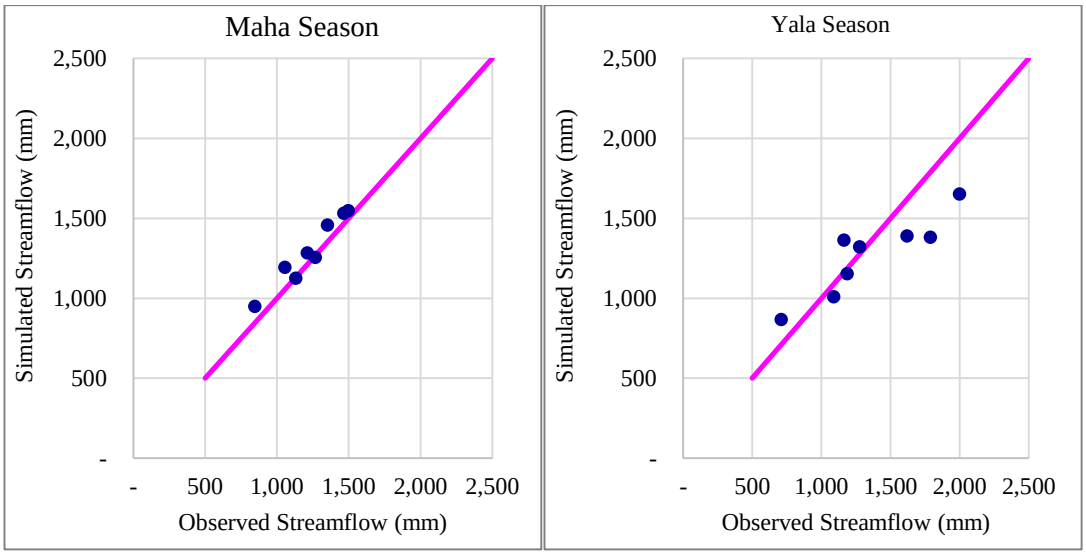

Figure D-51: Seasonal comparison – 3PM (Daily) – Calibration – Tawalama

Table D-1: Data points with Disparities – Ellagawa Watershed

Date	Rainfall	Observed Streamflow
Apr-07	338.33	65.67
Aug-07	306.65	75.94
Jun-08	281.69	40.79
Aug-08	159.26	55.44
Jun-09	504.15	201.72
Sep-09	337.15	132.34
Nov-09	340.57	111.29
Apr-10	341.14	73.19
Jun-10	410.17	169.00
Jul-10	330.32	170.40
Aug-10	305.84	117.76
Sep-10	308.38	109.21
Nov-10	486.36	217.66
Apr-11	562.23	241.49
Jul-11	168.29	45.50
Aug-11	249.16	69.67
Oct-11	303.01	67.49
Nov-11	272.41	74.77
Mar-12	251.25	41.92
Jun-12	256.62	50.67
Aug-12	282.97	65.01
Sep-12	273.96	79.01
Oct-12	442.50	111.29
Dec-12	394.84	102.75
Feb-13	189.56	47.93
Mar-13	332.97	59.34
Apr-13	214.45	50.06
Jul-13	382.71	143.51
Oct-13	368.23	96.22
Nov-13	361.83	137.25
Jan-14	253.36	52.52
Feb-14	60.22	26.42
Mar-14	130.76	30.31
Apr-14	331.34	47.14
May-14	214.76	55.57
Sep-14	388.64	99.54

