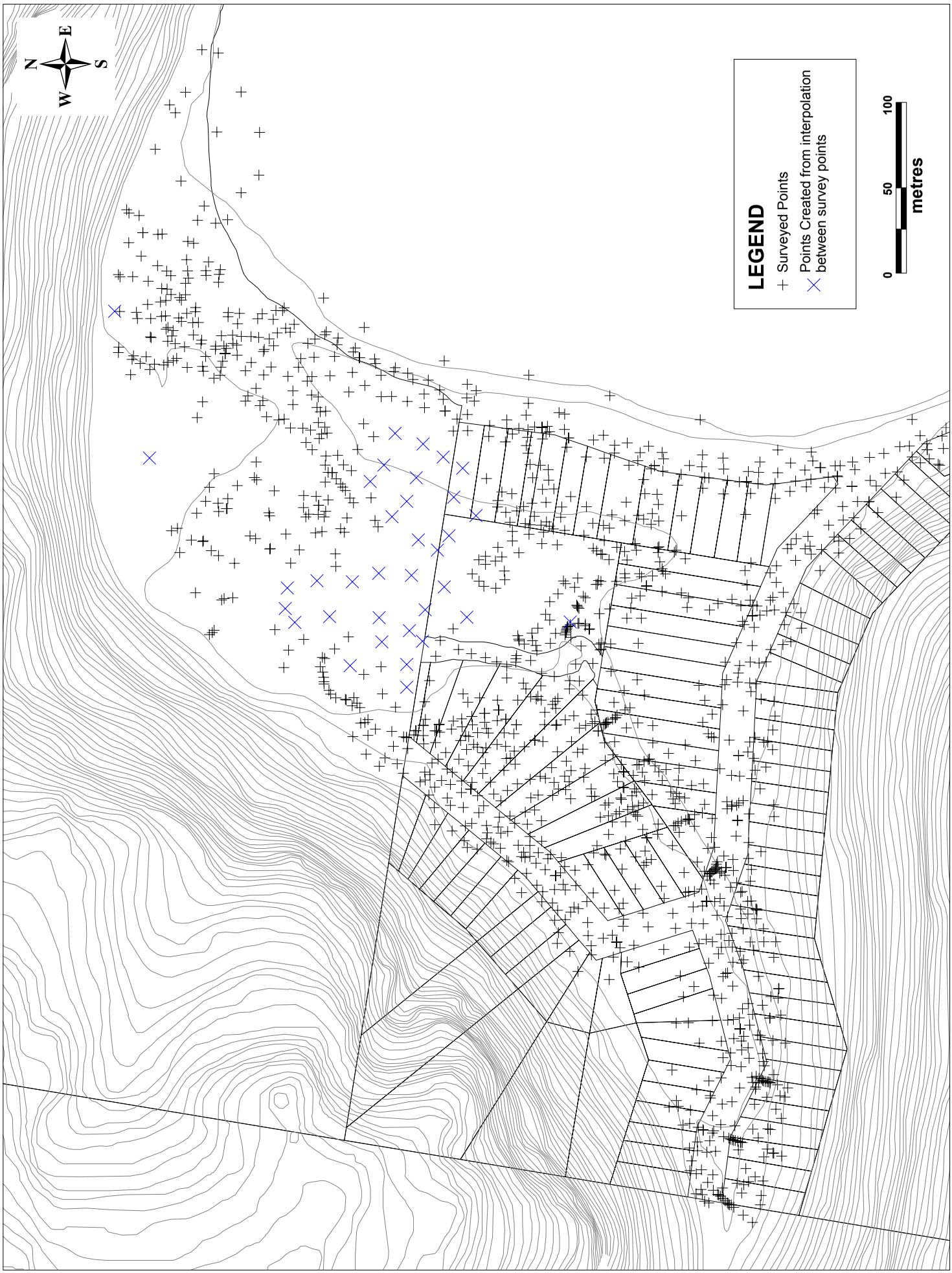
APPENDIX A

Survey Data

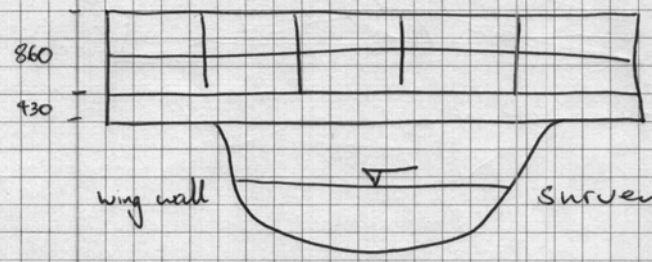

E
N
S
W
LEGEND
Surveyed Points
Points Created from interpolation between survey points
0
50
100
metres

LAWSON & TRELOAR PTY LTD

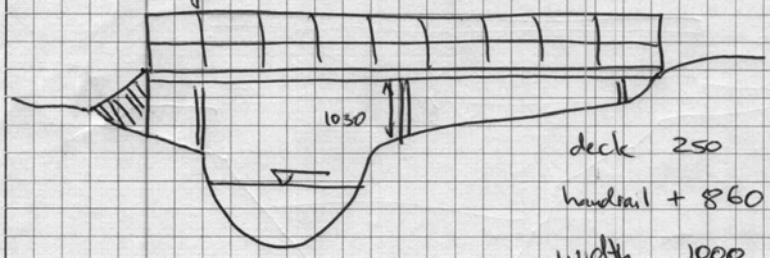
Subject: .....
.....
By: CBC

Project No: J2296
Date: 20/11/03
Page: ..... of: .....
Checked

1st Bridge width 3030

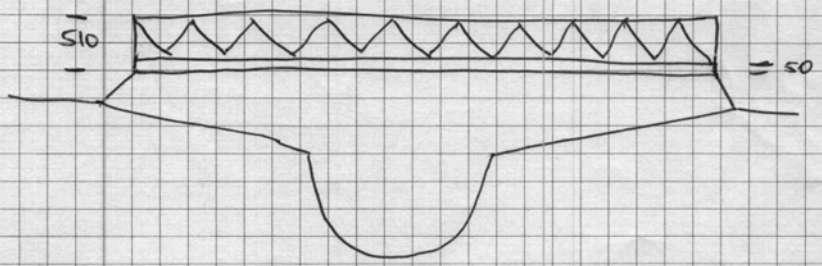


2nd Bridge



deck 250
handrail + 860
width 1000

3rd Bridge width 1050



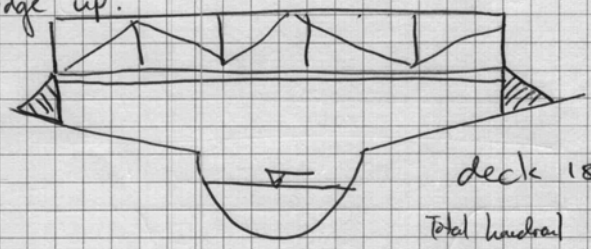
LAWSON & TRELOAR PTY LTD

Subject: .....
.....
By: CJBC

Project No: 2246
Date: 20/11/03
Page: ..... of: .....

Checked

4th Bridge up.

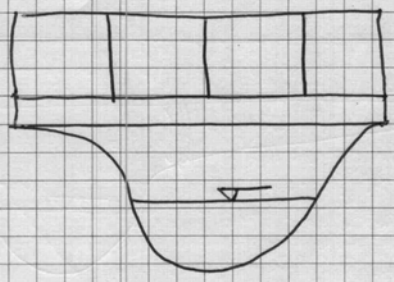


deck 180
Total headroom 920
width 1090

wooden.

5th Bridge

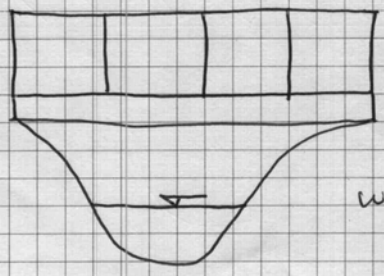
wooden



1000
250
width 1800

6th Bridge

wooden



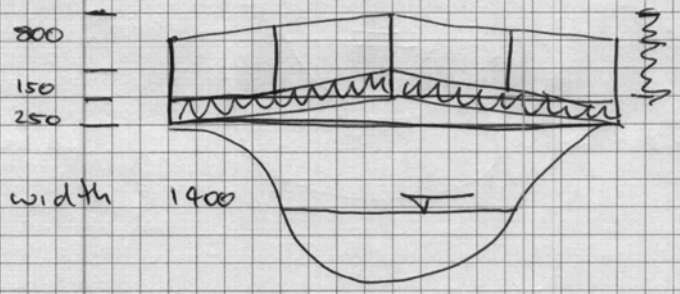
1030
180
width 1200.

LAWSON & TRELOAR PTY LTD

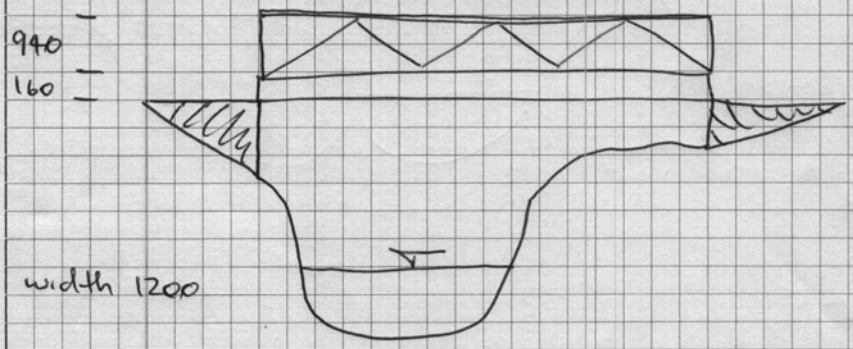
Subject: .....
.....
By: CBK

Project No: 52296
Date: 20.11.03
Page: ..... of: .....
Checked

7th Bridge. wooden.

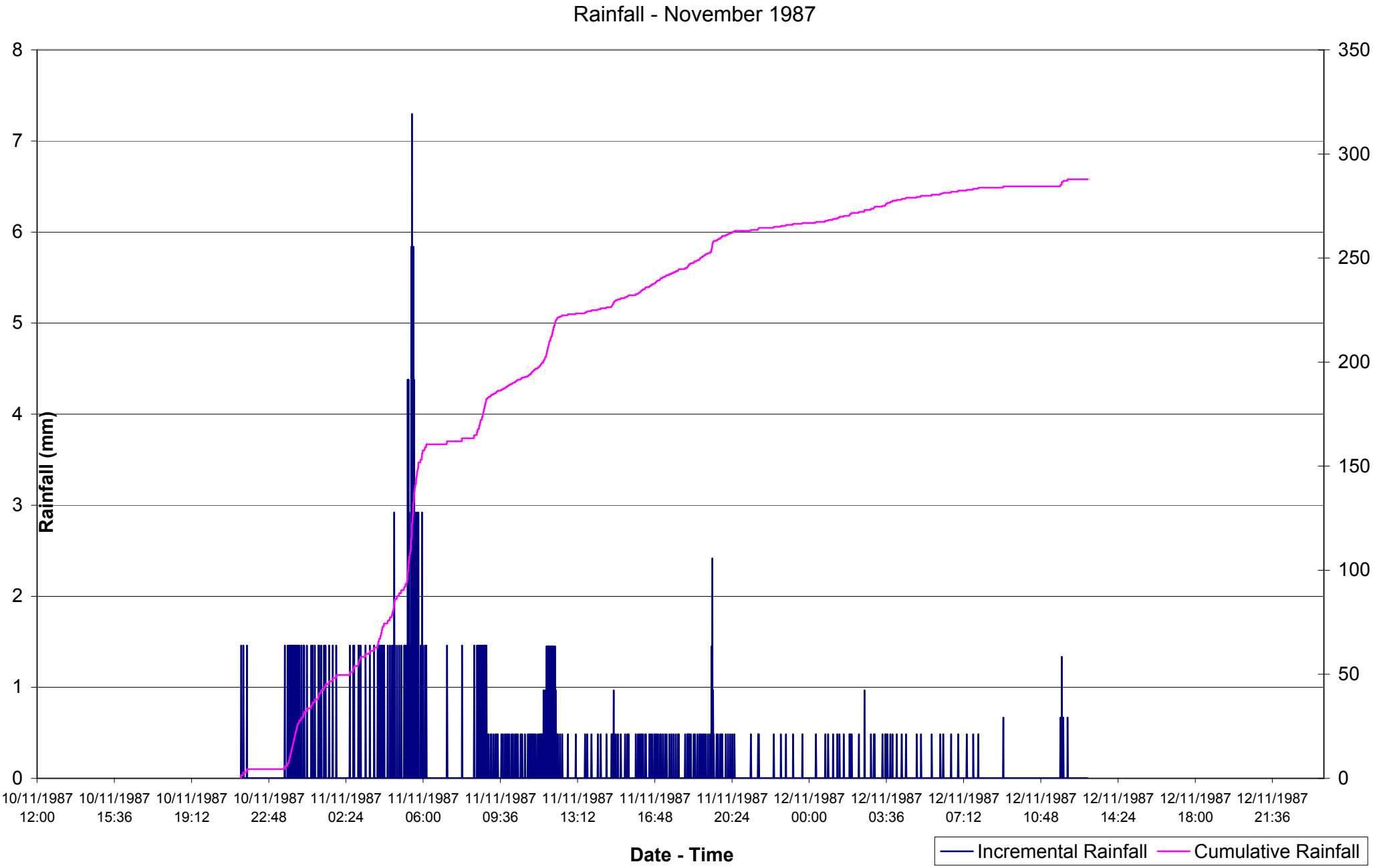


8th Bridge up (most u/s)



APPENDIX B

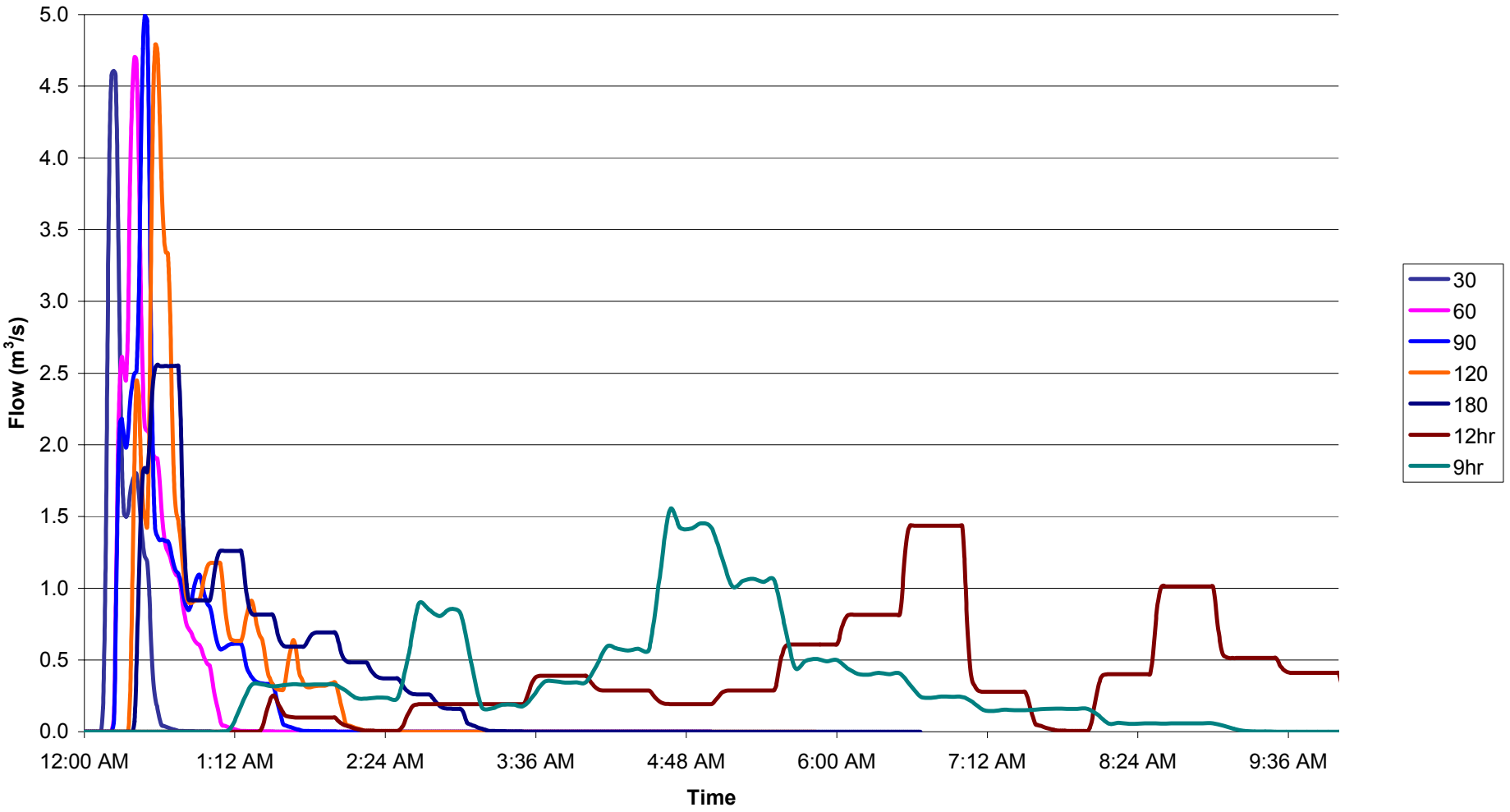
Pluviograph Traces


Rainfall - November 1987
Rainfall (mm)
0
1
2
3
4
5
6
7
8
0
50
100
150
200
250
300
350
10/11/1987 12:00
10/11/1987 15:36
10/11/1987 19:12
10/11/1987 22:48
11/11/1987 02:24
11/11/1987 06:00
11/11/1987 09:36
11/11/1987 13:12
11/11/1987 16:48
11/11/1987 20:24
12/11/1987 00:00
12/11/1987 03:36
12/11/1987 07:12
12/11/1987 10:48
12/11/1987 14:24
12/11/1987 18:00
12/11/1987 21:36
Date - Time
Incremental Rainfall
Cumulative Rainfall

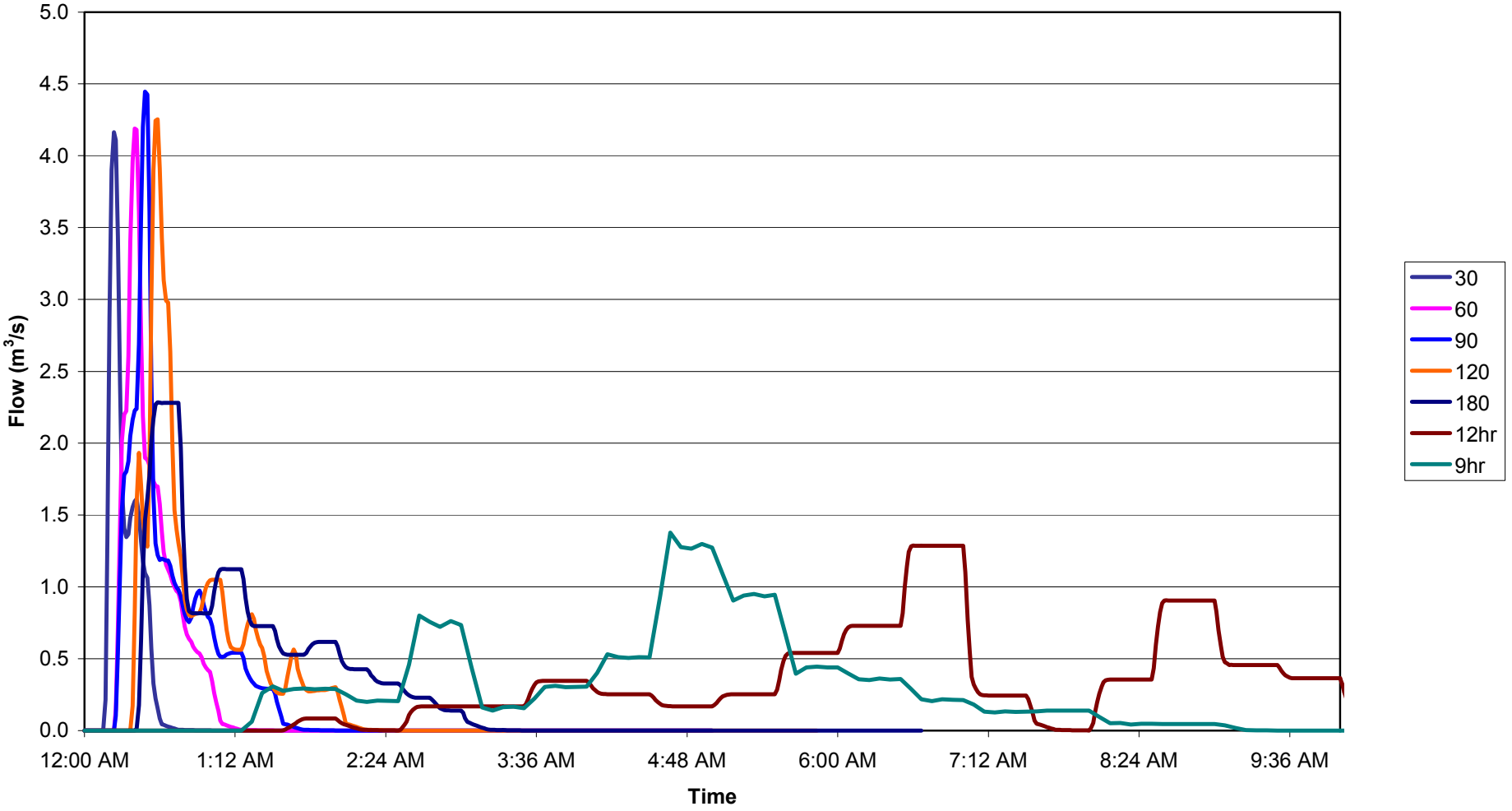
APPENDIX C

Flow Hydrographs
(Design events and 1987 event)

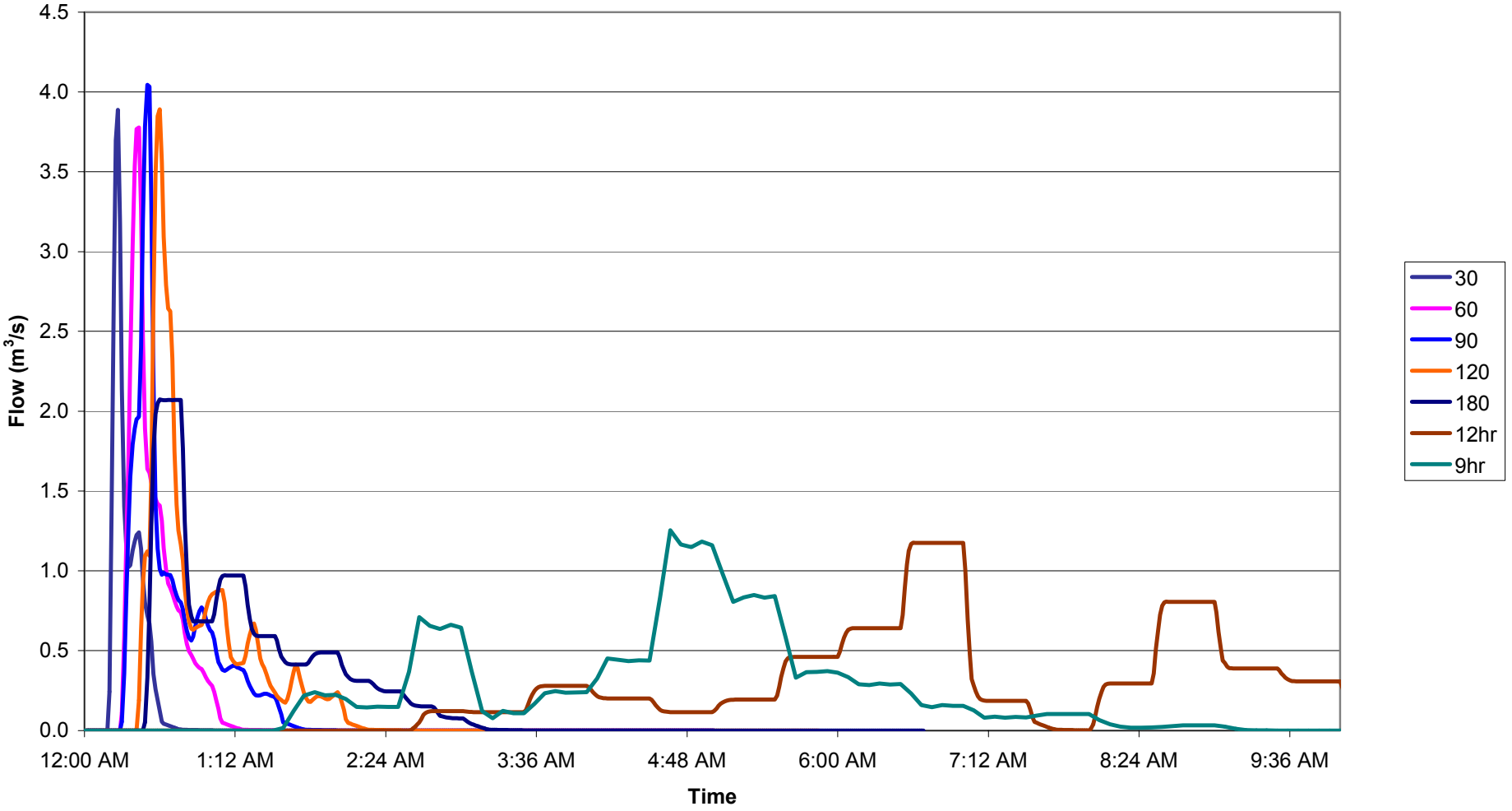
Node A1, 1% AEP Hydrograph - All Durations



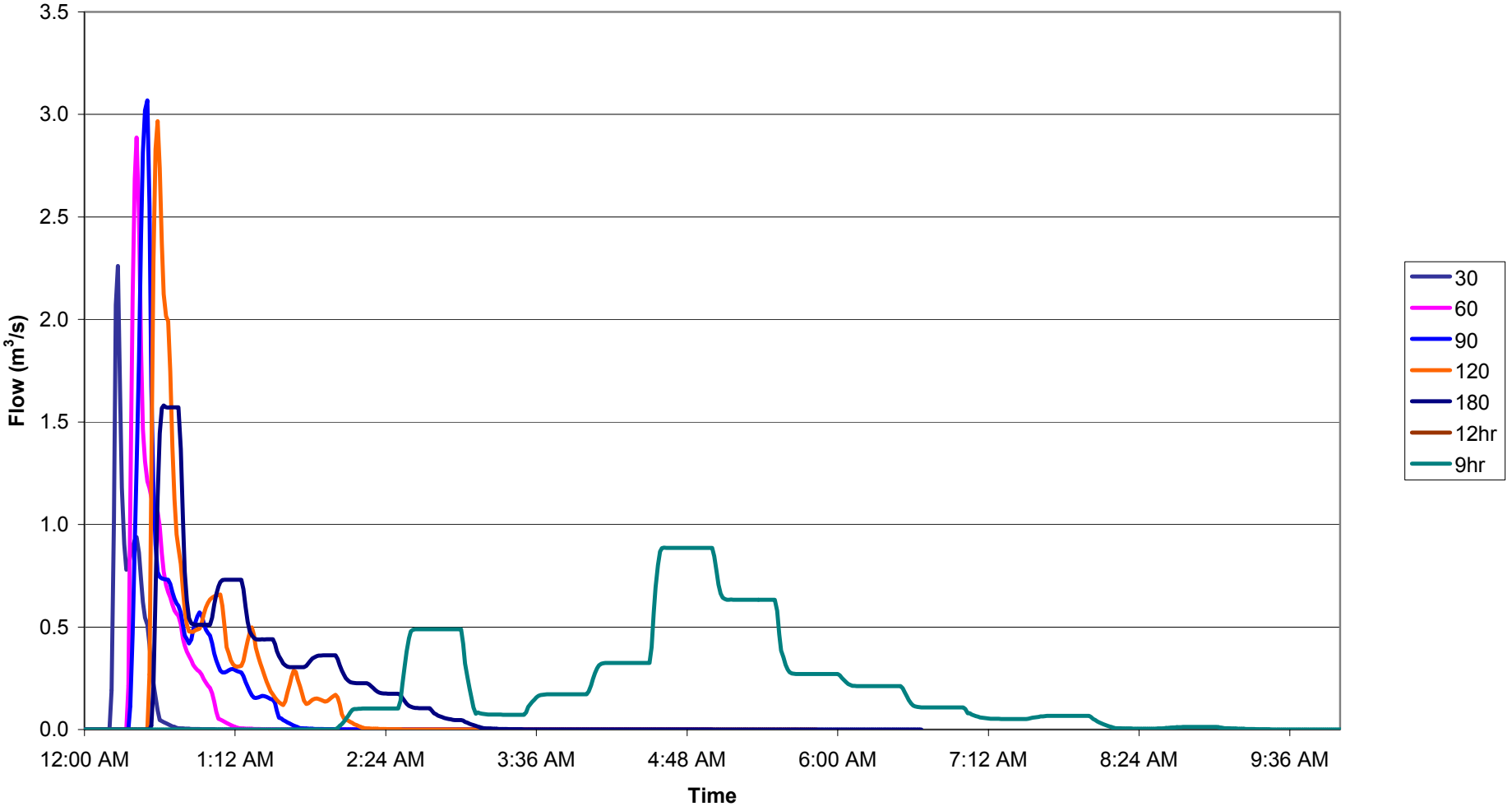
Node A1, 2% AEP Hydrograph - All Durations

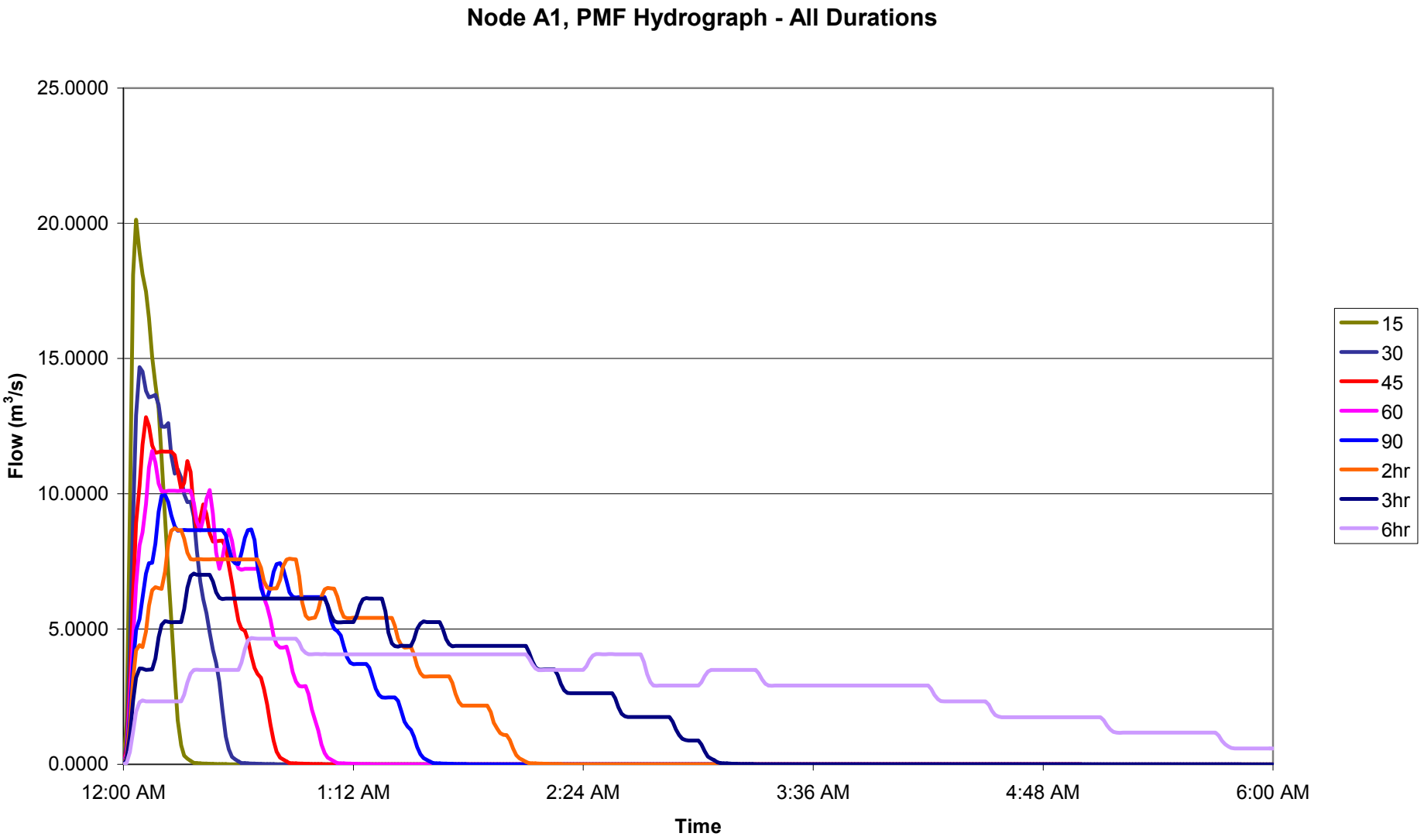


Node A1, 5% AEP Hydrograph - All Durations

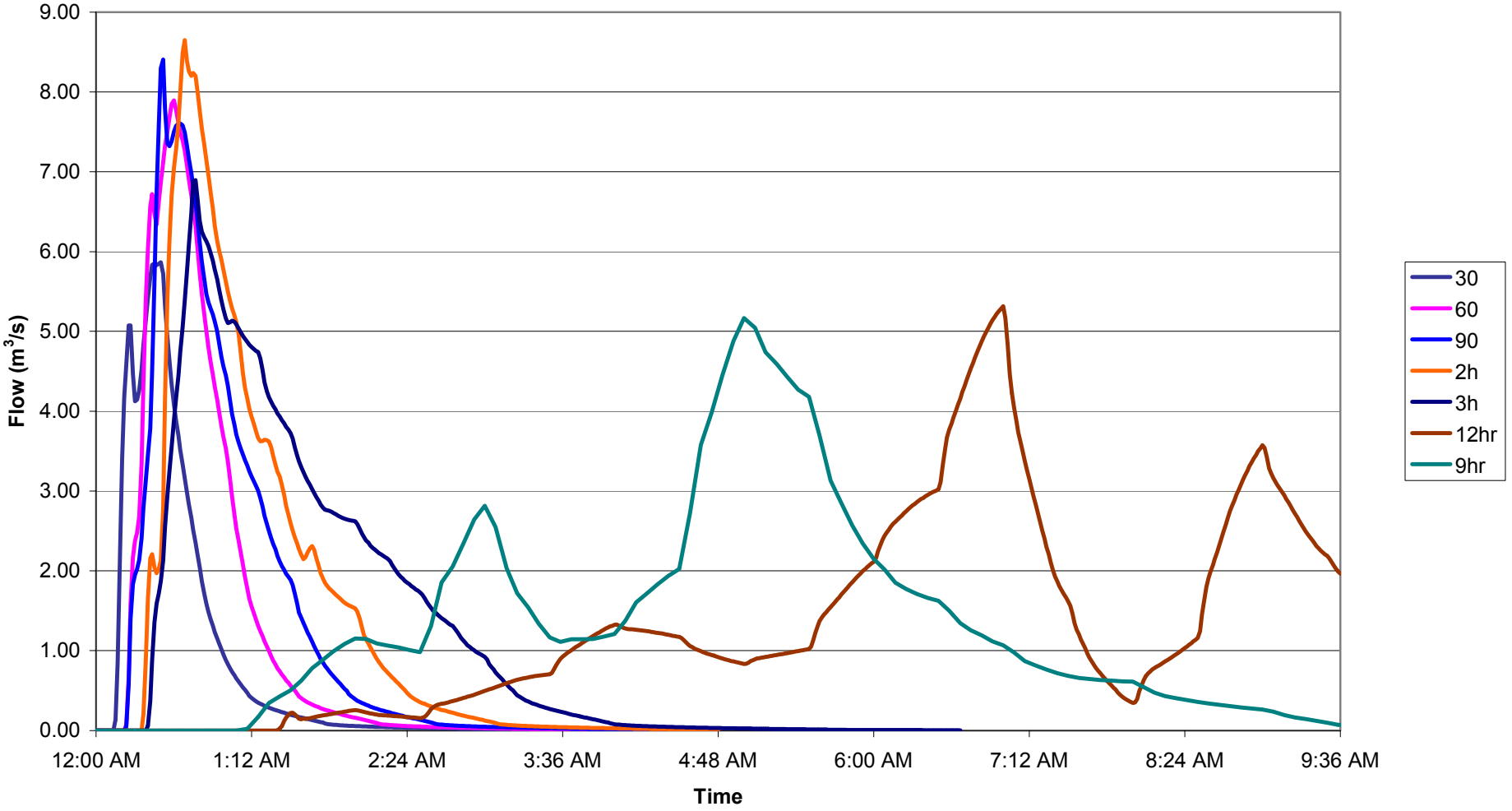


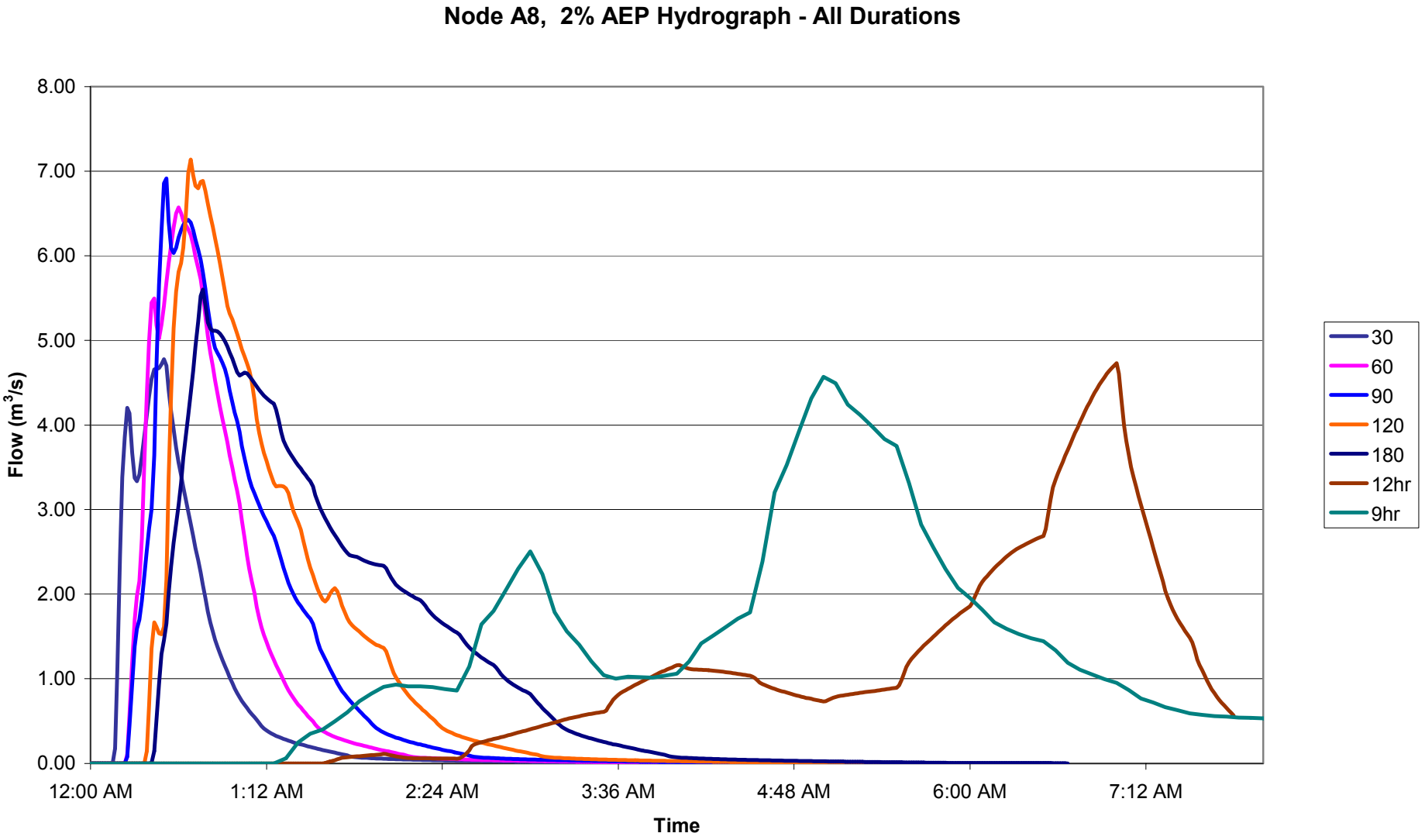
Node A1, 20% AEP Hydrograph - All Durations



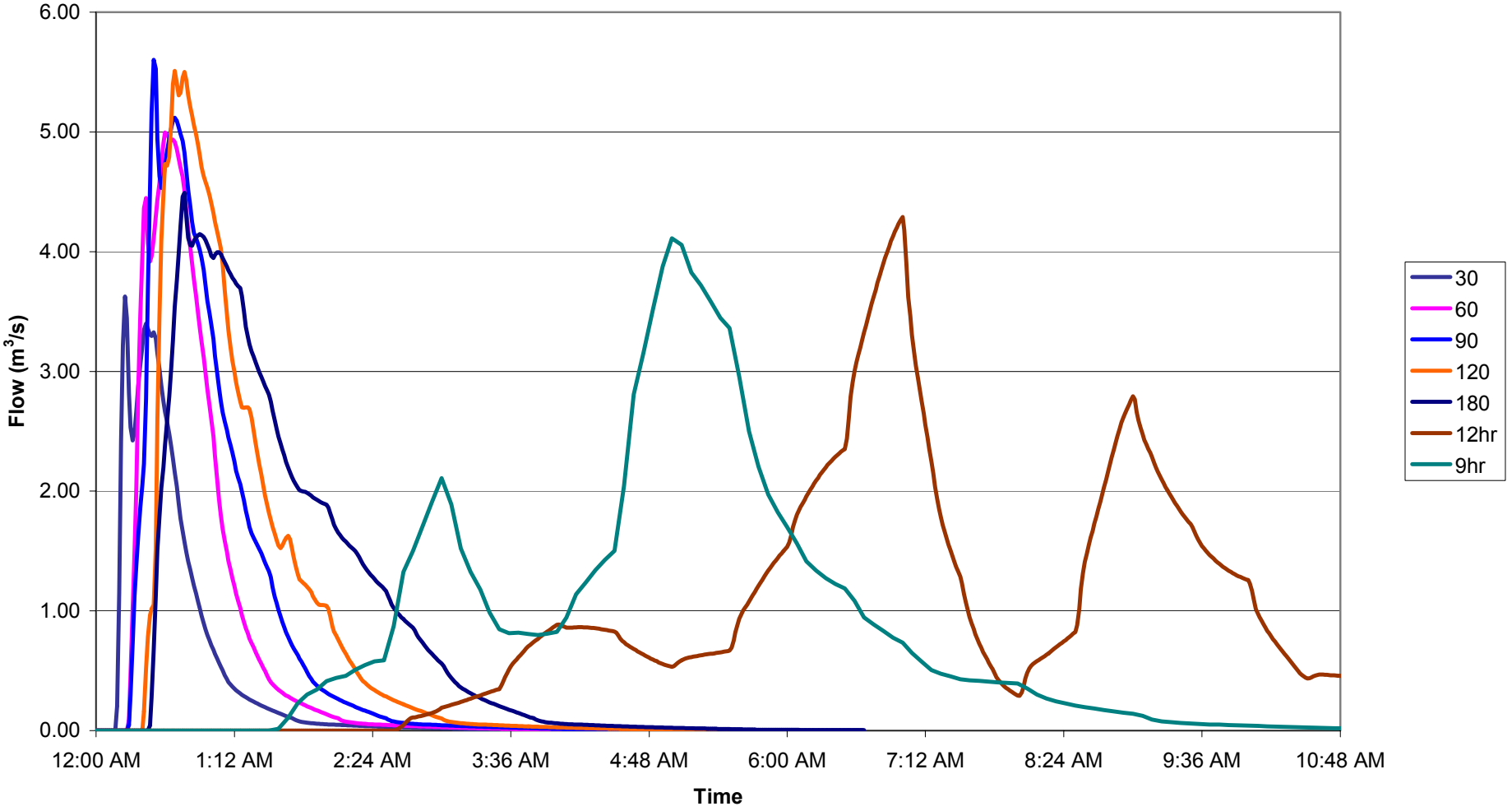

Node A1, PMF Hydrograph - All Durations
25.0000
20.0000
15.0000
10.0000
5.0000
0.0000
Flow (m3/s)
12:00 AM
1:12 AM
2:24 AM
3:36 AM
4:48 AM
6:00 AM
Time
15
30
45
60
90
2hr
3hr
6hr