Table D-2: Data points with Disparities – Ellagawa Watershed

Month	Monthly Rainfall	Observed Streamflow
Dec-00	309.97	155.45
Apr-01	503.77	263.34
Jun-01	131.45	69.75
Jul-01	144.98	66.37
Aug-01	71.13	43.62
Sep-01	321.48	120.50
Feb-02	159.20	78.16
Jul-02	195.11	91.61
Sep-02	105.37	46.84
Jan-03	207.62	102.86
Mar-04	291.60	117.89
Feb-06	241.85	117.63
May-06	429.07	185.79
Feb-07	205.79	58.08
Apr-07	530.95	191.34
Aug-07	310.12	124.91
Mar-08	471.04	259.43
Nov-08	479.42	267.76
Feb-09	50.50	35.16
Apr-09	458.71	224.09
May-09	447.86	267.79
Aug-10	243.94	147.38
Feb-11	289.07	169.29
Jun-11	131.77	198.98
Jul-11	163.16	78.32
Feb-12	190.63	81.22
Aug-12	339.87	146.67
Sep-12	410.72	232.94
Oct-12	702.48	420.51
Aug-13	132.70	245.12
Oct-13	297.36	164.65
Apr-14	385.04	163.83
May-14	300.37	171.92
Sep-14	467.89	258.18
Mar-15	270.70	126.78

Table D-3: Behaviour of MRAE with c & Sc – Tawalama Watershed

Initial Parameters		Optimized Parameters		Optimized MRAE
c	**Sc**	**c**	**Sc**	
0.0001	0.10	5,368.71	0.10	0.31453
0.10	1.00	5,368,709.22	1.00	0.31456
0.0001	200.00	-	-	No value
0.0001	2,500.00	-	-	No value
0.0001	10,000.00	-	-	No value
0.20	200.00	0.60	-	No value
0.20	2,500.00	0.37	-	No value
0.20	10,000.00	0.36	-	No value
0.30	0.10	0.95	0.10	0.29750
0.30	200.00	1.25	-	No value
0.30	2,500.00	0.68	-	No value
0.80	1,500.00	1.42	1,288.71	0.206687562518
0.80	0.10	0.95	0.10	0.29750
0.80	10,000.00	2.56	-	No value
2.50	200.00	2.50	1,288.71	0.206687563469
2.50	2,500.00	2.50	1,288.71	0.206687564383
2.50	10,000.00	2.50	-	No value
100.00	0.10	100.00	0.10	0.31453
100.00	1,500.00	100.00	1,288.71	0.206687562608
100.00	10,000.00	100.00	-	No value
1,000.00	0.20	1,000.00	0.20	0.31453
1,000.00	1,500.00	1,000.00	1,288.71	0.206687562608
1,000.00	10,000.00	1,000.00	-	No value
10,000.00	0.10	10,000.00	0.10	0.31453
10,000.00	1,500.00	10,000.00	1,288.71	0.206687562608
10,000.00	10,000.00	10,000.00	-	No value
0.00	10.00	6.81	1,288.58	0.206687658
0.00	10.00	0.96	-	No value
0.01	10.00	0.96	-	No value
0.01	100.00	0.02	-	No value
0.10	10.00	2.66	-	No value
0.00	1,000.00	0.001	577.83	0.559781457
0.00	10,000.00	0.00	-	No value
0.01	1,000.00	0.52	-	No value
0.01	10,000.00	0.01	-	No value
1.00	1.00	0.95	1.00	0.297504552
0.00	100.00	0.00	-	No value
10.00	10.00	10.00	-	No value
100.00	10.00	100.00	-	No value
1,000.00	10.00	1,000.00	-	No value
10,000.00	10.00	10,000.00	-	No value
1,000,000.00	10.00	1,000,000.00	-	No value
1,000,000.00	10,000.00	1,000,000.00	-	No value
1,000.00	100.00	1,000.00	-	No value
10,000.00	100.00	10,000.00	-	No value
1,000,000.00	1,000.00	1,000,000.00	1,288.71	0.206687565
100,000.00	100.00	100,000.00	-	No value