Node A8, 1% AEP Hydrograph - All Durations

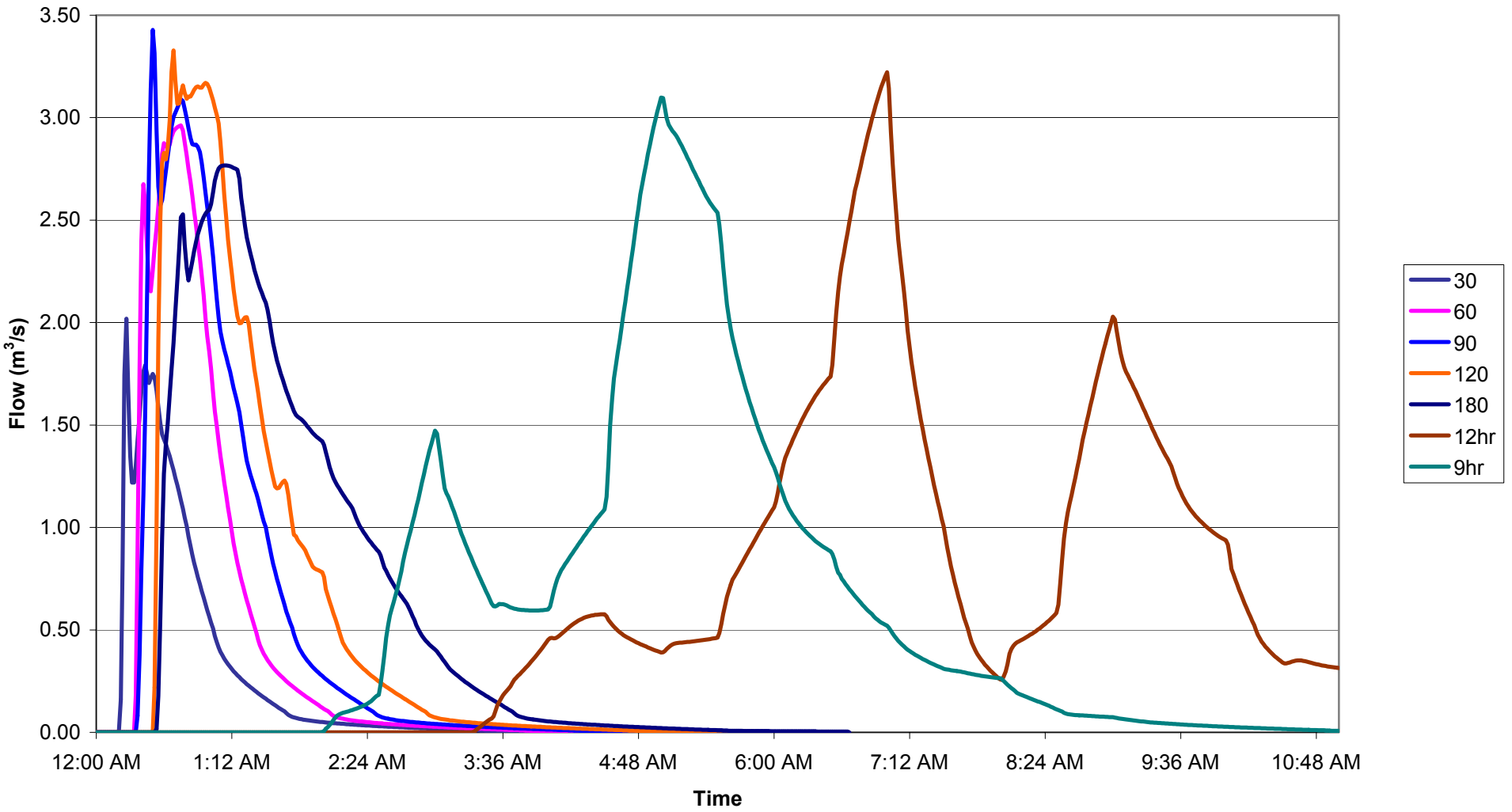



Node A8, 2% AEP Hydrograph - All Durations
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Flow (m3/s)
12:00 AM
1:12 AM
2:24 AM
3:36 AM
4:48 AM
6:00 AM
7:12 AM
Time
30
60
90
120
180
12hr
9hr

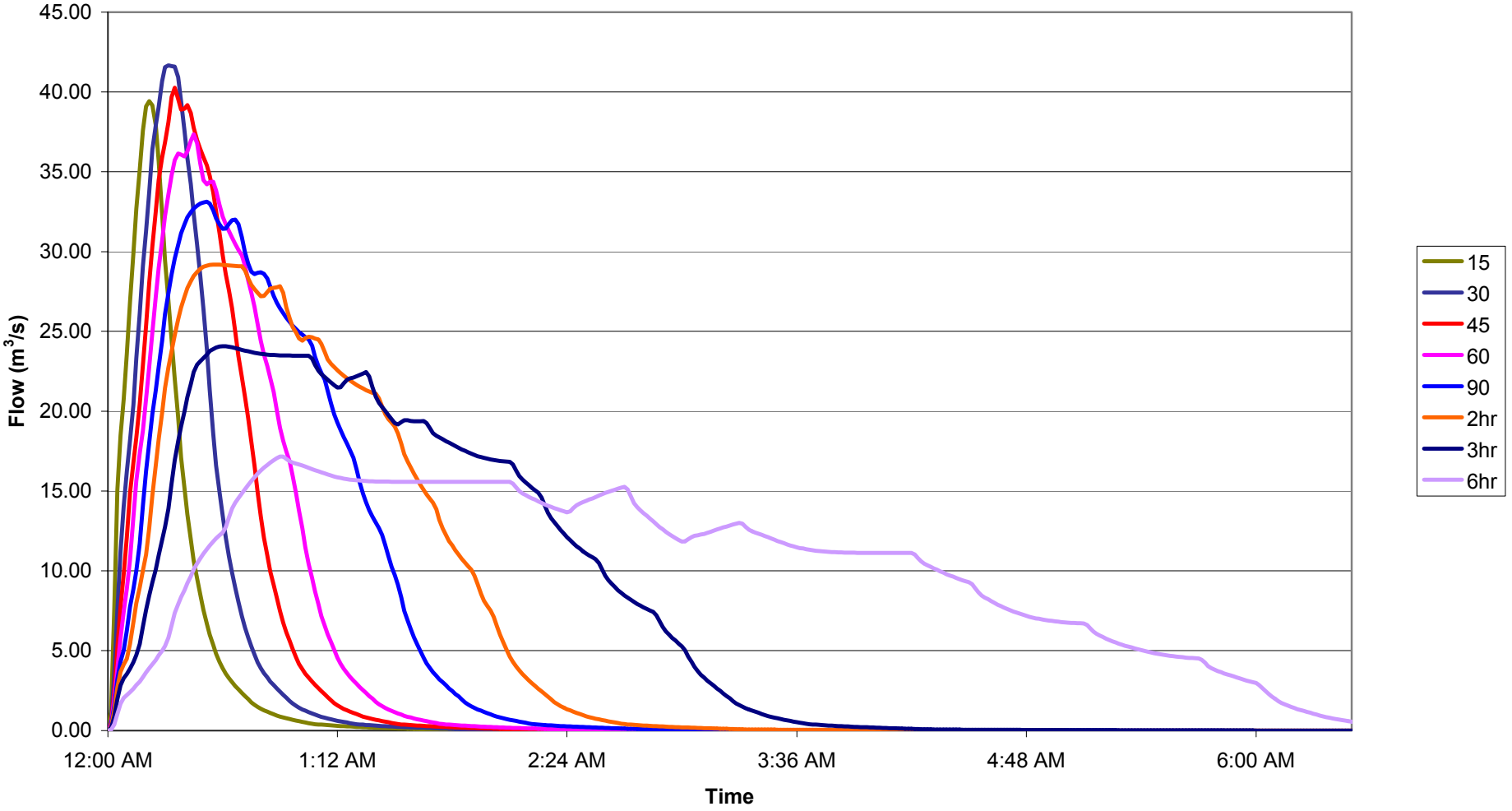
Node A8, 5% AEP Hydrograph - All Durations

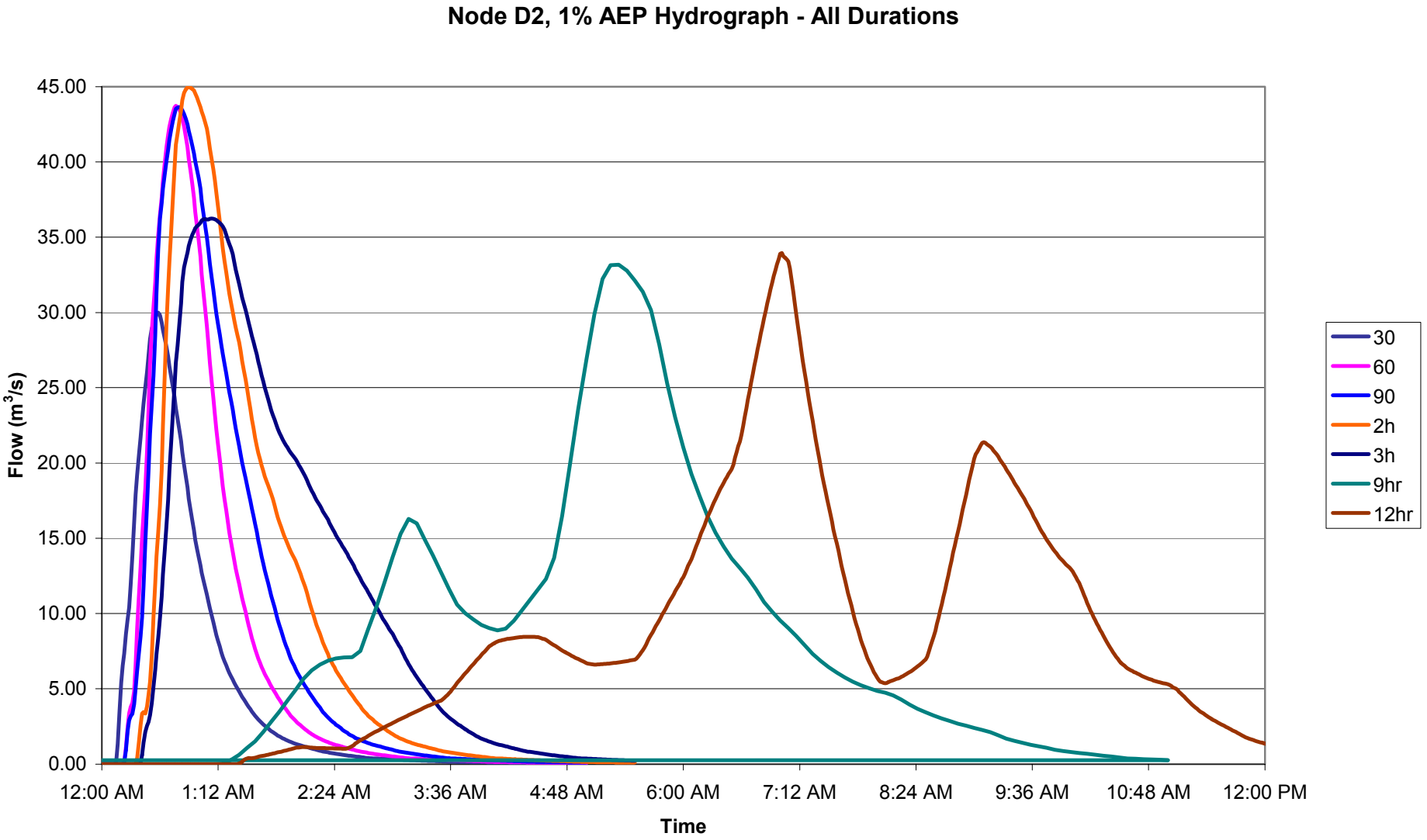


Node A8, 20% AEP Hydrograph - All Durations

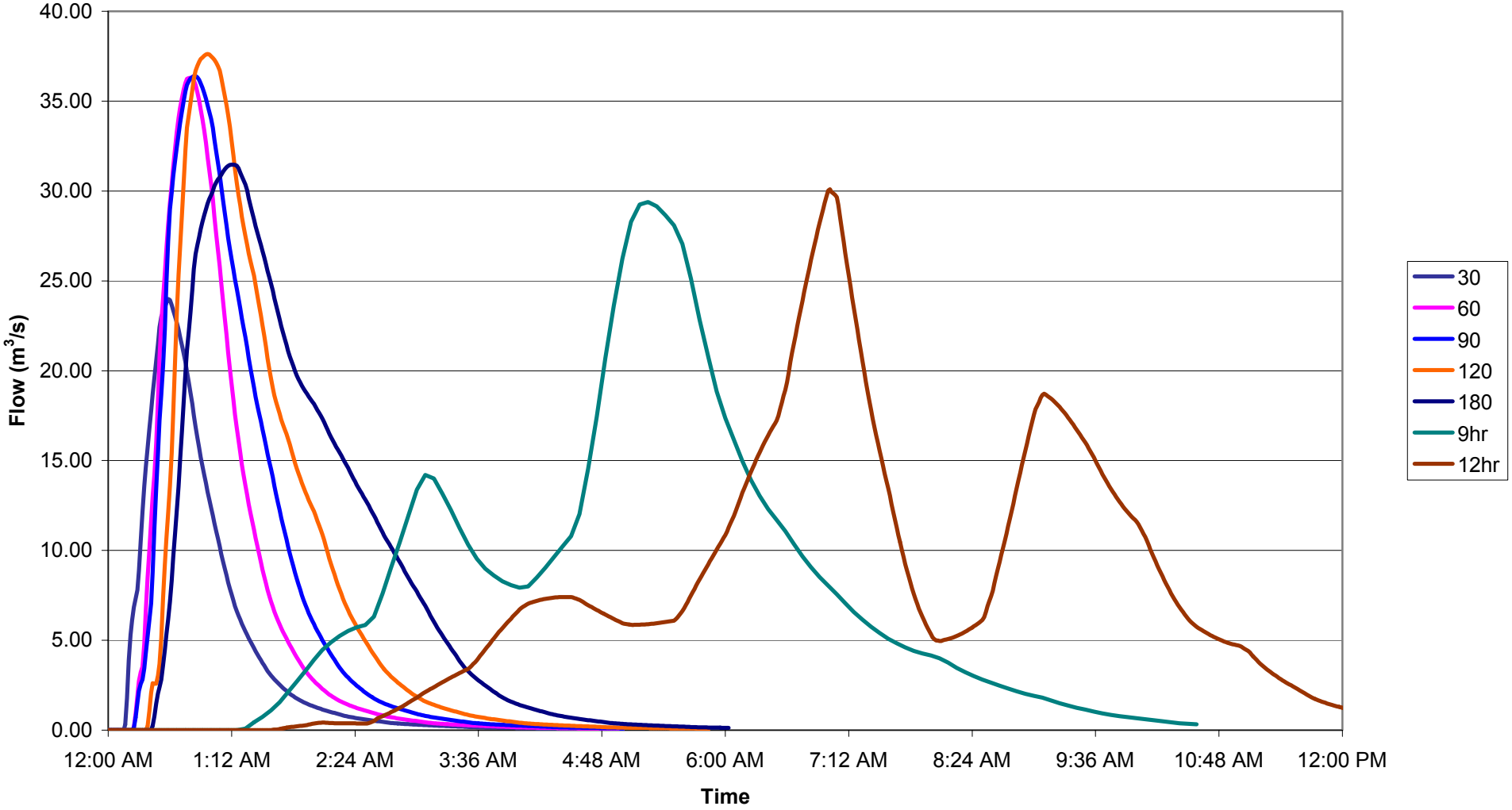


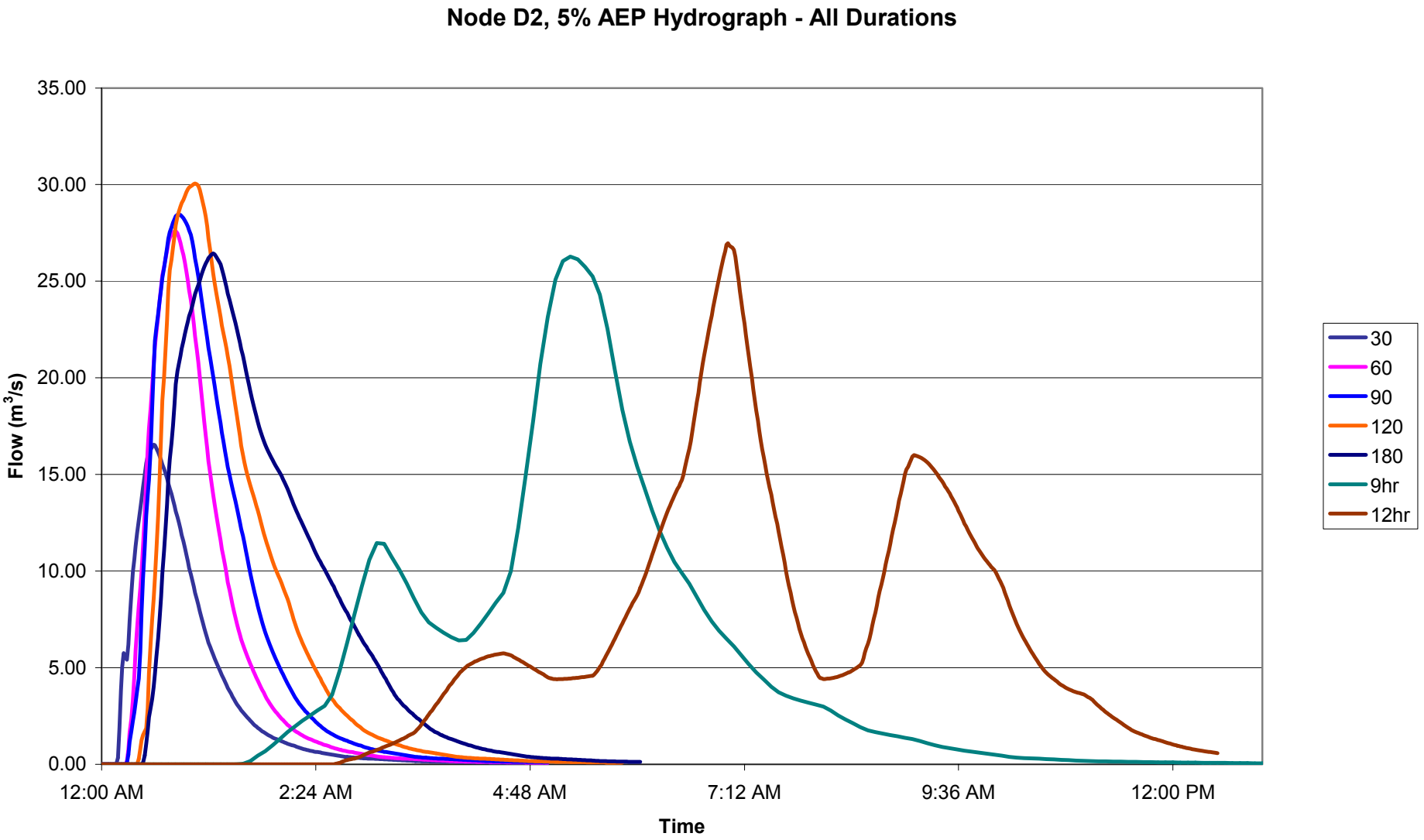
Node A8, PMF Hydrograph - All Durations



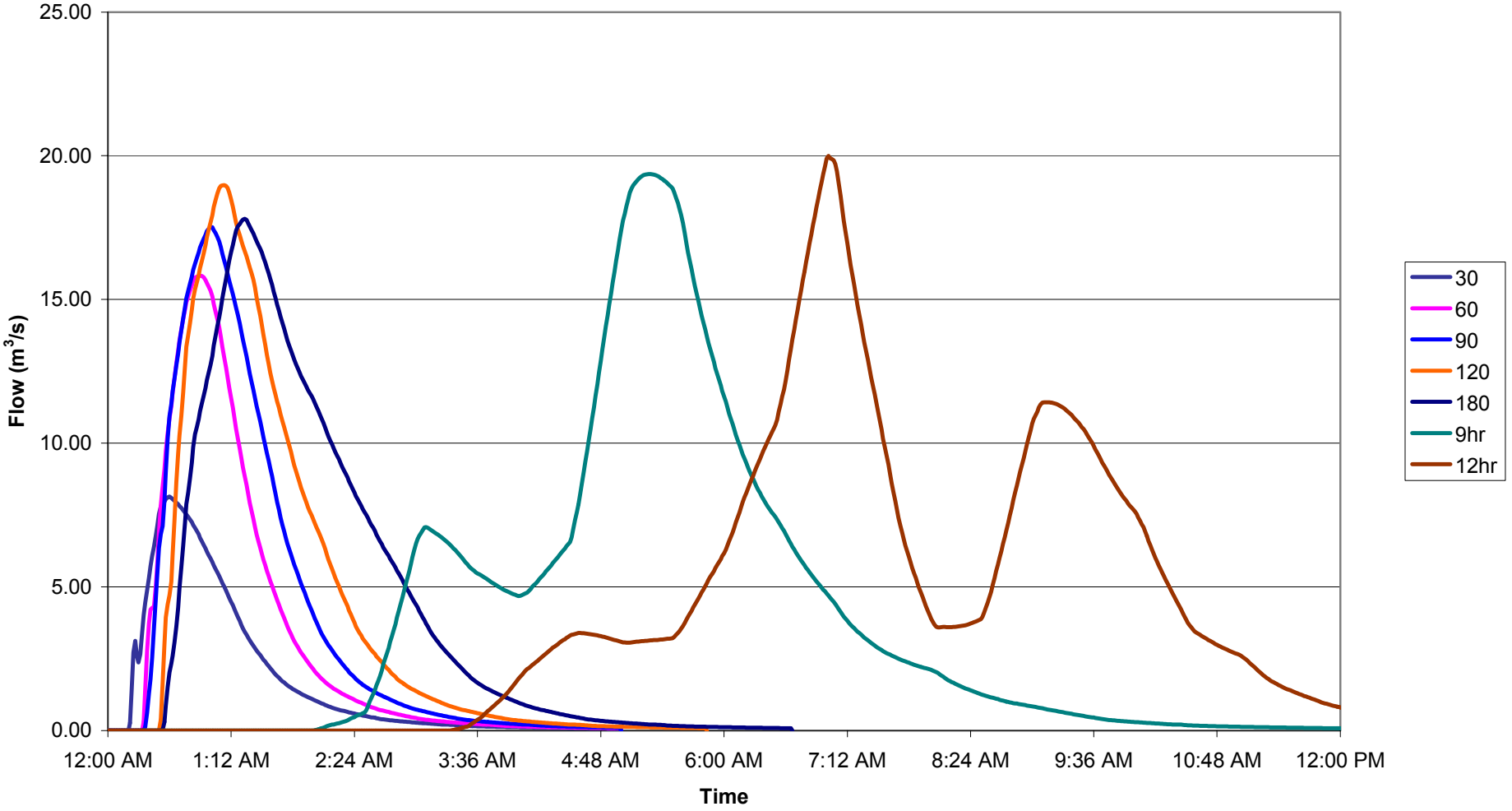

Node D2, 1% AEP Hydrograph - All Durations
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Flow (m3/s)
12:00 AM
1:12 AM
2:24 AM
3:36 AM
4:48 AM
6:00 AM
7:12 AM
8:24 AM
9:36 AM
10:48 AM
12:00 PM
Time
30
60
90
2h
3h
9hr
12hr