Table D-4: Behaviour of MRAE with c & Sc – Ellagawa Watershed – 2PM

Initial Parameters		Optimized Parameters		Optimized MRAE
c	Sc	c	Sc	
0.0001	0.10	1.77	0.10	0.6689
0.10	1.00	1.77	1.00	0.6689
0.0001	200.00	0.00	188.20	1.3566
0.0001	2,500.00	-	-	No Value
0.0001	10,000.00	0.00	-	No Value
0.20	200.00	7.43	959.01	0.5056
0.20	2,500.00	0.32	-	No Value
0.20	10,000.00	0.32	-	No Value
0.30	0.10	1.77	0.10	0.6689
0.30	200.00	16.46	959.01	0.5056
0.30	2,500.00	0.58	-	No Value
0.80	1,500.00	1.75	853.02	0.48576
0.80	0.10	1.00	0.10	0.6791
0.80	10,000.00	2.82	-	No Value
2.50	200.00	1.27	827.88	0.48478
2.50	2,500.00	1.33	853.02	0.4850
2.50	10,000.00	3.02	-	No Value
100.00	0.10	100.00	0.10	0.7450
100.00	1,500.00	100.00	959.01	0.5056
100.00	10,000.00	100.00	-	No Value
1,000.00	0.20	1,000.00	0.20	0.7450
1,000.00	1,500.00	1,000.00	959.01	0.5056
1,000.00	10,000.00	1,000.00	-	No Value
10,000.00	0.10	10,000.00	0.10	0.7450
10,000.00	1,500.00	10,000.00	959.01	0.5056
10,000.00	10,000.00	10,000.00	-	No Value
0.00	10.00	0.00	-	No Value
0.00	10.00	0.00	-	No Value
0.01	10.00	0.04	-	No Value
0.01	100.00	0.81	-	No Value
0.10	10.00	2.48	-	No Value
0.00	1,000.00	0.00	-	No Value
0.00	10,000.00	0.00	-	No Value
0.01	1,000.00	0.01	-	No Value
0.01	10,000.00	0.01	-	No Value
1.00	1.00	1.00	1.00	0.679114956
0.00	100.00	1.07	1,165.89	0.568388273
10.00	10.00	10.00	-	No Value
100.00	10.00	100.00	-	No Value
1,000.00	10.00	1,000.00	-	No Value
10,000.00	10.00	10,000.00	-	No Value
1,000,000.00	10.00	1,000,000.00	-	No Value
1,000,000.00	10,000.00	1,000,000.00	-	No Value
1,000.00	100.00	1,000.00	97.59	0.68787592
10,000.00	100.00	10,000.00	97.59	0.68787592
1,000,000.00	1,000.00	1,000,000.00	959.01	0.505634092
100,000.00	100.00	100,000.00	97.59	0.68787592

Table D-5: Annual Water Balance 2PM (Monthly Input - Calibration) - Tawalama Watershed

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2000/2001	3006	2293	1920	1085	713	372
2001/2002	2842	1988	1935	908	854	53
2002/2003	3783	2745	3055	727	1038	-311
2003/2004	3719	2768	2674	1044	951	93
2004/2005	3560	2652	2410	1151	908	242
2005/2006	3763	2879	2628	1136	884	252
2006/2007	3924	2905	2513	1410	1018	392
2007/2008	4176	3352	3489	688	824	-137
Average				1019	899	120

Table D-6: Annual Water Balance 2PM (Monthly Input - Validation) - Tawalama Watershed

Year	Thiessen Averaged Rainfall	Simulated Streamflow	Observed Streamflow	Observed Water Balance	Simulated Water Balance	Annual Water Balance Error
2008/2009	4167	3053	2705	1461	1114	348
2009/2010	3807	2892	2743	1063	914	149
2010/2011	4149	3315	3034	1115	834	281
2011/2012	3437	2386	2370	1067	1050	16
2012/2013	4684	3823	4473	210	860	-650
2013/2014	3666	2750	2496	1171	916	254
2014/2015	4639	3740	3236	1403	899	504
Average				1070	941	129

Table D-7: Annual Water Balance 2PM (Monthly Input - Calibration) - Ellagawa Watershed

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2006/2007	2873	1955	1394	1479	917	561
2007/2008	2920	1955	2089	831	965	-134
2008/2009	2932	1899	1403	1529	1034	496
2009/2010	3436	2466	1621	1814	970	845
Average	3040	2069	1627	1413	971	442

Table D-8: Annual Water Balance 2PM (Monthly Input - Validation) - Ellagawa Watershed

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2010/2011	3387	2475	1770	1617	912	705
2011/2012	2597	1594	748	1849	1004	845
2012/2013	3976	3033	1761	2214	942	1272
2013/2014	3460	2564	1352	2108	896	1212
Average	3355	2416	1408	1947	939	1008

Table D-9 : Annual Water Balance - 2PM (Daily Input) – Calibration Period – Tawalama Watershed

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2000/2001	3006	2554	1919	1086	451	635
2001/2002	2842	2307	1934	909	536	373
2002/2003	3794	3117	3054	740	677	63
2003/2004	3719	3056	2673	1046	663	383
2004/2005	3565	2894	2408	1157	672	485
2005/2006	3763	3188	2650	1114	576	538
2006/2007	3924	3347	2512	1411	576	835
2007/2008	4339	3790	3494	845	549	296
Average				1038	587	451

Table D-10 : Annual Water Balance - 2PM (Daily Input) – Validation Period – Tawalama Watershed

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2008/2009	4167	3502	2705	1461	665	796
2009/2010	3807	3214	2743	1063	592	471
2010/2011	4149	3674	3034	1115	475	640
2011/2012	3437	2757	2370	1067	680	387
2012/2013	4684	4248	4473	210	435	-225
2013/2014	3666	3097	2496	1171	569	602
2014/2015	4639	3975	3236	1403	663	739
Average				1070	583	487

Table D-11 : Annual Water Balance - 2PM (Daily Input) – Calibration Period – Tawalama Watershed

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2006/2007	2760	2261	1394	1366	500	867
2007/2008	2920	2289	2088	832	631	201
2008/2009	2929	2242	1395	1535	687	848
2009/2010	3438	2798	1630	1808	641	1167
Average				1385	615	771

Table D-12 : Annual Water Balance - 2PM (Daily Input) – Validation Period – Ellagawa Watershed

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2010/2011	3388	2808	1770	1618	580	1038
2011/2012	2593	1855	747	1846	738	1108
2012/2013	3948	3148	1761	2187	800	1387
2013/2014	3493	2874	1354	2139	619	1521
Average	3355	2671	1408	1947	684	1263

Table D-13: Behaviour of MRAE with c & Sc – Tawalama Watershed – 2PM

Initial Parameters			Optimized Parameters			Optimized MRAE
c	Sc	Rc	c	Sc	AF	
0.0001	0.10	0.00	0.4010	0.10	0.72	0.22538
0.10	1.00	0.10	0.40	1.00	0.72	0.22538
0.0001	200.00	0.20	(0.03)	200.00	0.64	0.27626
0.0001	2,500.00	10.00	25.4969	2,500.00	0.81	0.19848
0.0001	10,000.00	100.00	2,670.1528	9,999.95	0.71	0.30552
0.20	200.00	100.00	3,282.05	200.25	0.83	0.33147
0.20	2,500.00	1,000.00	284,415.67	2,475.57	0.81	0.19753
0.20	10,000.00	10,000.00	26,843,608.17	9,545.64	0.71	0.30291
0.30	0.10	100.00	3,285.40	0.10	0.85	0.28099
0.30	200.00	10,000.00	33,922,806.53	2,377.46	0.82	0.19357
0.30	2,500.00	10.00	26.53	2,500.00	0.81	0.19848
0.80	0.10	10.00	38.61	0.10	0.85	0.28099
0.80	10,000.00	100,000.00	53,687,092.00	9,129.99	98,315.06	125,630.53315
2.50	200.00	0.10	2.50	200.29	0.82	0.331485946057
2.50	2,500.00	1,000.00	2.50	2,465.86	0.81	0.197142926238
2.50	10,000.00	100.00	2.50	9,999.94	0.71	0.30552
100.00	0.10	1.00	100.00	0.10	0.85	0.28099
100.00	10,000.00	10,000.00	100.00	9,444.11	0.71	0.30230
1,000.00	0.20	10.00	1,000.00	0.20	0.85	0.28099
1,000.00	10,000.00	10,000.00	1,000.00	9,444.11	0.71	0.30230
10,000.00	0.10	0.01	10,000.00	0.10	0.85	0.28099
10,000.00	10,000.00	10,000.00	10,000.00	9,444.11	0.71	0.30230
1.00	1,500.00	0.8	1.02	1,292.00	0.83	0.173326027
0.00	10.00	10.00	29.56	10.00	0.85	0.282298351
0.00	10.00	100.00	3,266.22	1.27	0.84	0.281586649
0.01	10.00	1,000.00	314,026.72	10.01	0.85	0.282299825
0.01	100.00	100.00	3,270.65	100.94	0.83	0.318225764
0.10	10.00	0.10	0.40	10.00	0.72	0.225384207