Node D2, 2% AEP Hydrograph - All Durations

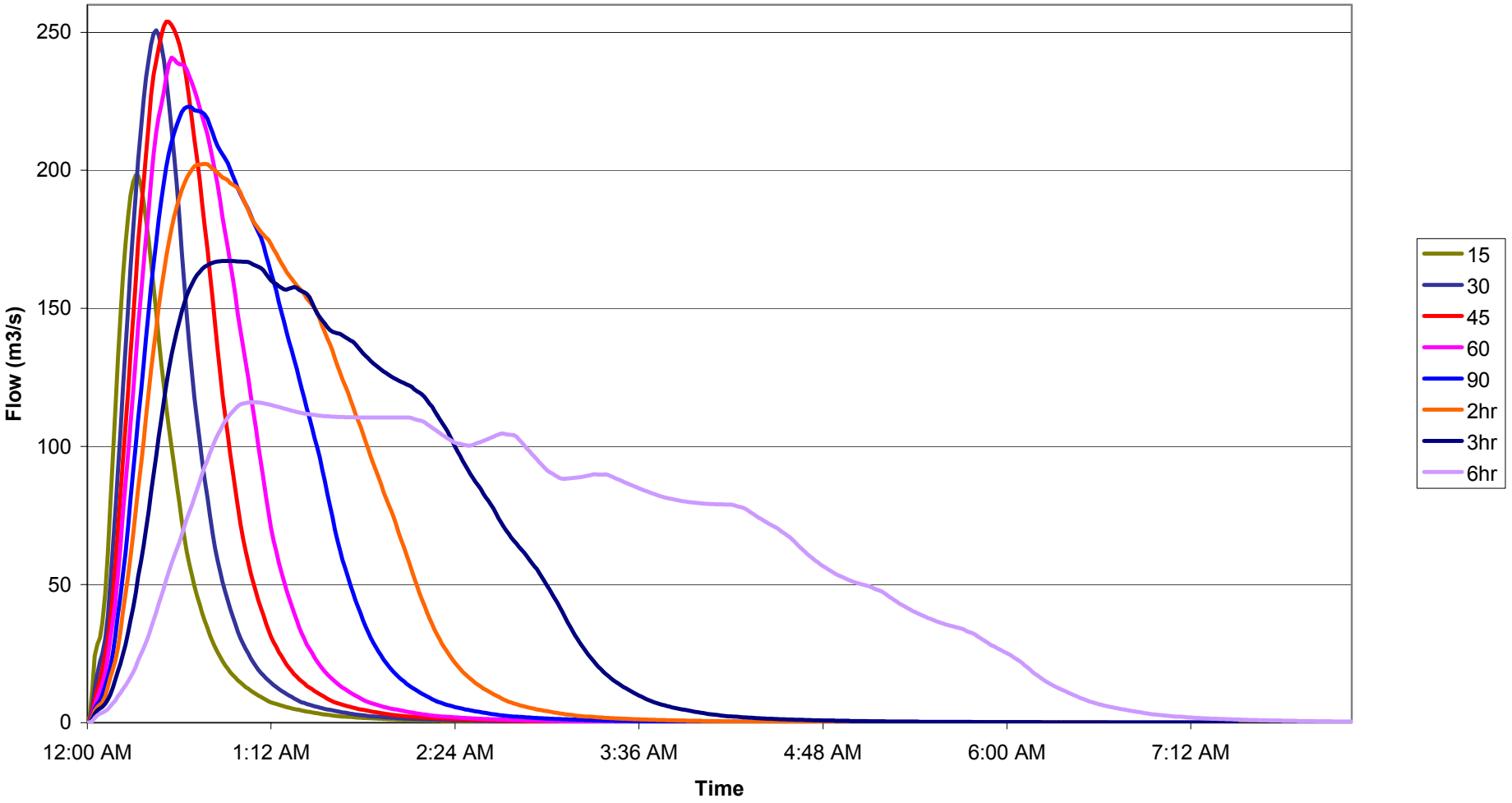



Node D2, 5% AEP Hydrograph - All Durations
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Flow (m3/s)
12:00 AM
2:24 AM
4:48 AM
7:12 AM
9:36 AM
12:00 PM
Time
30
60
90
120
180
9hr
12hr

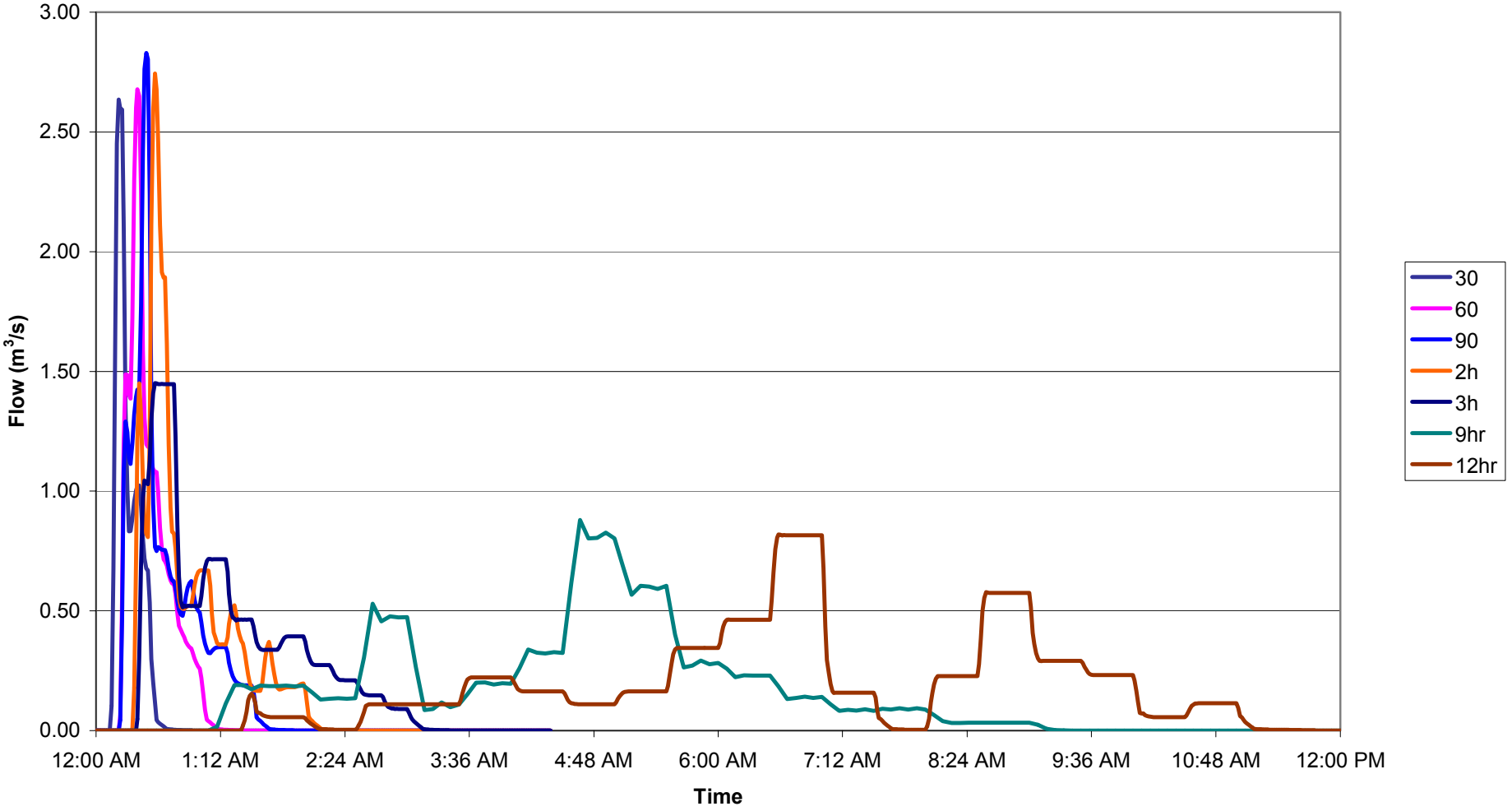
Node D2, 20% AEP Hydrograph - All Durations



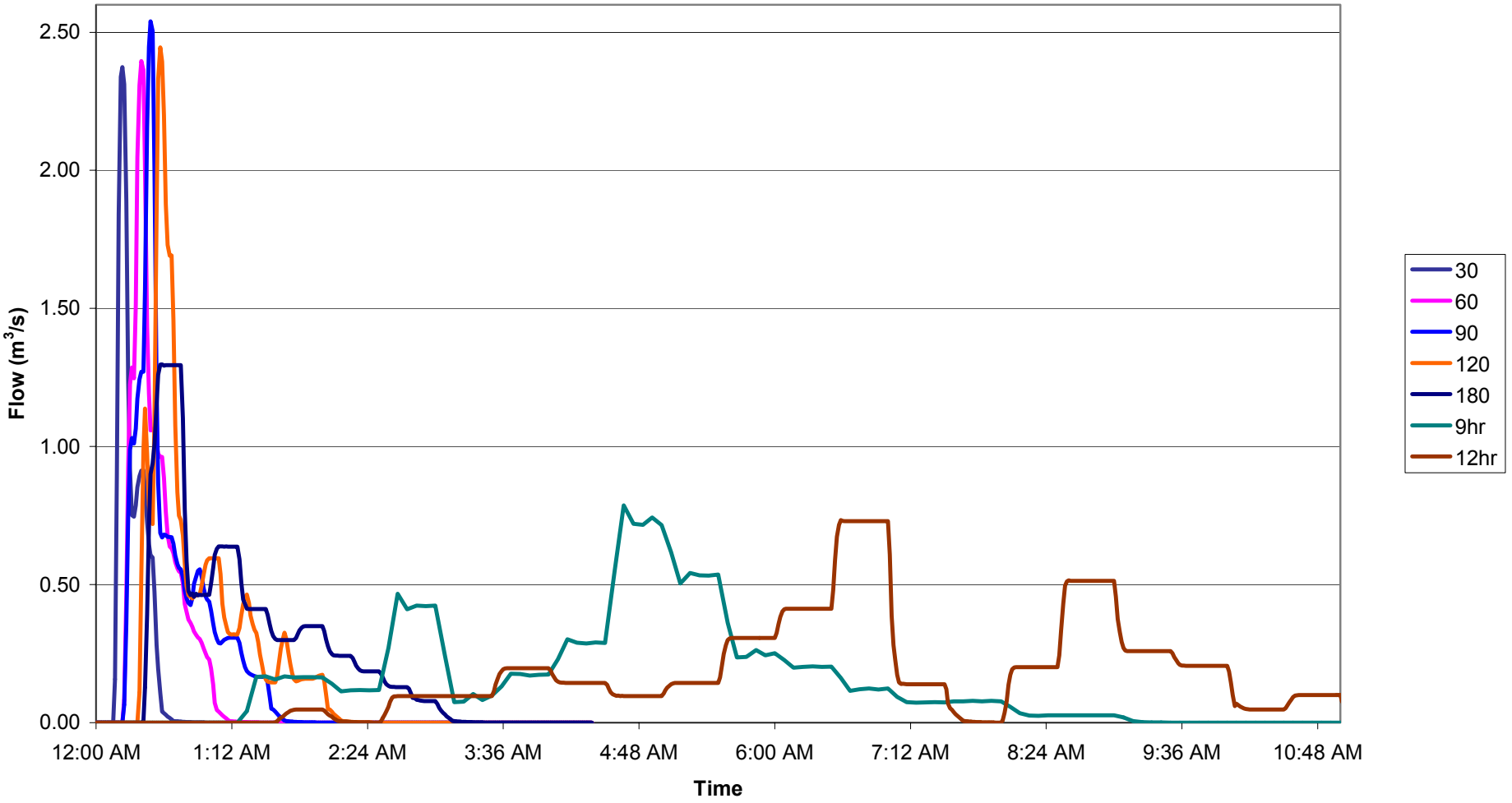
Node D2, PMF Hydrograph - All Durations



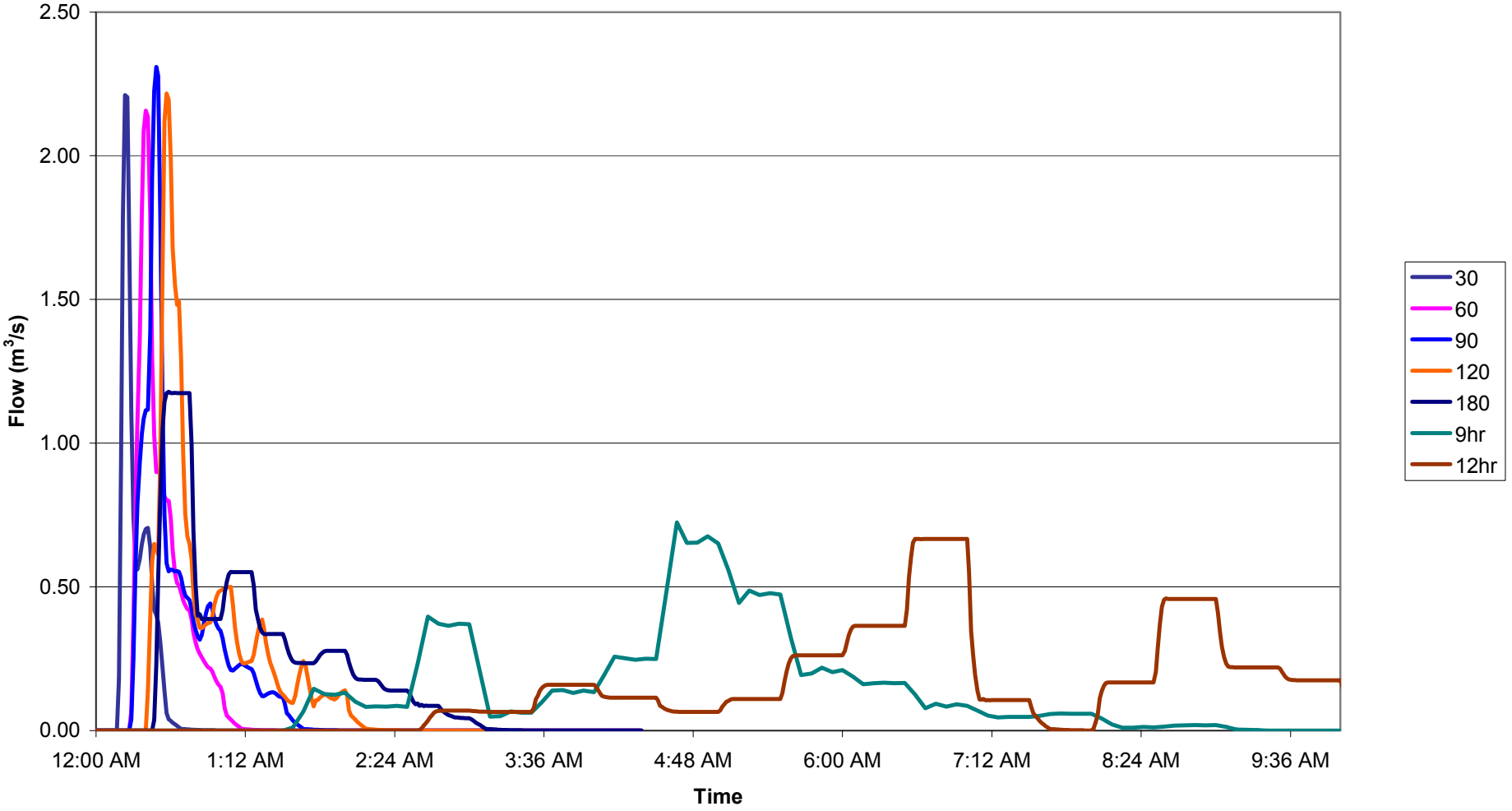
Node A10, 1% AEP Hydrograph - All Durations



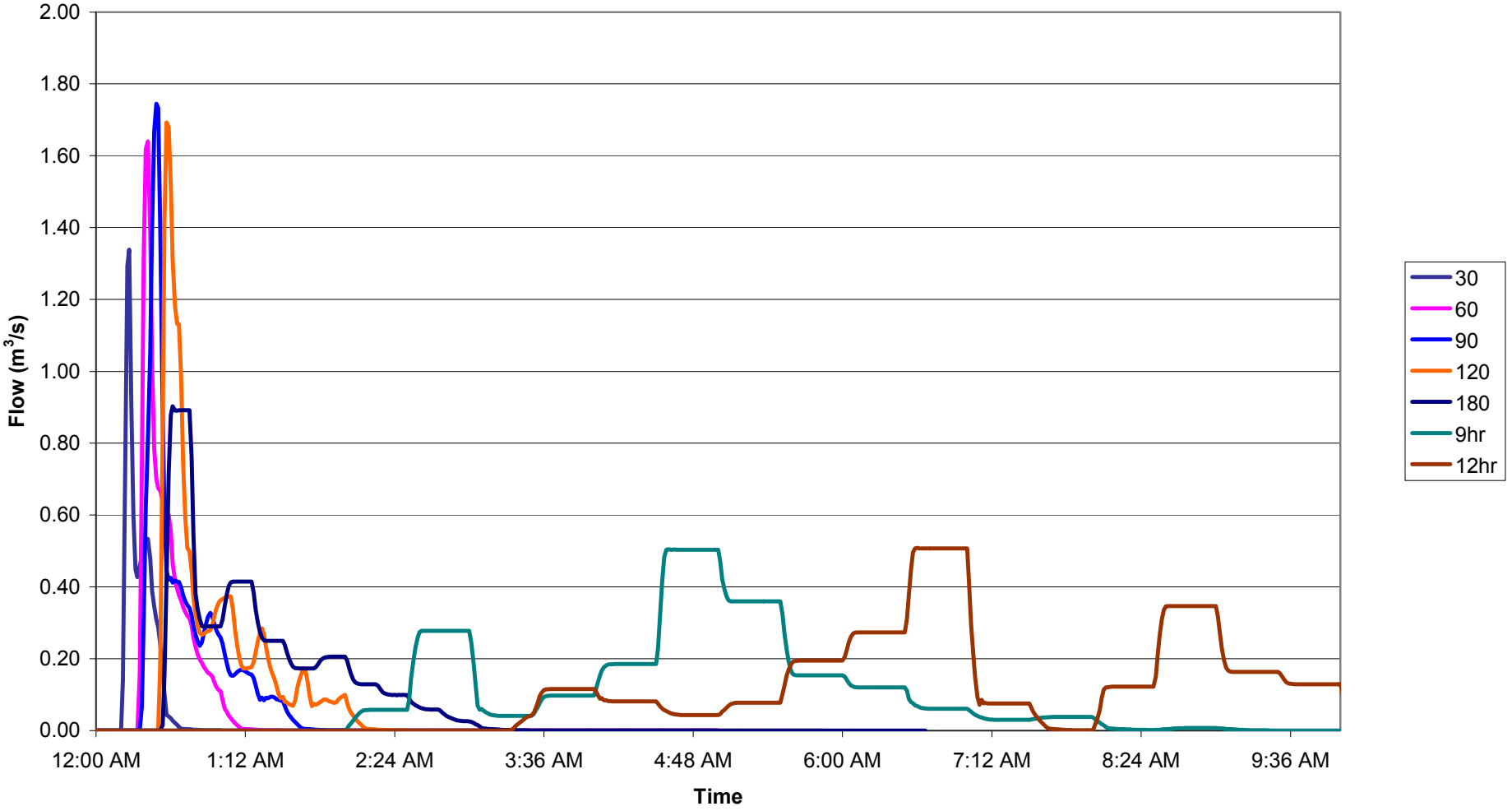
Node A10, 2% AEP Hydrograph - All Durations



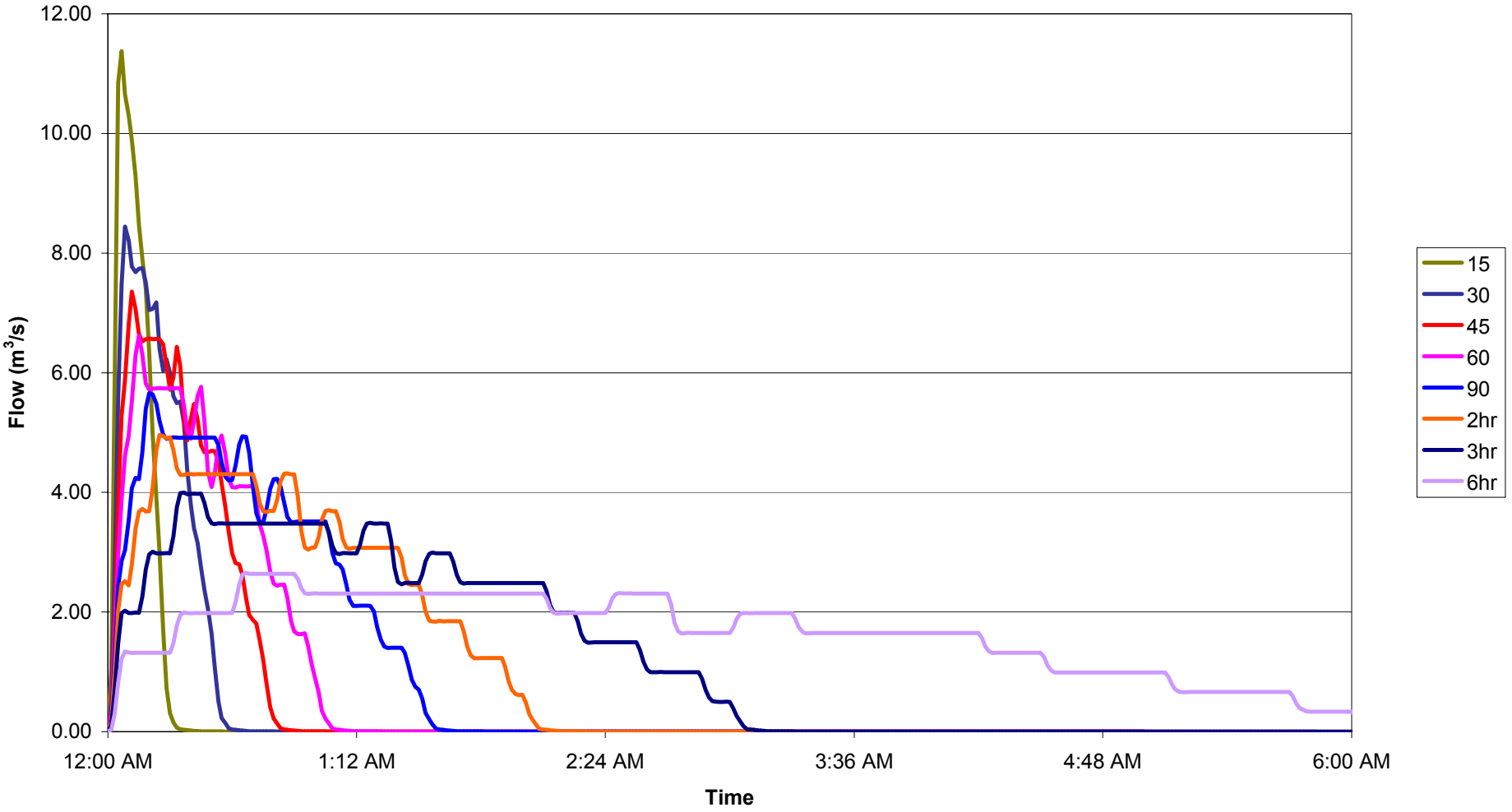
Node A10, 5% AEP Hydrograph - All Durations



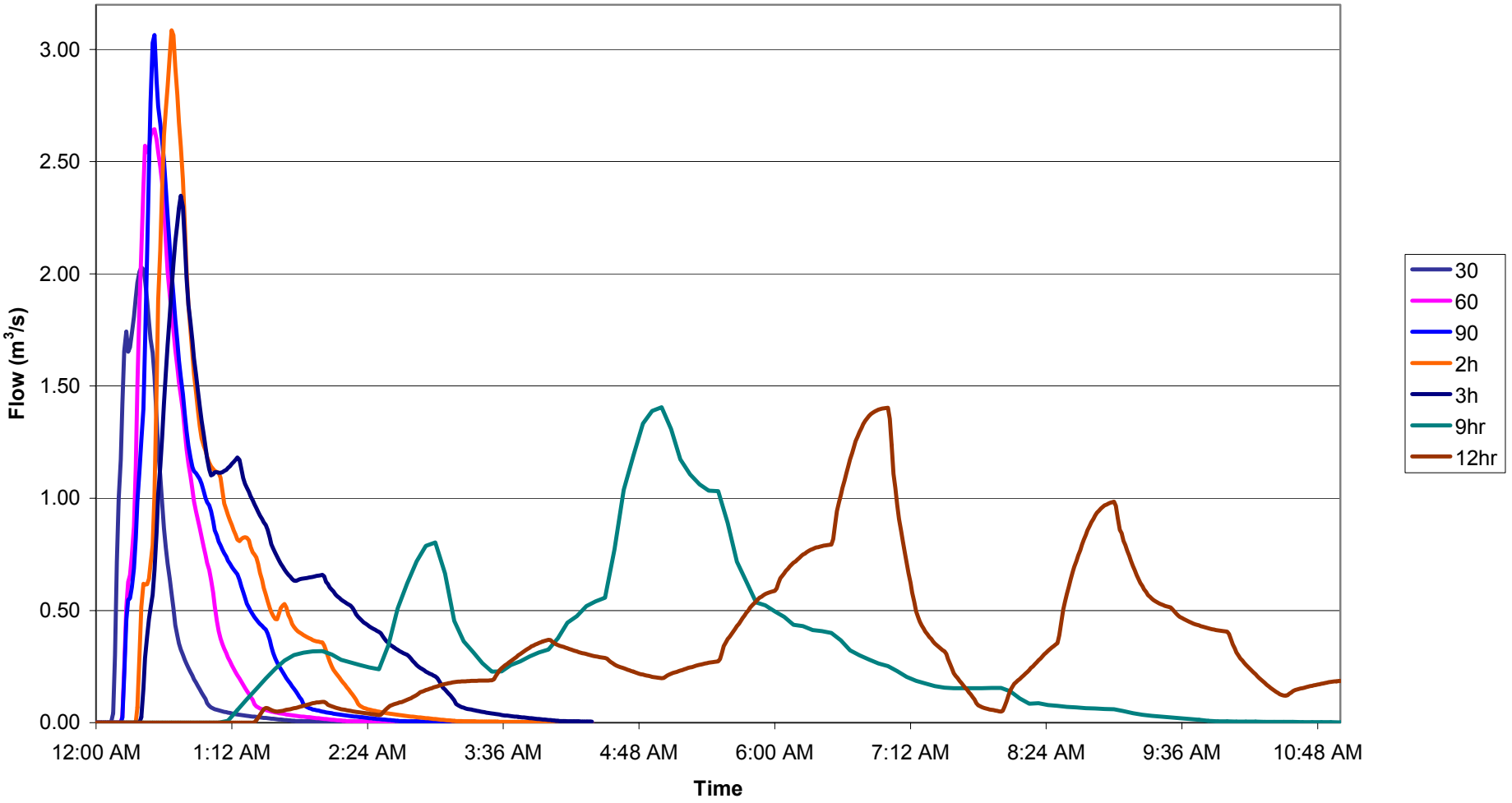
Node A10, 20% AEP Hydrograph - All Durations



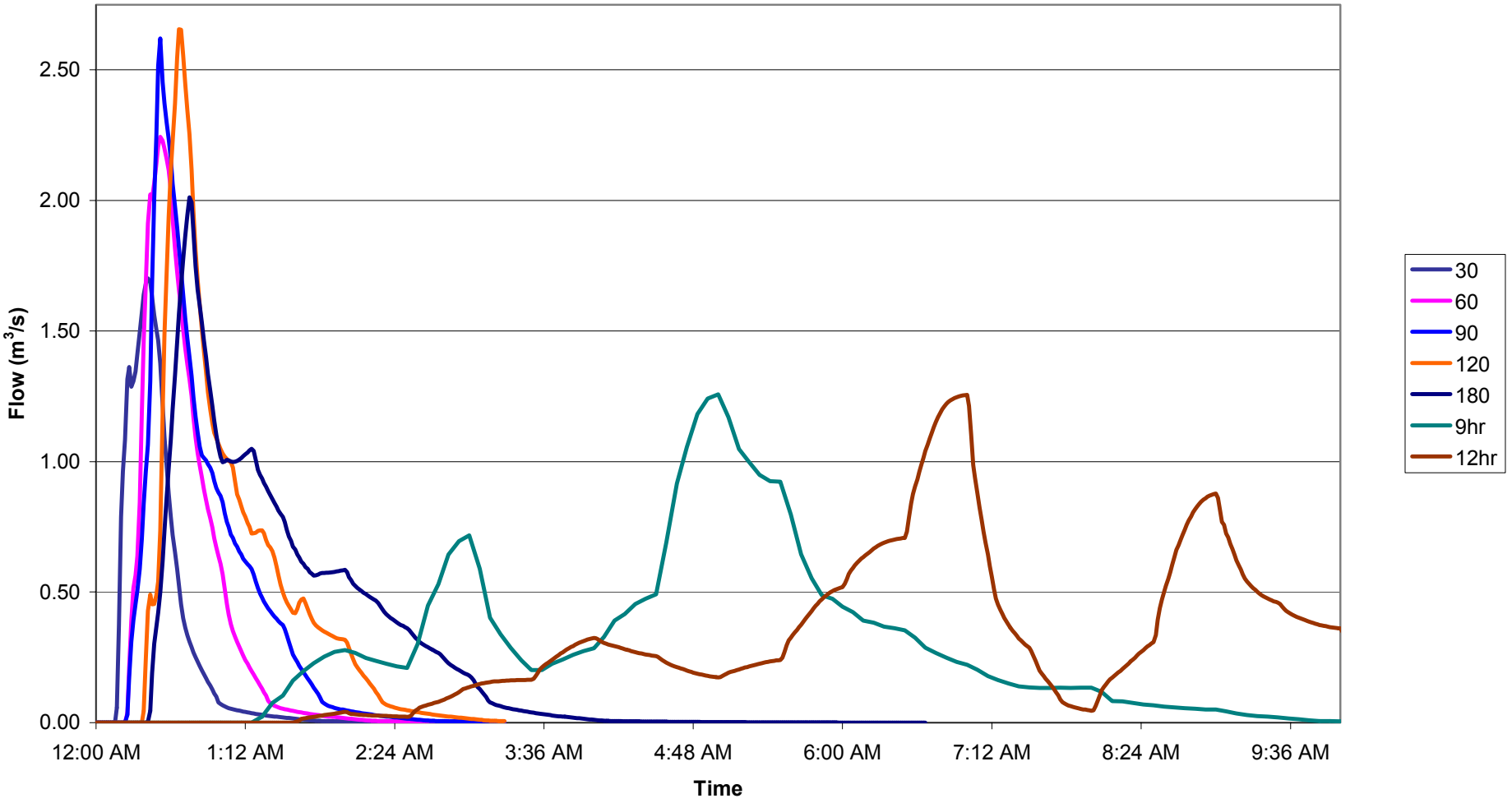
Node A10, PMF Hydrograph - All Durations



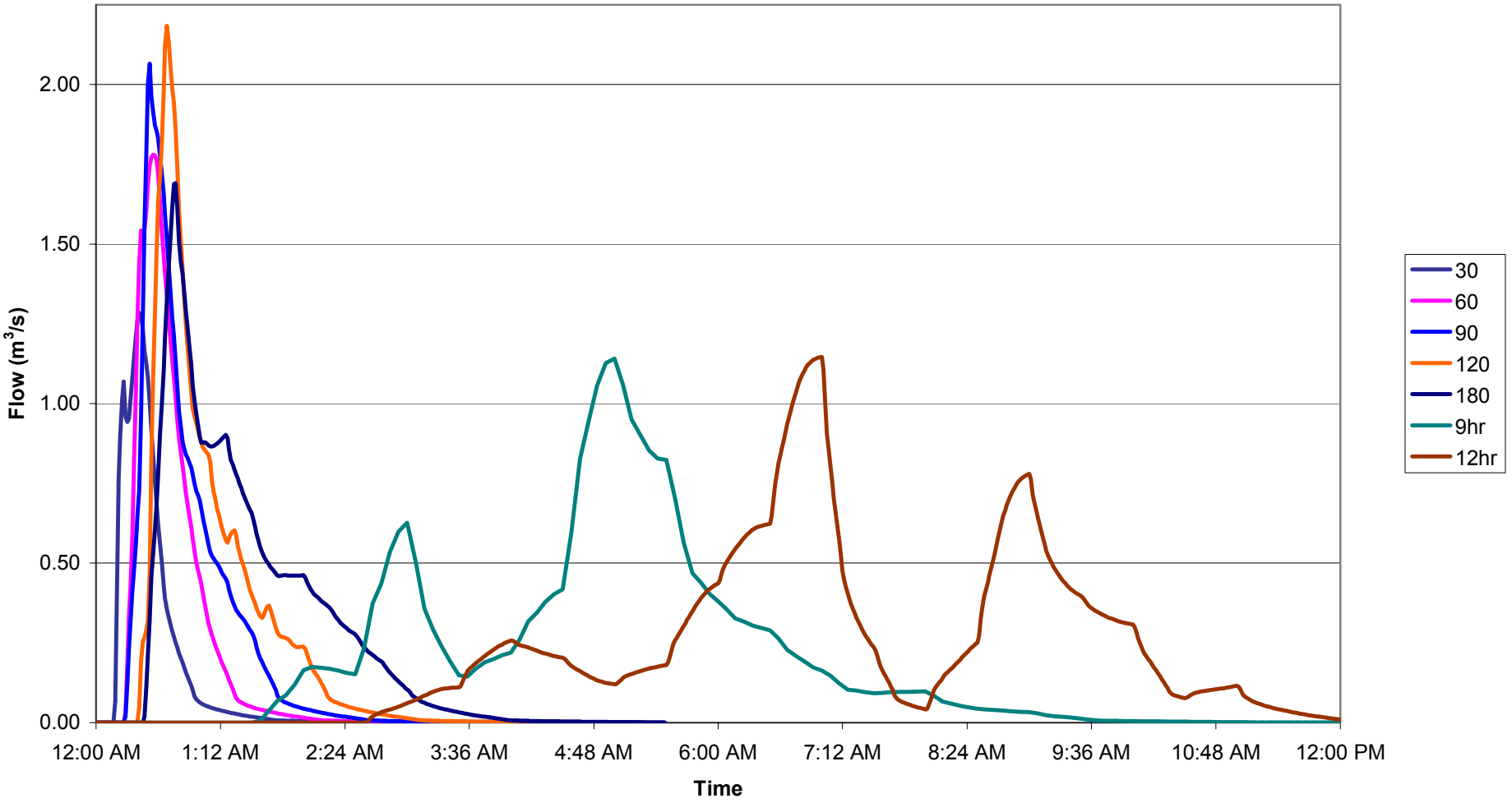
Node A13, 1% AEP Hydrograph - All Durations



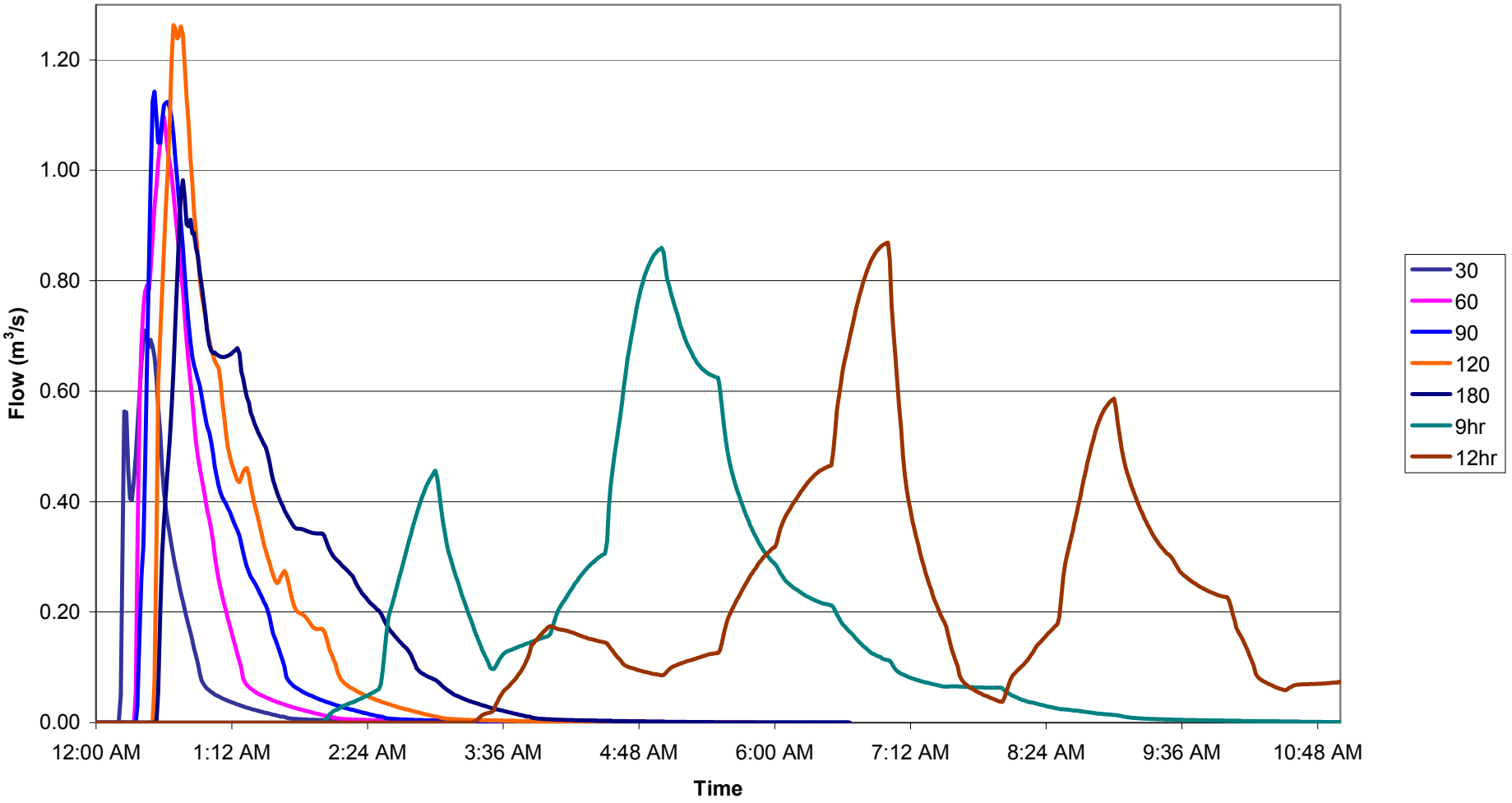
Node A13, 2% AEP Hydrograph - All Durations



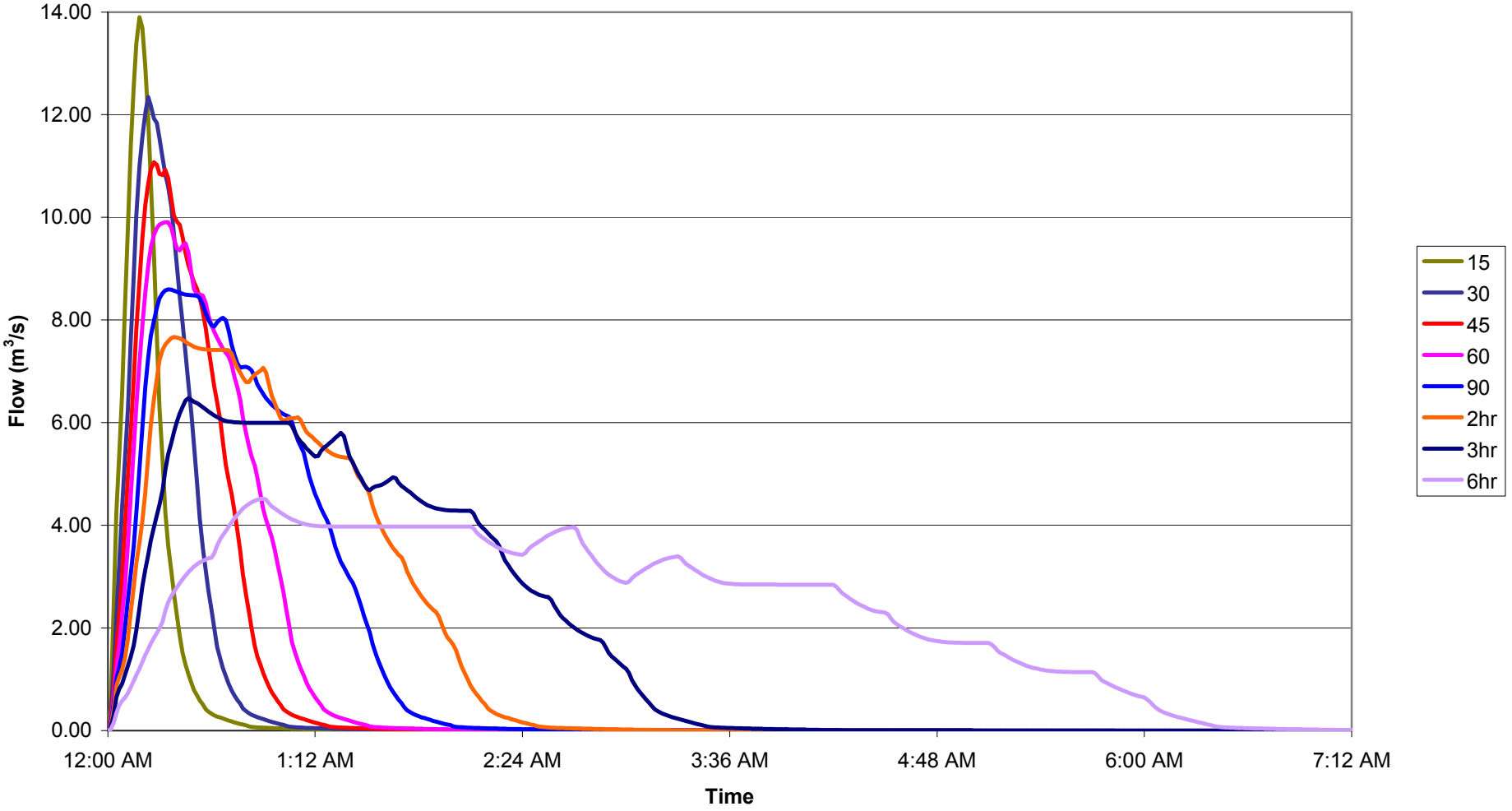
Node A13, 5% AEP Hydrograph - All Durations