Initial Parameters			Optimized Parameters			Optimized MRAE
c	Sc	Rc	c	Sc	AF	
0.00	1,000.00	0.10	(0.01)	1,000.00	0.64	0.223035331
0.00	10,000.00	100.00	2,671.48	9,999.95	0.71	0.305521864
0.01	1,000.00	10.00	26.13	1,000.00	0.89	0.189740959
0.01	10,000.00	100.00	2,684.67	9,999.95	0.71	0.305521863
1.00	1.00	1.00	0.40	1.00	0.72	0.225383439
0.00	100.00	10.00	29.90	100.01	0.83	0.317894135
10.00	10.00	10.00	10.00	10.01	0.85	0.282299131
100.00	10.00	100.00	100.00	10.76	0.85	0.282383628
1,000.00	10.00	1,000.00	1,000.00	116.71	0.84	0.323216999
10,000.00	10.00	10,000.00	10,000.00	10.00	10,000.00	10279.18348
1,000,000.00	10,000.00	10,000.00	1,000,000.00	9,444.11	0.71	0.302295429
1,000.00	100.00	1,000.00	1,000.00	169.94	0.83	0.3318077
10,000.00	100.00	10,000.00	10,000.00	7,098.92	0.73	0.284566407
100,000.00	100.00	1,000.00	100,000.00	169.94	0.83	0.3318077