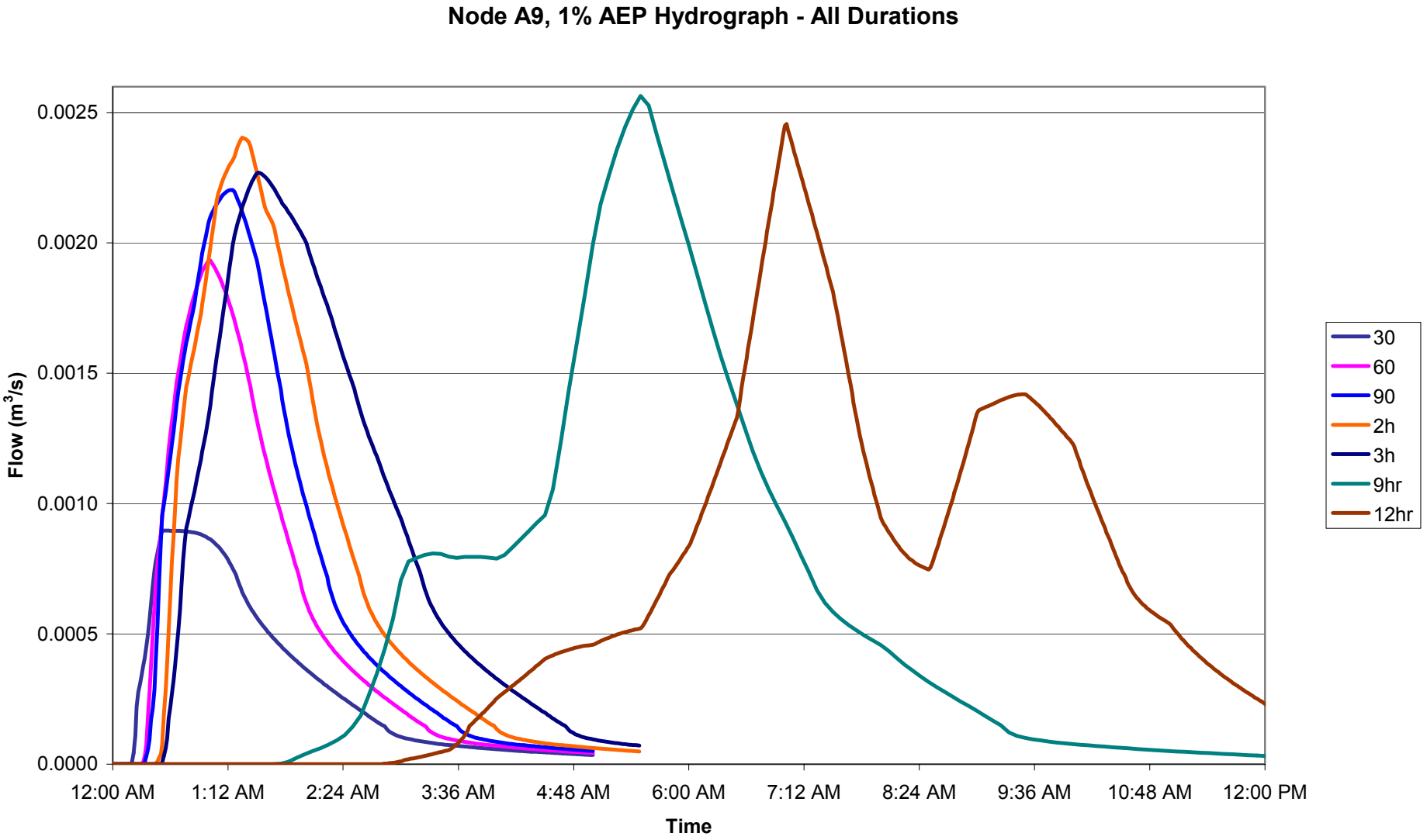


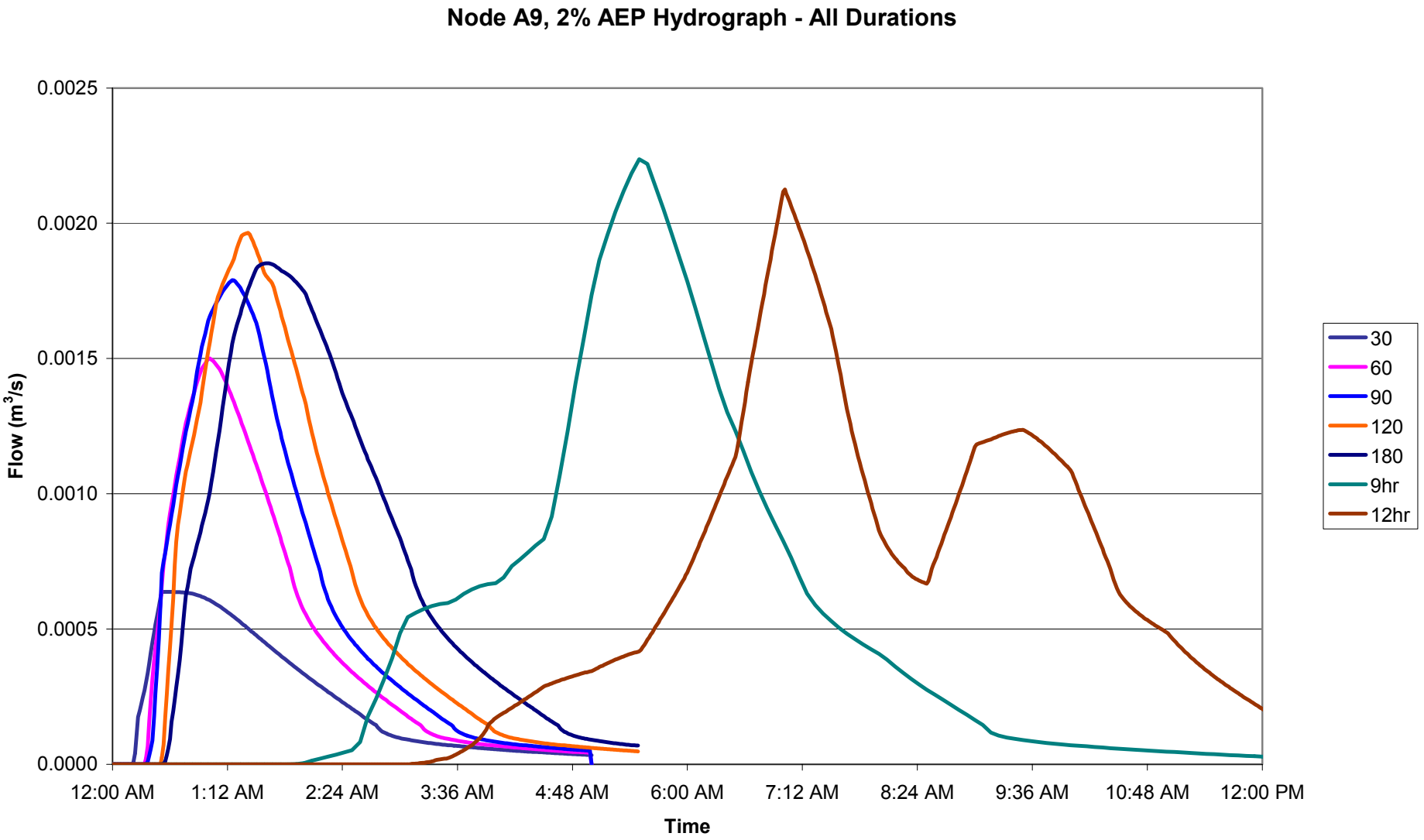
Node A13, 20% AEP Hydrograph - All Durations

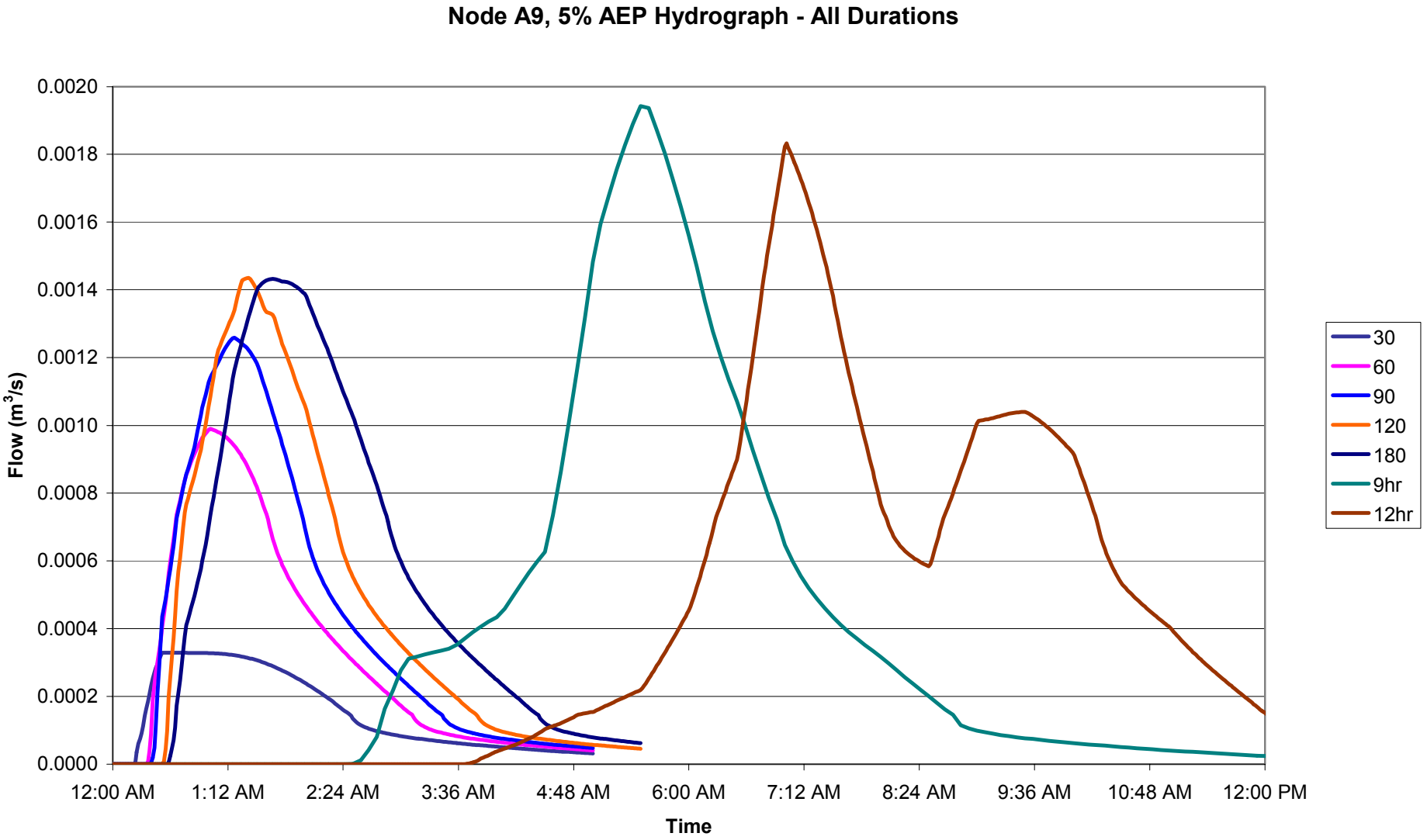


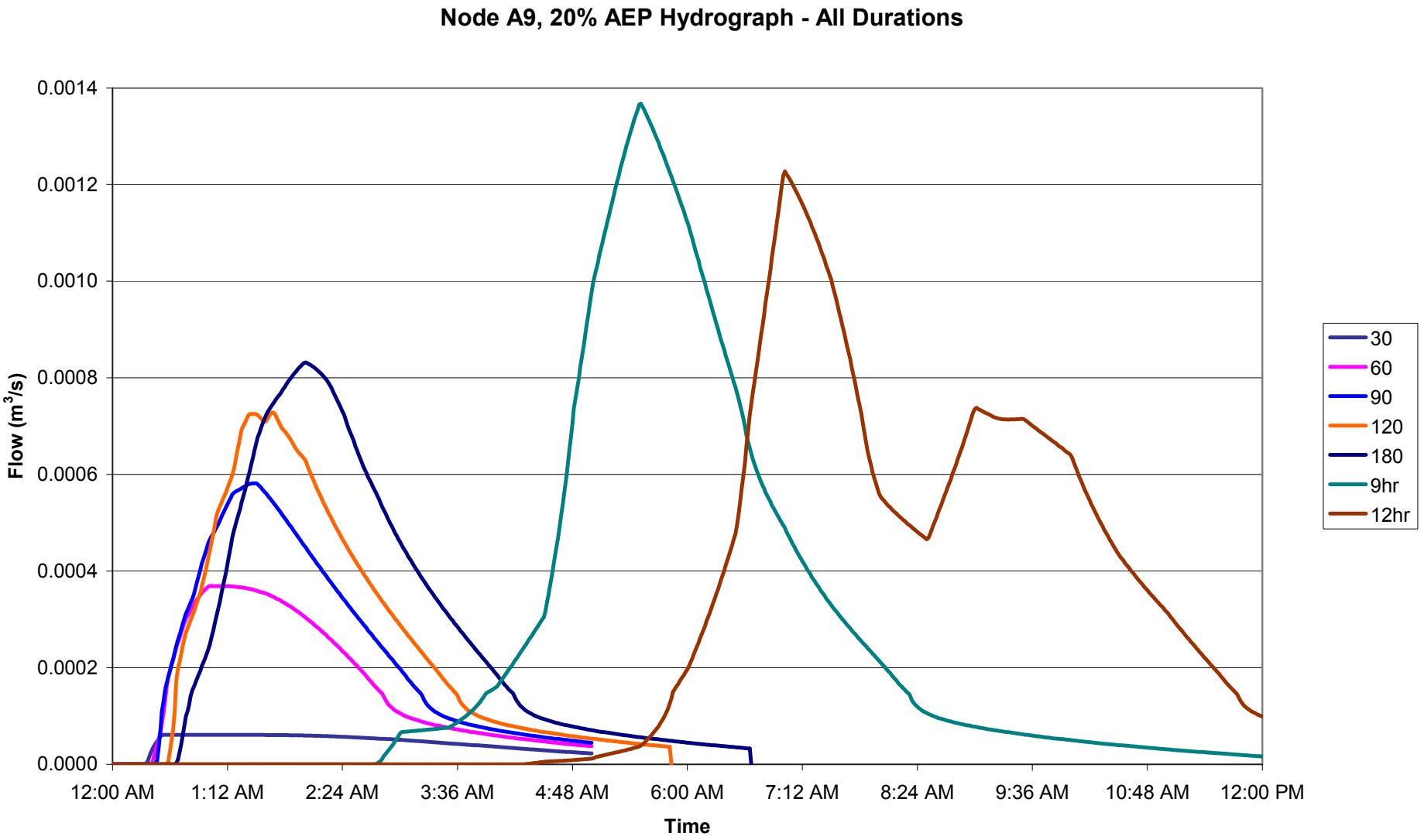
Node A13, PMF Hydrograph - All Durations



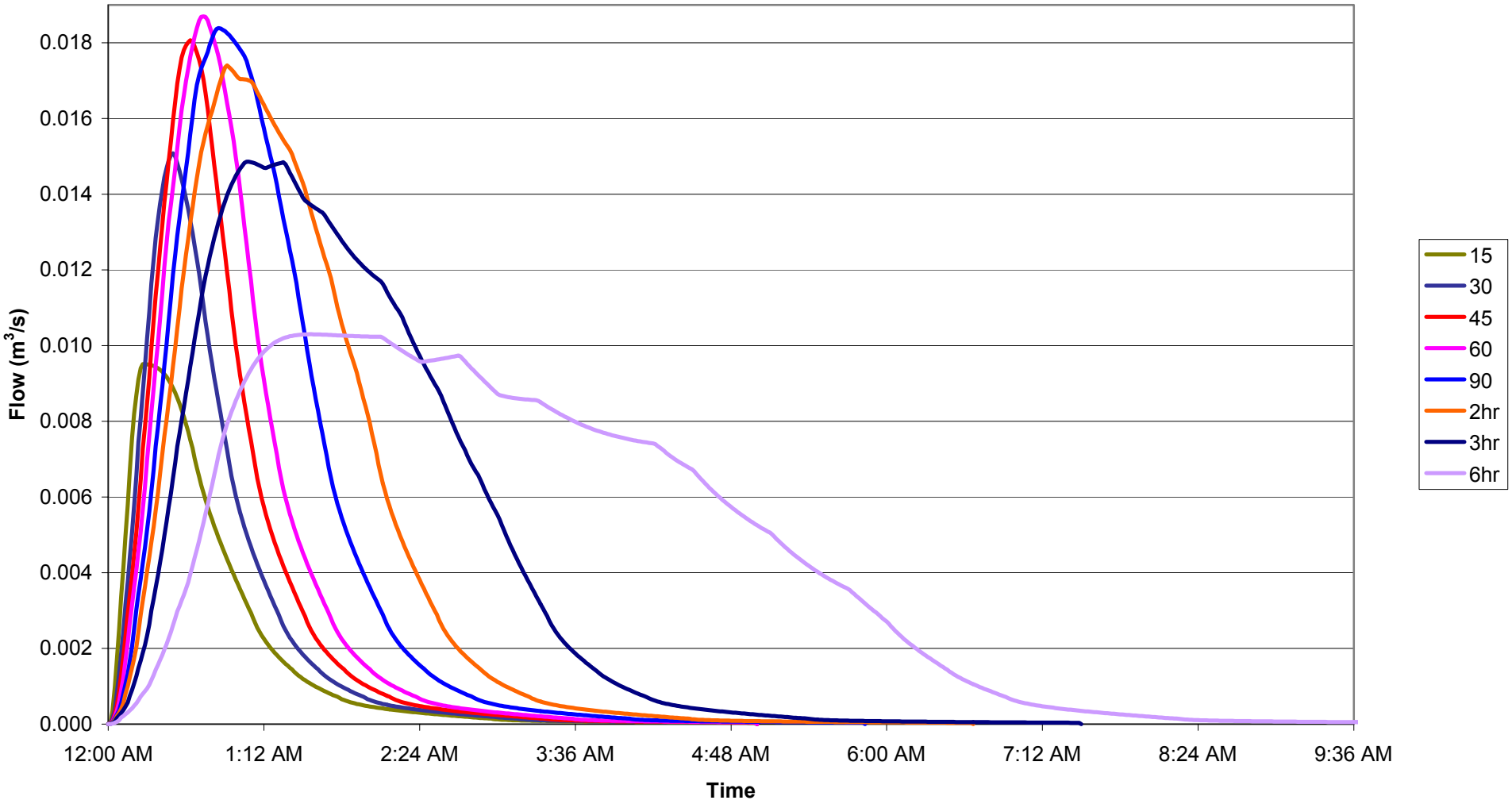

Node A9, 1% AEP Hydrograph - All Durations
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
Flow (m3/s)
12:00 AM
1:12 AM
2:24 AM
3:36 AM
4:48 AM
6:00 AM
7:12 AM
8:24 AM
9:36 AM
10:48 AM
12:00 PM
Time
30
60
90
2h
3h
9hr
12hr

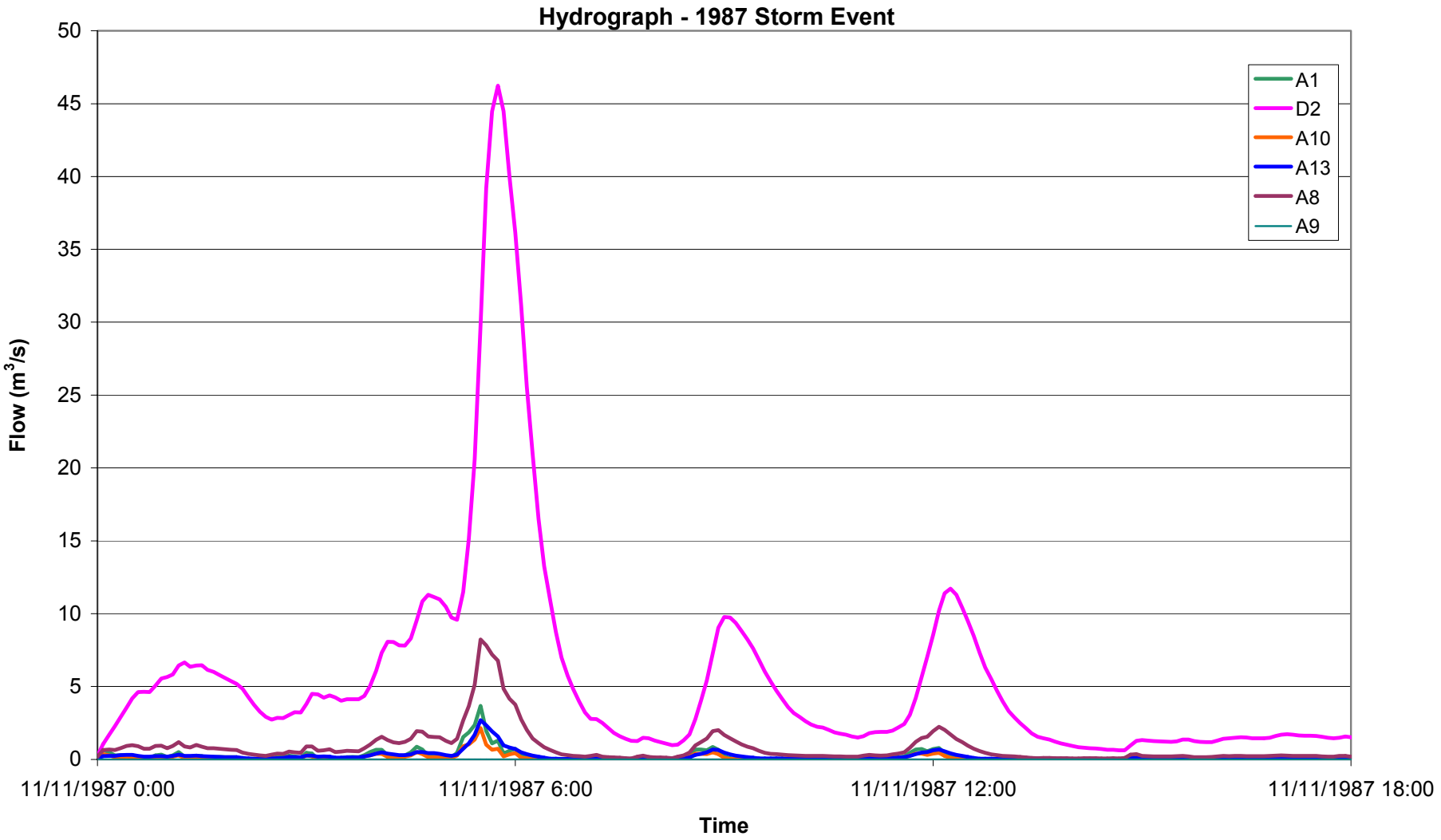

Node A9, 2% AEP Hydrograph - All Durations
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
Flow (m3/s)
12:00 AM
1:12 AM
2:24 AM
3:36 AM
4:48 AM
6:00 AM
7:12 AM
8:24 AM
9:36 AM
10:48 AM
12:00 PM
Time
30
60
90
120
180
9hr
12hr


Node A9, 5% AEP Hydrograph - All Durations
Flow (m3/s)
0.0020
0.0018
0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
12:00 AM
1:12 AM
2:24 AM
3:36 AM
4:48 AM
6:00 AM
7:12 AM
8:24 AM
9:36 AM
10:48 AM
12:00 PM
Time
30
60
90
120
180
9hr
12hr


Node A9, 20% AEP Hydrograph - All Durations
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
Flow (m3/s)
12:00 AM
1:12 AM
2:24 AM
3:36 AM
4:48 AM
6:00 AM
7:12 AM
8:24 AM
9:36 AM
10:48 AM
12:00 PM
Time
30
60
90
120
180
9hr
12hr

Node A9, PMF Hydrograph - All Durations




Hydrograph - 1987 Storm Event
50
45
40
35
30
25
20
15
10
5
0
Flow (m3/s)
11/11/1987 0:00
11/11/1987 6:00
11/11/1987 12:00
11/11/1987 18:00
Time
A1
D2
A10
A13
A8
A9

APPENDIX D

Sample Resident Survey

Directors
N.V. Lawson BE(Hons), MEngSc, FIEAust, CPEng
P.D. Treloar BE(Hons), ME, PhD, FIEAust, CPEng, MASCE
R.A. Rice BE(Hons), BSc, MEngSc, MIEAust, CPEng
N.I. Collins BE(Civil), MEngSc, MIEAust, CPEng

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Gordon NSW 2072
PO Box 852,
Pymble NSW 2073
Australia
Phone: +61-2-9499 3000
Fax: +61-2-9499 3033
Email: nsw@lat.com.au

17 November 2003

To: The Resident,
Great Mackerel Beach Pittwater

Dear Resident

RE: GREAT MACKEREL BEACH FLOOD STUDY

Pittwater Council has recently commissioned specialist consultants, Lawson and Treloar Pty Ltd, to undertake a detailed Flood Study of Great Mackerel Beach. The Study Area is shown on the attached plan.

Enclosed is a questionnaire, which focuses on whether your property has been flooded in the past or if you know of others nearby that have.

Please take time to read the questions (there are only 8) and answer them as best as you can. Lawson & Treloar and your Council are in the initial stages of the Flood Study and any information you provide may prove vital to the success and accuracy of the study results.

As part of the flood study, a detailed ground survey of the flood-affected area is being carried out on 18, 19 and 20 November 2003. The survey will include taking levels of the drainage system, landforms, boundaries and buildings.

Lawson & Treloar thanks you for your assistance in these matters and should you require any further information, please do not hesitate to contact Council's consultant representative Mr. Greg Collings from Lawson and Treloar Pty Ltd on (02) 9499 3000 or Council's project manager, Ms. Jennifer Pang (02). 9970 1111.

Yours faithfully

Lawson & Treloar
Neil Lawson

Great Mackerel Beach Flood Study

QUESTIONNAIRE

Please answer the following eight questions as best as you can. When you have finished answering the questions, please return these pages to:

Lawson & Treloar Pty Ltd
PO Box 852
Pymble NSW 2073

Alternatively an Engineer from Lawson & Treloar will be conducting topographic survey of the area on Wednesday 19 November 2003 and Thursday 20 November 2003, and will gladly accept the completed surveys.

Q1. Could you please provide us with the following details? We may need to contact you to check some of the information with you.

(The information will remain completely CONFIDENTIAL)

Name……..

Address…….
……
……
……
……

Day time phone Number…….

Q2. How long have you either lived, worked or shopped in this locality?

..... months
..... years

Q3. Have you ever been inconvenienced, or has your property been flooded because of uncontrolled floodwater in this locality?

(Your property may have been flooded, inside or outside, or you might have been stopped from getting to work)

PROPERTY FLOODED ☐ NO ☐

INCONVENIENCED ☐

Q4. Can you remember when that was?

YES (Tick O☐ox)

NO ☐

If you answered YES, please give us as much detail as possible.
To assist, flooding may have occurred on the following dates.

Details of when flooding occurred:

.....
.....
.....
.....
.....

Q5. If you have experienced flooding in this locality, do you have any evidence of the extents of the floods?

YES (Tick One Box) ☐

NO ☐

If you answered YES, please give as much detail as possible.

You may have an old photograph, or may have taken a video. Some people remember marks on walls and posts, and this information could prove quite important.

Alternatively, you may know someone who has lived in the locality for a long time who might have that type of information.

Details of information:

.....
.....
.....
.....
.....
.....

Q6. If you answered Yes to Question 5, what type of property did you see flooded?

RESIDENTIAL ☐

PARKS ☐

ROADS & PATHS ☐

OTHER ☐

(You May Tick More Than One Box)

Please Specify.....

Can you describe the area of the property that was flooded?

BACKYARD ☐

GARAGE ☐

BUILDING (ABOVE FLOOR LEVEL) ☐

BUILDING (BELOW FLOOR LEVEL) ☐

FRONTYARD ☐

OTHER ☐

(You May Tick More Than One Box)

Please Specify.....

Q7. If possible, can you show the location of the flooding on the enclosed map?

YES ☐ (Tick One Box)

NO ☐

If you have indicated Yes, please remember to enclose the map in the envelope, clearly marked.

Q8. Is there anything else you can tell us about the flooding in this locality?

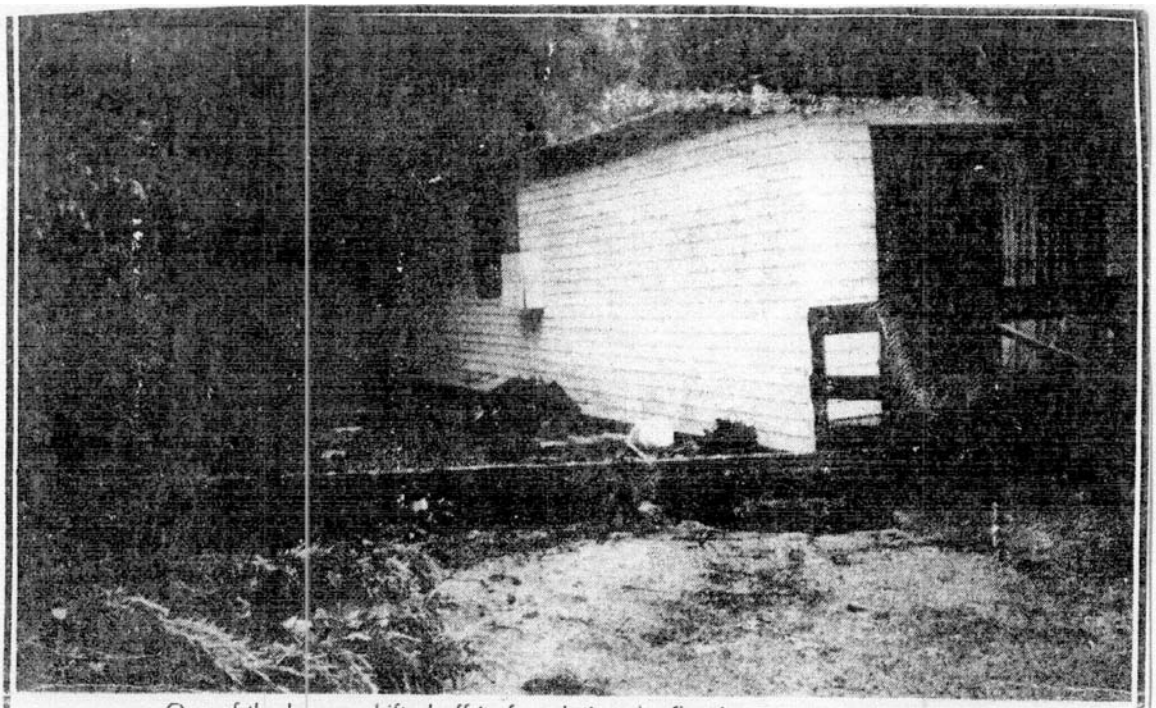
If so, please provide the information below (if insufficient space please attach extra pages).

.....
.....
.....
.....
.....
.....
.....
.....

Thank you for providing the above information.

APPENDIX E

Reports in Local Newspapers of Flood Events



One of the houses shifted off its foundations by floodwaters at Mackerel Beach. ON 11/11/87

The spirit disaster can't beat

Following the devastating storm several weeks ago, which hit the tiny Pittwater village of Mackerel Beach particularly hard, residents are still struggling to get their lives back into order.

Several houses shifted from their foundations have to be rebuilt, but the owners are philosophical.

They will rebuild on higher foundations to withstand future floods.

The wife of volunteer fire brigade captain Bob Mitchell said the floods which ran shoulder-high through houses were frightening enough, but it had been a nightmare since repairing the damage.

"Fifteen of the 42 permanent residents had to be evacuated from their homes due to rising floodwaters," Christine Mitchell said.

People and dogs were saved by residents who left their belongings behind to help others.

In the last two weeks people such as the Mitchells have been trying to get their lives together.

The Mitchells found they were not insured. They let their policy lapse because money was needed for their son's optical problems.

Others were in the same boat and nearly lost everything.

As soon as news of the disaster spread, town folk who use their houses only for holidays were quick to offer accommodation, beds and clothes.

"Everyone was helping everyone. It was a great demonstration of community unity and goodwill," Richard Cornielje said.

"Many of the people weren't worrying about their own uninsured possessions because they were busy helping others.

"Even last weekend, everyone was still scrubbing, cleaning and trying to get their lives back in order. It has been a physical and mental drain on everyone."

Mr Mitchell said the floods had caused about $10 000 damage to his house and contents, but he hoped he had learnt by the experience.

The loss of carpet, a pump, refrigerator, washing machine, mattresses and shoes hurt, but he was heartened by the response shown by people under disaster conditions.

The Sydney County Council restored power under very trying conditions and workmen helped by carrying generators and filling potholes.

Most insurance claims have been settled, but some companies were "trying to wriggle out of it", Mr Mitchell said.

Seven of the residents who lost uninsured possessions are being helped by the disaster relief committee of Youth and Community Services.

One thing shines through the adversity ... if it happens again the people of Mackerel Beach will cope.

Source: *The Manly Daily* 11 November 1987

APPENDIX F

Rational Method Calculations

Mackerel Beach

Rational Method Check
Rural - Adams Method

Required Inputs

Downstream Location	Area I
Subcatchment Area (km^2)	2.6
Fraction impervious	0.1
Surface Roughness	0.1
Location Name	Mackerel Beach
1 hr Duration, 2yr ARI:	38
12 hr Duration, 2yr ARI:	8.6
72 hr Duration, 2yr ARI:	2.6
1 hr Duration, 50yr ARI:	78
12 hr Duration, 50yr ARI:	17
72 hr Duration, 50 yr ARI:	5.5
G	0
F2	4.298
F50:	15.88

Results

Mackerel Beach

Design Event		Q (m^3/s)	Tc (min)
20% AEP		18.29	66
5% AEP		26.78	66
2% AEP		34.71	66
1% AEP		40.51	66

APPENDIX G

Model Cross Sections

CRS_1

X	Y	Z
327375.2	1281760	2.343
327374.9	1281759	1.096
327374.3	1281758	0.3
327372.8	1281757	-0.781
327371.5	1281755	-0.535
327370.3	1281754	-0.226
327369.5	1281754	0.151
327369.3	1281753	0.656
327369.2	1281752	1.612

CRS_2

X	Y	Z
327409.1	1281756	2.169
327408.2	1281753	0.212
327407.6	1281752	-0.25
327407.3	1281751	-0.564
327406.9	1281751	-0.6
327406.8	1281750	-0.313
327406.3	1281748	-0.161
327405.7	1281747	0.609
327405.5	1281745	2.005

CRS_3

X	Y	Z
327430.7	1281740	2.175
327429.3	1281738	0.12
327428.3	1281737	-0.28
327427.5	1281736	-0.081
327426.1	1281734	-0.062
327425.8	1281734	0.211
327425.7	1281734	1.757

CRS_4

X	Y	Z
327443.2	1281735	1.969
327442.7	1281734	0.492
327442	1281734	-0.044
327441.6	1281733	-0.287
327441.2	1281732	-0.411
327441.1	1281731	-0.223
327441	1281730	-0.067
327440.8	1281729	0.466
327440.3	1281729	1.648

CRS_5

X	Y	Z
327452.1	1281732	1.813
327451.7	1281731	0.289
327451.1	1281728	-0.043
327450.5	1281727	0.173
327450.2	1281725	1.889

CRS_6

X	Y	Z
327487.3	1281744	1.627
327487.2	1281742	1.375
327487.6	1281740	0.316
327487.3	1281739	-0.256
327486.8	1281736	-0.269
327487	1281736	0.283
327487.5	1281735	1.372
327487.8	1281733	1.465

CRS_7

X	Y	Z
327510.3	1281745	1.503
327510.2	1281743	0.196
327510.4	1281741	-0.356
327510.4	1281739	-0.225
327510.4	1281738	0.624
327510.4	1281736	1.702

CRS_8

X	Y	Z
327537.6	1281754	1.163
327537.7	1281753	0.364
327538.3	1281751	-0.35
327538.8	1281749	0.097
327539.4	1281747	0.42
327539.6	1281746	1.249

CRS_9

X	Y	Z
327562.5	1281765	1.531
327563	1281764	0.059
327563.8	1281763	-0.435
327564.3	1281763	-0.577
327564.8	1281762	-0.503
327565.2	1281762	-0.12
327565.7	1281761	0.477
327565.6	1281761	1.631

CRS_10

X	Y	Z
327590.8	1281786	1.182
327590.8	1281784	0.429
327592.3	1281783	-0.074
327593.4	1281781	-0.141
327594	1281779	-0.052
327594.7	1281777	0.316
327594.7	1281777	1.102

CRS_11

X	Y	Z
327626.3	1281807	1.255
327626.5	1281806	0.005
327628.3	1281803	-0.346
327629.4	1281801	-0.407
327629.7	1281800	-0.004
327629.7	1281800	1.289

CRS_12

X	Y	Z
327649.8	1281827	1.016
327650.2	1281826	0.102
327650.7	1281825	-0.363
327651	1281825	-0.415
327651.3	1281824	-0.301
327653	1281821	-0.215
327653.7	1281820	-0.076
327654	1281820	0.554

CRS_13

X	Y	Z
327702.3	1281849	0.933
327703.5	1281849	0.555
327704.4	1281848	0.001
327705.3	1281848	-0.446
327706	1281848	-0.793
327706.9	1281848	-0.797
327707.3	1281847	-0.872
327707.6	1281846	-0.798
327708.2	1281846	-0.029

CRS_14

X	Y	Z
327698.9	1281868	1.62
327700	1281867	0
327700.5	1281862	-0.797
327697.3	1281858	0.615

CRS_15

X	Y	Z
327687.3	1281869	0.834
327685.6	1281869	0.3
327682.7	1281868	-0.797
327680.9	1281868	0.939

CRS_16

X	Y	Z
327690.2	1281877	0.987
327688.4	1281878	0.335
327686.4	1281878	-0.166
327683	1281878	0.968

CRS_17

X	Y	Z
327704.8	1281889	1.552
327702.7	1281889	0.86
327697.3	1281890	0.397
327688.6	1281892	-0.095
327687.8	1281892	1.051

CRS_18

X	Y	Z
327695.3	1281930	0.729
327697.5	1281931	-0.19
327708.8	1281936	0.363
327712.1	1281938	1.352

CRS_19

X	Y	Z
327665.5	1281983	0.773
327667.6	1281986	0.214
327669.9	1281987	-0.081
327673.6	1281990	0.052
327675	1281990	0.064
327677.5	1281990	0.155
327680.5	1281991	0.228
327683.7	1281992	0.238
327686	1281993	0.209
327687.3	1281994	0.791

CRS_20

X	Y	Z
327683.2	1282012	0.713
327681.7	1282013	0.173
327679.1	1282014	-0.187
327674.6	1282015	-0.272
327672.1	1282016	-0.151
327669.6	1282016	0.164
327669	1282016	1.54

CRS_21

X	Y	Z
327689.4	1282030	0.662
327689	1282031	0.203
327687.2	1282035	-0.044
327684.9	1282039	0
327684.1	1282041	0.191

CRS_22

X	Y	Z
327704.4	1282040	0.72
327706.1	1282044	0.159
327706.7	1282051	-0.241
327707.1	1282055	-0.39
327707.9	1282057	-0.295
327708.5	1282059	0.349

CRS_23

X	Y	Z
327741.7	1282036	0.861
327744.1	1282042	0.775
327748.6	1282052	0.312
327751.5	1282056	-0.126
327755.6	1282061	0.836
327755.7	1282061	1.11

APPENDIX H

Model Sensitivity

Roughness

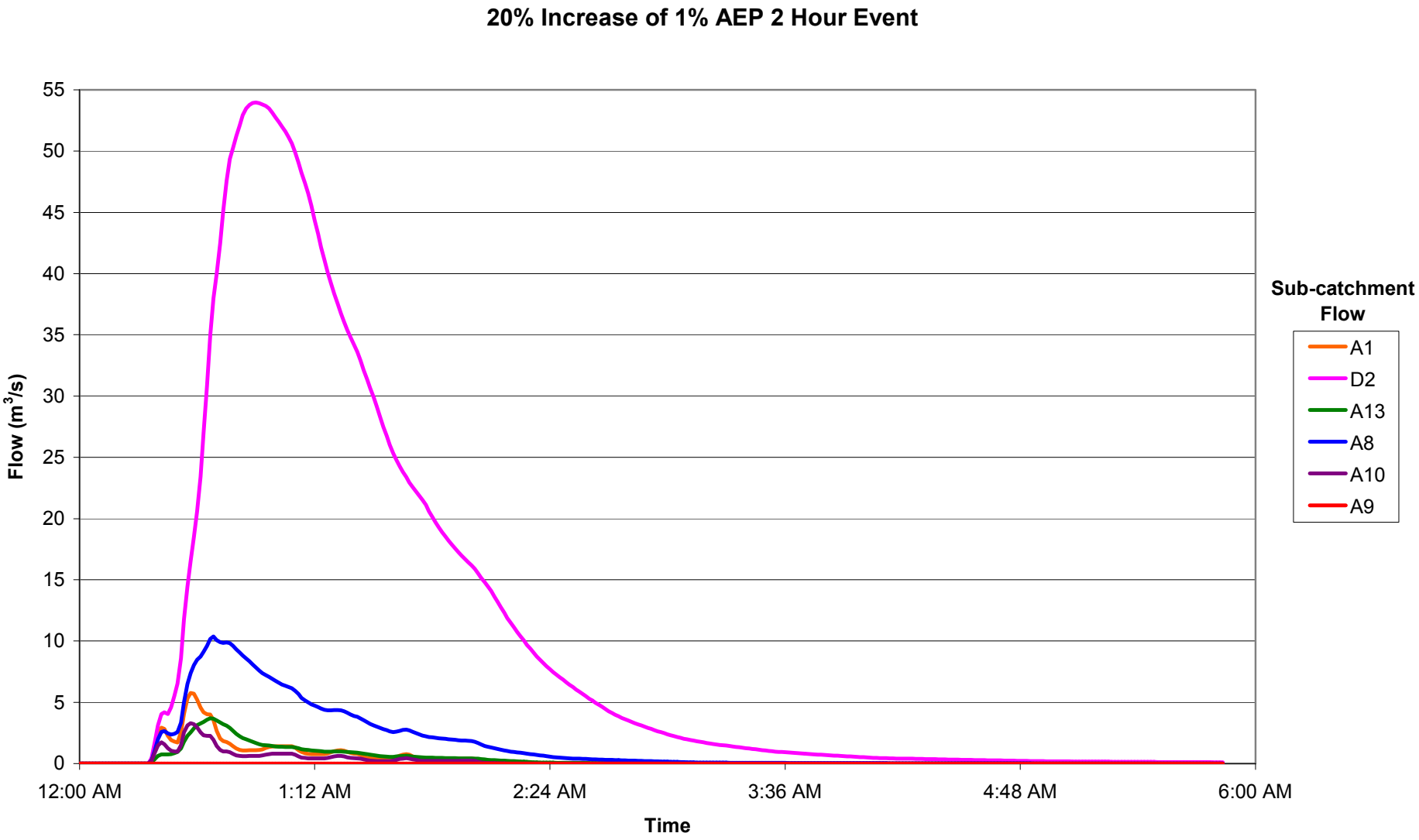
Variation in Manning's 'n' values

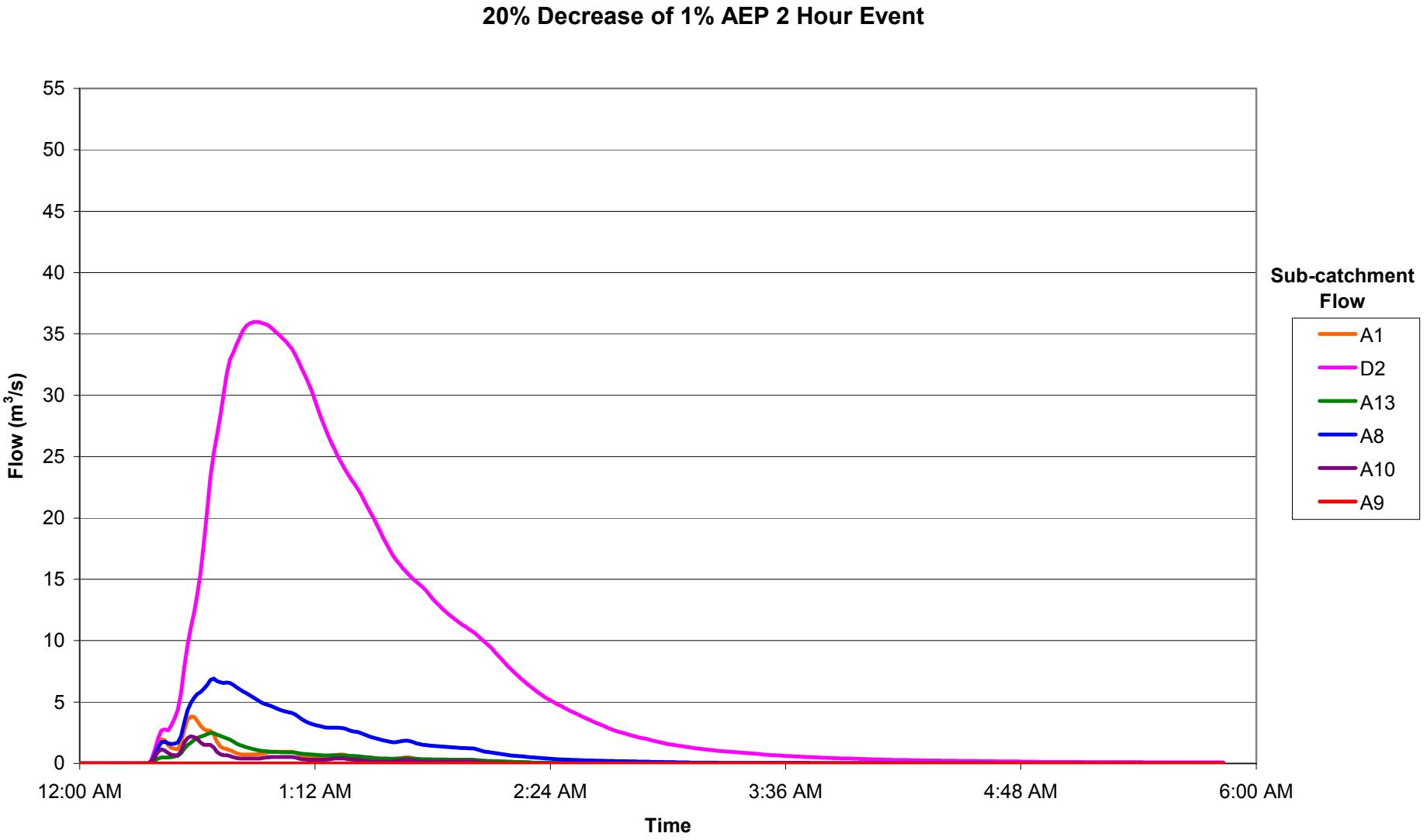
1D Creek Description	Low	Design Event	High
Brush bed	0.06	0.1	0.12
Sand bed	0.03	0.04	0.06
2D Grid - Land Description	**Low**	**Design Event**	**High**
Creek channel[#]	0.06	0.06	0.06
Sand bed	0.025	0.03	0.04
Urban grass	0.03	0.05*	0.05*
Forest swamp	0.1	0.12	0.16
Forest urban	0.08	0.1	0.14
Buildings	0.15	0.2	0.5

[#]The majority of the friction is accounted for in the 1D section of the model
*This is the highest recommended value for this element, (Chow, 1973).

Hydrology

Hydrographs for the 20% variations of the 1% AEP 2 hour event are shown on the following pages.


20% Increase of 1% AEP 2 Hour Event
Flow (m3/s)
55
50
45
40
35
30
25
20
15
10
5
0
12:00 AM
1:12 AM
2:24 AM
3:36 AM
4:48 AM
6:00 AM
Time
Sub-catchment Flow
A1
D2
A13
A8
A10
A9


20% Decrease of 1% AEP 2 Hour Event
55
50
45
40
35
30
25
20
15
10
5
0
Flow (m3/s)
12:00 AM
1:12 AM
2:24 AM
3:36 AM
4:48 AM
6:00 AM
Time
Sub-catchment Flow
A1
D2
A13
A8
A10
A9

APPENDIX I

Management of Creek Entrance

I1. Introduction

Mackerel Beach Creek discharges to Pittwater at the northern end of Great Mackerel Beach across the beach (Figure 2.1). The 'entrance' of the creek is ephemeral making the creek system akin to an intermittently opening and closing Lake or Lagoon (ICOLL). The entrance dynamics are controlled by both catchment and coastal processes.

Council has requested a consideration of the entrance dynamics in the context of determining whether a formal management practice is required for the management of flood risk from catchment flooding. This type of action is undertaken for other ICOLL systems where flooding of property is an issue (e.g. Narrabeen Lagoon, Dee Why Lagoon, Manly Lagoon).

Studies undertaken by Kulmar (1985), Kulmar and Gordon (1987), Cowell (1989), Cowell and Nelson (1991) and Cowell (1992) have been drawn upon to aid in the development of this assessment.

I2. Coastal and Catchment Processes at Mackerel Beach

Great Mackerel Beach is enclosed between two high headlands. The beach is approximately 650 m long and crescent shaped (Kulmar, 1985). As outlined in the main report, Mackerel Beach Creek (the creek) forms a small lagoon at the northern end of the beach, fed by an intermittent stream which rises to the plateau of the Lambert Peninsula. The lagoon is often open to tidal action and supports a shallow nearshore sandbar (also referred to as a delta in this report) (evident in Figure 2.1).