Table D-14: Behaviour of MRAE with c & Sc – Ellagawa Watershed – 2PM

Initial Parameters			Optimized Parameters			Optimized MRAE
c	**Sc**	**AF**	**c**	**Sc**	**AF**	
0.0001	0.1000	0.1000	0.0001	0.10	0.3925	0.2895
0.1000	1.0000	0.0001	0.0017	0.80	0.3927	0.2895
0.0001	200.0000	0.5000	0.0001	823.80	0.3802	0.2402
0.0001	2,500.0000	10.0000	0.0001	823.28	0.3802	0.2402
0.0001	10,000.0000	100.0000	0.0001	6,125.80	0.2326	0.4336
0.2000	200.0000	100.0000	0.2176	199.94	0.44	0.3385
0.2000	2,500.0000	1,000.0000	0.2149	2,216.33	0.38	0.2881
0.2000	10,000.0000	10,000.0000	0.2135	9,025.00	0.34	0.4544
0.2000	200.0000	0.0001	0.1088	908.77	0.39	0.2364
0.2000	2,500.0000	100,000.0000	0.2149	2,217.52	0.37659	0.2881
0.2000	10,000.0000	0.0000	-	1,312,837,369,303	3,176.19	0.5753
0.0001	0.1000	10,000.0000	0.0001	0.10	0.39253	0.2895
0.1000	1.0000	1,000.0000	0.1042	1.00	0.40	0.2923
0.0001	200.0000	100.0000	0.0001	200.03	0.39	0.3240
0.3000	0.1000	100,000.0000	0.3418	0.10	0.46	0.3080
0.3000	200.0000	10.0000	0.3316	205.43	0.45	0.3494
0.3000	2,500.0000	0.0100	-	-	0.19	No value
0.8000	1,500.0000	0.0100	-	-	0.24	No value
0.8000	0.1000	100.0000	1.1864	0.10	0.60	0.4483
0.8000	10,000.0000	0.8000	0.9735	-	0.52	No value
2.5000	200.0000	0.0010	3.2933	-	0.03	No value
2.5000	2,500.0000	0.0000	0.1384	25,386,706.76	0.24	0.5710
2.5000	10,000.0000	1,000.0000	2.5794	8,732.21	0.45	0.4259
100.0000	0.1000	100.0000	100.0000	0.10	0.52	0.4115
100.0000	1,500.0000	0.5000	100.0000	1,991.07	0.62	0.2576
100.0000	10,000.0000	0.8000	100.0000	-	0.46	No value
1,000.0000	0.2000	0.4000	1,000.0000	0.20	0.52	0.4115
1,000.0000	1,500.0000	1,000.0000	1,000.0000	1,260.20	0.65	0.2816
1,000.0000	10,000.0000	10,000.0000	1,000.0000	8,702.49	0.46	0.4215
10,000.0000	0.1000	0.5000	10,000.0000	0.10	0.52	0.4115
10,000.0000	1,500.0000	0.1000	10,000.0000	1,991.42	0.62	0.2576

Initial Parameters			Optimized Parameters			Optimized MRAE
c	**Sc**	**AF**	**c**	**Sc**	**AF**	
10,000.0000	10,000.0000	10,000.0000	10,000.0000	8,702.49	0.46	0.4215
0.0001	10.0000	0.8000	0.0001	-	0.39	No value
0.0010	10.0000	10.0000	0.0010	10.00	0.39	0.2896
0.0100	10.0000	0.5000	0.0053	-	0.39	No value
0.0100	100.0000	100,000.0000	0.0100	100.27	0.39	0.3170
0.1000	10.0000	0.5000	-	6.93	0.39	0.2895
0.0010	1,000.0000	0.0000	-	7,724,606.97	0.20	0.5723
0.0010	10,000.0000	0.5000	0.0010	-	0.30	No value
0.8000	1,000.0000	0.8000	0.5234	975.20	0.4637	0.22538
0.8000	1,000.0000	10,000.0000	1.1362	899.52	0.66	0.2595
0.8000	1,000.0000	100.0000	0.8995	1,202.03	0.56	0.2338
0.5234	975.2002	0.0001	0.0018	591,927.69	0.21	0.5681
0.5234	975.2002	0.0100	0.4310	932.91	0.45	0.2264
0.5234	975.2002	1,000.0000	0.6507	893.84	0.50	0.2302
0.5234	975.2002	0.8000	0.5234	975.29	0.46	0.2253758
0.0100	10,000.0000	0.5000	0.0100	-	0.30	No value
1.0000	1.0000	0.1000	-	1.00	0.39	0.2894595
0.0010	100.0000	10.0000	0.0010	-	0.43	No value
10.0000	10.0000	10.0000	10.0000	10.05	0.52	0.4140
100.0000	10.0000	100.0000	100.0000	10.08	0.52	0.4140
1,000.0000	10.0000	0.1000	1,000.0000	-	0.52	No value
10,000.0000	10.0000	100.0000	10,000.0000	10.08	0.52	0.4140

Table D-15: Annual Water balance (Calibration) - 3PM (Monthly Input) – Tawalama

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2000/2001	3006	1928	1920	1085	1078	8
2001/2002	2842	1678	1935	908	1165	-257
2002/2003	3783	2304	3055	727	1479	-752
2003/2004	3719	2319	2674	1044	1400	-355
2004/2005	3560	2219	2410	1151	1342	-191
2005/2006	3763	2401	2628	1136	1363	-227
2006/2007	3924	2448	2513	1410	1475	-65
2007/2008	4176	2799	3489	688	1377	-690
Average				1019	1335	-316

Table D-16: Annual Water balance (Validation) - 3PM (Monthly) – Tawalama

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2008/2009	4167	2694	2705	1461	1473	-11
2009/2010	3807	2551	2743	1063	1255	-192
2010/2011	4149	2884	3034	1115	1265	-150
2011/2012	3437	2103	2370	1067	1334	-267
2012/2013	4684	3323	4473	210	1361	-1150
2013/2014	3666	2415	2496	1171	1252	-81
2014/2015	4639	3245	3236	1403	1394	9
Average				1070	1333	-263

Table D-17: Annual Water balance (Calibration) - 3PM (Monthly Input) – Ellagawa

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2006/2007	2873	1127	1394	1479	1746	-267
2007/2008	2920	1138	2089	831	1781	-950
2008/2009	2932	1111	1403	1529	1821	-292
2009/2010	3436	1366	1621	1814	2070	-256
Average	3040	1186	1627	1413	1854	-441

Table D-18: Annual Water balance (Calibration) - 3PM (Monthly Input) – Ellagawa

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2006/2007	2873	1127	1394	1479	1746	-267
2007/2008	2920	1138	2089	831	1781	-950
2008/2009	2932	1111	1403	1529	1821	-292
2009/2010	3436	1366	1621	1814	2070	-256
Average	3040	1186	1627	1413	1854	-441

Table D-19: Annual Water balance (Calibration Period) - 3PM (Daily Input) – Tawalama

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2000/2001	3006	1928	1920	1085	1078	8
2001/2002	2842	1678	1935	908	1165	-257
2002/2003	3783	2304	3055	727	1479	-752
2003/2004	3719	2319	2674	1044	1400	-355
2004/2005	3560	2219	2410	1151	1342	-191
2005/2006	3763	2401	2628	1136	1363	-227
2006/2007	3924	2448	2513	1410	1475	-65
2007/2008	4176	2799	3489	688	1377	-690
Average	3,596.65	2,261.90	2,578.09	1,018.56	1,334.75	(316.18)

Table D-20: Annual Water balance (Validation Period) - 3PM (Daily Input) – Tawalama

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2008/2009	4167	2694	2705	1461	1473	-11
2009/2010	3807	2551	2743	1063	1255	-192
2010/2011	4149	2884	3034	1115	1265	-150
2011/2012	3437	2103	2370	1067	1334	-267
2012/2013	4684	3323	4473	210	1361	-1150
2013/2014	3666	2415	2496	1171	1252	-81
2014/2015	4639	3245	3236	1403	1394	9
Average	4,078.18	2,744.96	3,008.14	1,070.04	1,333.23	(263.19)

Table D-21: Annual Water balance (Calibration Period) - 3PM (Daily Input) – Ellagawa

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2000/2001	2760	1178	1394	1366	1583	-216
2001/2002	2920	1222	2088	832	1698	-866
2002/2003	2929	1186	1395	1535	1744	-209
2003/2004	3438	1450	1630	1808	1988	-180
Average	3012	1259	1627	1385	1753	-368

Table D-22: Annual Water balance (Validation Period) - 3PM (Daily Input) – Ellagawa

Year	Thiessen Averaged Rainfall (mm)	Simulated Streamflow (mm)	Observed Streamflow (mm)	Observed Water Balance (mm)	Simulated Water Balance (mm)	Annual Water Balance Error (mm)
2004/2005	3388	1455	1770	1618	1933	-315
2005/2006	2593	1030	747	1846	1563	283
2006/2007	3948	1648	1761	2187	2300	-113
2007/2008	3493	1478	1354	2139	2015	124
Average	3355	1403	1408	1947	1953	-5