Mackerel Beach lies in a zone where the coastal processes affecting the entrance include:

- swell wave action (i.e. longer period waves from the ocean that penetrate into Pittwater). Kulmar (1985) reports that the wave climate is low to moderate in comparison to the open coast. However, rare storm events can result in surf conditions along the beach.
- sea wave action (i.e. shorter period waves generated locally within Pittwater by wind)
- tidal currents within Pittwater
- the presence of the Pittwater shoal adjacent to the beach, a source of sand (evident in Figure 2.1)
- a predominant longshore sediment movement in a southerly direction delivering sand around the headland from the north from Resolute Beach (Kulmar, 1985) (evident in Figure 2.1). No rock reef is present at the south end of Resolute Beach to inhibit the bypass of sediment around the headland. The rate of longshore transport is estimated to be in the order of 1500 m^3/year (Kulmar, 1985).

Lawson and Treloar (2002) describes sediment movement and coastal processes within Pittwater in further detail.

Presuming a starting condition of a closed berm at the beginning of a flood event, floodwaters would build behind the berm until they reach the level of the berm and scour a small channel through the berm. This channel would widen and deepen to a limiting depth and width until the floodwaters had passed to Pittwater. Following the event, the berm would recover and the channel would progressively close via the delivery of sand from the north (via swell wave action) and the reworking of the delta area under normal tidal conditions and local wind wave action. Aeolian deposition may also play a small role in the closure of the entrance.

Kulmar (1985) indicates that the source of the transported littoral material is the shallow entrance shoal that extends south to a 'drop-over' between Observation Point and the northern end of Mackerel Beach. Sediment is moved off the Pittwater entrance shoal by deepwater (ocean) waves and tidal action into the nearshore zone between Resolute Beach and Mackerel Beach. Kulmar (1985) states that the action of the lagoon entrance induces a shallow sandbar to be formed in the surf zone adjacent to the northern headland. Although patches of seagrass appear to indicate a boundary between the lagoon sandbar (delta) and Pittwater entrance shoal, Kulmar (1985) argued that it is reasonable to assume that sediment movement between the two regions occurs based on past aerial photography indicating that the boundary is unstable.

From the lagoon sandbar, sediment moves south along the beach in the nearshore zone, driven by longshore currents induced by deepwater swell and wind waves. The persistence of dense seagrass beds in the deeper water south of the lagoon sandbar suggests that little or no significant transfer of sediment between the offshore and nearshore zones in this area (Kulmar, 1985). However, Kulmar and Gordon (1987) state that during extreme events sediment may be moved from the sand bar areas into the seagrass beds south of the sand bar and then are lost from the system.

I3. Historical Entrance and Beach Configuration

Historically, the entrance has been located both at the northern end of the beach, adjacent to the headland as well as further south in the centre of the beach, near the existing properties. A chronology of the entrance conditions has been prepared from available information:

- Examination of aerial photography since 1941 shows that beach and shoreline alignment had not changed significantly since 1941 (Kulmar, 1985). This is supported by Cowell (1989) who states that there is little evidence of general long-term erosion in the form of irreversible shoreline recession.
- prior to 1970 the entrance was located adjacent to the northern headland, meandering behind a dune barrier which trained the creek to discharge at this location. The beach berm was wide between the period 1950 and

1966 as no ocean storms were reported resulting in an abnormally wide berm (Cowell, 1989).

- 1970 aerial photography indicates the entrance barrier ranges from 15 – 42 m in width. The widest point was near the northern end of the barrier where it was covered with a stand of casuarinas which help to bind the sand against scour by the stream mouth. The narrowest point was where a stream meander of the creek occurred (Cowell, 1989).
- between 1970 and 1974 the dune barrier became degraded over time (i.e. stabilising vegetation was progressively degraded) and may have first breached to the south sometime in 1972 (an accurate assessment is limited by the quality of aerial photography) (Cowell, 1989).
- severe ocean storms of 1974 and associated catchment flood events resulted in the creek breaking across the degraded dune barrier approximately 100 m south of its location adjacent to the headland (Cowell, 1989)
- aerial photography held by the Land Information Centre (1977, Figure I3) indicates the barrier dune was absent in this period.
- damage occurred at Great Mackerel Beach in 1974 – 1978 due to large ocean swells originating from the east to south sector (Kulmar, 1985) and high storm surge
- during the 1984/1985 period most of the sandbar dries at low tide (Kulmar, 1985)
- Flood event of November 1987 (of the order of a 1%AEP event). No details of entrance configuration at the time of the event were available for this study. A berm condition was inferred from 1978 aerial photography (Section 6.5.2).
- Elevated high tides in the 1988/1989 Christmas period highlighted the severe beach erosion that had occurred at Mackerel Beach since the entrance had relocated south. Ten properties on the foredune came under threat from erosion. Warringah Council barged in heavy machinery to the beach to move sand from the northern section of the beach to immediately in front of the affected properties. Sand bags were also installed for further protection (Cowell and Nelson, 1991).
- Cowell commissioned to investigate and identified ‘delta margin’ erosion associated with the relocated entrance was in part contributing to the severe erosion. Recession rates at the shoreline associated with the delta margin averaged at 1.6 m/year (Cowell, 1989). Cowell recommended that an option of relocating the entrance to its original location (as per aerial photography pre 1972) be implemented. The recommendations were a base width of 25 m with a height of up to 3 m AHD to resist overtopping by the stream or the sea.
- Works recommended by Cowell (1989) were implemented by Warringah Shire Council (Cowell and Nelson, 1991). A total of 4000 m3 was placed to create the new barrier and 4000 m3 to renourish the beach area in front of properties. Construction of the stream channel was carried out by a dragline working from the headland south to the inlet until it was redirected and the old entrance sealed. Sand removed to create the channel was used to reconstruct the barrier dune. Work commenced in August 1989

and was completed in November 1989. Between February 1990 and April 1990 sand was moved from the delta shoal by scrape dozer to nourish the delta margin beachface and to move material off the shoal to further build up the dune and reduce batters for planting. Planting with spinifex was carried out in November 1990 after the dune profile had stabilised and a mixture of coastal species planted in May 1991 to further stabilise the dune. Shoreline reestablished and built seawards by some 30 m along the northern part of the beach. The realignment promoted recovery of the shoreline several hundred metres from the new inlet location. Dune suffered only minor stream scouring following heavy rainfall (Cowell and Nelson, 1991).

- Aerial photography available from Council (1998) shows the constructed barrier dune in place (Figure 2.1)
- Oblique aerial photography available from DIPNR (2000) shows the constructed barrier dune in place.

There is no data available on the frequency and duration of entrance opening and closing to assist with determining the current regime.

I4. Current Berm Configuration

In addition to the recent aerial photography outlined above, the current berm configuration is shown in Figure 6.2 from detailed survey shown in Appendix A.

At the time of the survey for the flood study (November 2003/January 2004) the lagoon was closed to tidal action (Figures I1 and I2) and the berm height where the creek exits the system to Pittwater was of the order of 1.3 m AHD (Figure 7.9 shows the creek invert, Figure I5 shows the dune profile along the length of the beach, Figures I6, I7 and I8 show the variation in creek cross section in the vicinity of the berm). As a guide, mean high water spring (MHWS) tide level in this location is of the order of 0.6 mAHD. The adopted tailwater conditions for the flood study are of the order of the height of the berm (1.36 mAHD at the 20%AEP through to 1.5 mAHD at the PMF). Thus, for the purposes of the flood study, the height of the berm does not generally form the control for the study, rather the tailwater conditions in Pittwater are the control.

A meander has developed adjacent to the barrier dune, resulting in a minimum dune width of approximately 15 m. The maximum dune width is of the order of 30 m (Figure 2.1).

I5. Possible Options for Managing the Entrance

Detailed assessments of the sensitivity of the flood levels to the entrance condition were not undertaken as part of this flood study. However, a qualitative assessment of the possible entrance management options has been undertaken to provide a preliminary assessment of possible options.

At present, the maximum depth of flow that leaves the entrance (which assumes a fixed bed that does not scour for the study) is ~ 0.7 m at the 1%AEP flood. The 1%AEP flood extent (Figure 7.1) indicates that the dune barrier is not substantially overtopped by flood flows. However, the PMF does substantially overtop the dune system across the entire beach (Figure 7.5).

If the entrance was permanently held open, this would allow for a more hydraulically efficient channel for the discharge of floodwaters. However, the outflow is controlled by the level in Pittwater.

For minor floods then, presuming the water level in Pittwater is less than 1.4 mAHD (c.f. the 0.6 mAHD MHWS level), the berm will be the control. If the berm were lowered, floodwaters could be conveyed more efficiently. However, analysis completed to date prevents a quantitative assessment of what the benefits might be.

Options for managing the lagoon are therefore:

- Maintain a pilot channel through the berm at 1 mAHD to allow for outflows once the water level in the lagoon exceeds 1 m AHD – this would prevent the ingress of tidal flows, but would allow some additional flows to exit the lagoon system. The pilot channel would need to be ~ 200 m in length based on available survey. Analysis of the benefits of this approach would need to be assessed using the model established for the flood study for a range of flood events.
- Excavate a pilot channel in the event of a flood. Given the remote nature of Mackerel Beach, this would need to be undertaken by a volunteer group (e.g. the Rural Fire Service). To alert the group for action a telemetered water level gauge would need to be installed and a trigger level selected to indicate when the channel excavation needed to be commenced. Alternately a simple flood depth marker that is checked periodically by a nominated resident could be installed at a suitable location. Analysis of the benefits of this approach would need to be assessed using the model established for the flood study for a range of flood events.

It is noted from Cowell (1989) that the southern location of the entrance provides a better hydraulic efficiency of the channel but threatens properties. Consequently, no entrance relocation options are proposed, nor any low level bypass arrangements recommended (i.e. the use of a pre-determined breach point in the barrier dune is not recommended). A useful approach in retaining the entrance at its current location would involve the installation of two ‘sight poles’ (poles that extend above the ground surface behind the entrance that can be seen from the beach berm) in an alignment that indicates the appropriate orientation of the pilot channel. This approach has been used at Dee Why Lagoon for many years.

Substantial changes to the entrance are not proposed as delta margin effects and general losses at the northern end may cause issues on the downdrift

side and may even cause problems for beaches southwards (e.g. Currawong and The Basin) (Cowell, 1989).

I6. Ecological and Human Health Issues

The ecology of the creek and adjacent estuarine system has not been considered in this investigation. Studies of other ICOLLs (eg Dee Why Lagoon, Fairy, Towradgi and Hewitts Creeks) indicate that the opening and closing of the entrance of ICOLLs is an important part of wider ecological processes (such as juvenile fish and prawn recruitment, macroinvertebrate and benthic organism cycles, avifauna use of lagoon areas, etc). The implications for aquatic flora (such as seagrass, saltmarsh and mangroves) is also important. Impacts on seagrass offshore of the creek entrance is also an important factor as catchment runoff may have implications for the health of the seagrass. Kulmar and Gordon (1987) and Cowell (1989) also indicate that seagrass growth in the area offshore of Mackerel Beach may be critical to the stability of the shoreline in this area.

Additionally, the potential for sewage pollution to occur in the nearshore zone of the beach as a result of the opening of the entrance and the possible human health implications need to be considered. The beach is monitored under the Beachwatch/Harbourwatch program by the Department of Environment and Conservation.

It is recommended that further consultation with the land manager (National Parks and Wildlife Service) and relevant authorities (eg Department of Primary Industries, Department of Environment and Conservation, NSW Health) be undertaken before any entrance management strategy is selected.

It is important to note that the mechanical opening of the entrance is treated as ‘maintenance dredging’ under State Environmental Planning Policy No 35 (SEPP35) and therefore relevant approvals/investigations will need to be undertaken in accordance with the requirements of SEPP35.

I7. Sea Level Rise Implications

In the management of the entrance it is important to consider the effects of sea level rise. Cowell (1989) suggests that a rise of 0.5 m in sea level will result in a recession of the shoreline, dune line and barrier by ~ 30 m. Cowell (1992) prepared a detailed reported on management actions (dune renourishment) to prevent dune recession due to sea level rise.

However, Mitchell et al (2001) report that the rate of rise observed to date in the Australian region is only of the order of 0.3 mm/year. Thus a rise of 0.5 m would be expected to occur in over 150 years.

Thus, an adaptive management approach to the management of the entrance is recommended in response to the issues associated with sea level rise.

I8 Recommended Actions

The following actions are recommended:

- Given that shoreline protrusions and connected shoals are associated with the recession of the adjacent shoreline, causing erosion to northern most beach front properties, there is a need to ensure the entrance is located as far north as possible to overcome these effects. Consequently, no entrance relocation options or low level bypass arrangements are proposed.
- The barrier dune be subject to ongoing maintenance and stabilised with vegetation and pedestrian access restricted. It is noted that the original plan to raise the berm to a level of 3 m AHD as part of the works undertaken in 1989/1990 was either not implemented or the berm level has reduced over time (Figure I5) to a minimum level away from the entrance of 2.15 mAHD. It may prudent to seek opportunities to raise the berm to a higher level to prevent overtopping during flooding. A review of any scour protection requirements may be required at the outlet location (i.e. the southern side of the outlet).
- Detailed analysis using modelling of the recommended options for management of the entrance should be undertaken.

It is recommended that these assessments be undertaken as part of the next stage of the floodplain management process, the floodplain risk management study.

I9 References

Cowell, P. J. and Nelson, H. (1991) Management of Beach Erosion due to Low Swell, Inlet and Greenhouse Effects: Case Study with Computer Modelling, *Proceedings, 'Coastal Engineering – Climate for Change' 10th Australasian Conference on Coastal and Ocean Engineering*, Auckland, 2 – 6 December.

Kumar, M.A. and Gordon, A. D. (1987) Coastal Processes of the Pittwater North Western Foreshores, *Proceedings, 8th Australasian Conference on Coastal and Ocean Engineering*, Launceston, pp 108- 112.

Mitchell, W., J. Chittleborough, B. Ronai and G.W. Lennon, Sea level rise in Australia and the Pacific, in M. Grzechnik and J. Chittleborough (Eds), *Proceedings of the Pacific Islands Conference on Climate Change, Climate Variability and Sea Level Rise: Linking Science and Policy*, The National Auditorium, Rarotonga, Cook Islands, 3-7 April 2000, National Tidal Facility Australia, Adelaide, 47-57, 2001.

Figure I1: Looking north to closed barrier outlet 4 December 2003 (No outflow from the creek to Pittwater)

Figure I2: Looking across barrier outlet (debris from high tide washed into creek system) 4 December 2003

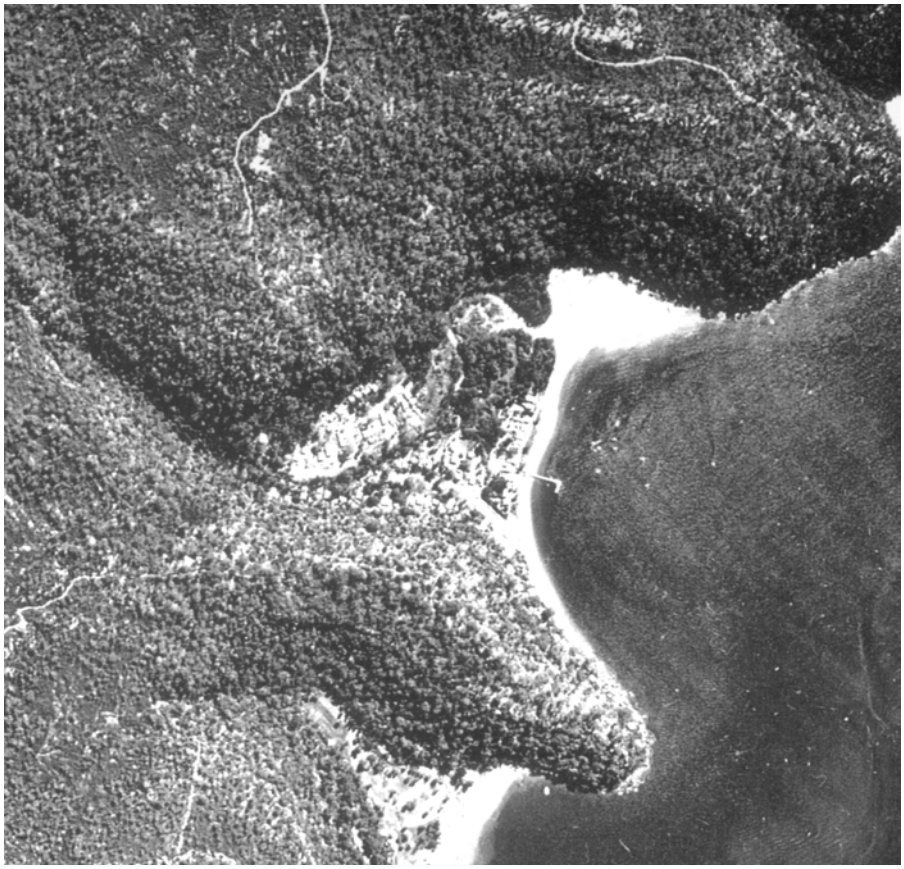


Figure I3 1978 Aerial Photography – No Evidence of Barrier Dune Directing the Creek to the North

Figure I4 Oblique Aerial Photography (DIPNR, 2000) Showing Reconstructed Barrier Dune in Place

Figure I5 - Elevation along top of Dune (South to North)

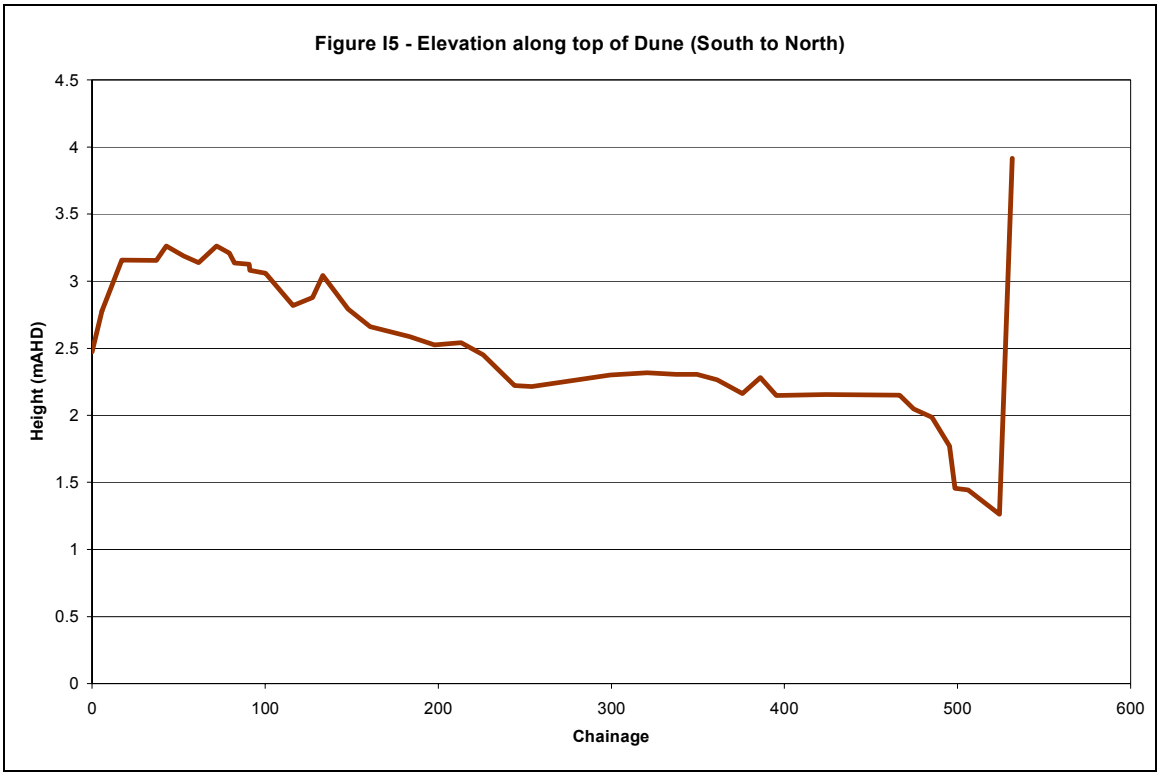
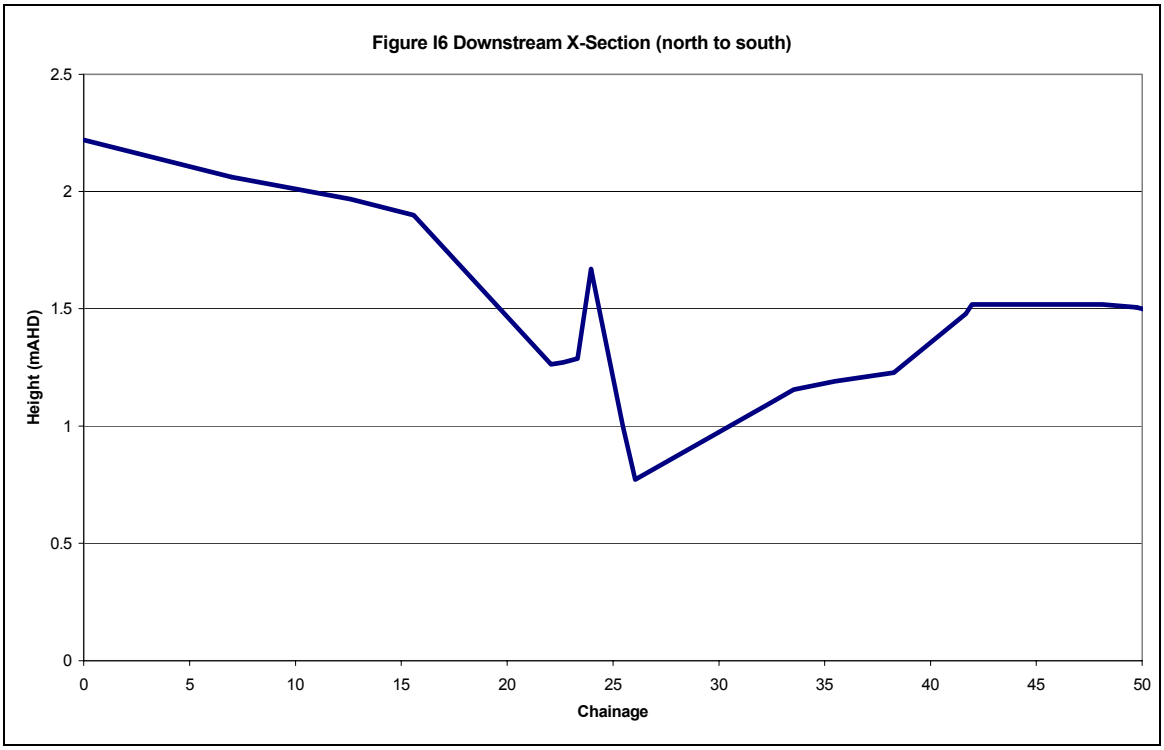


Figure I6 Downstream X-Section (north to south)



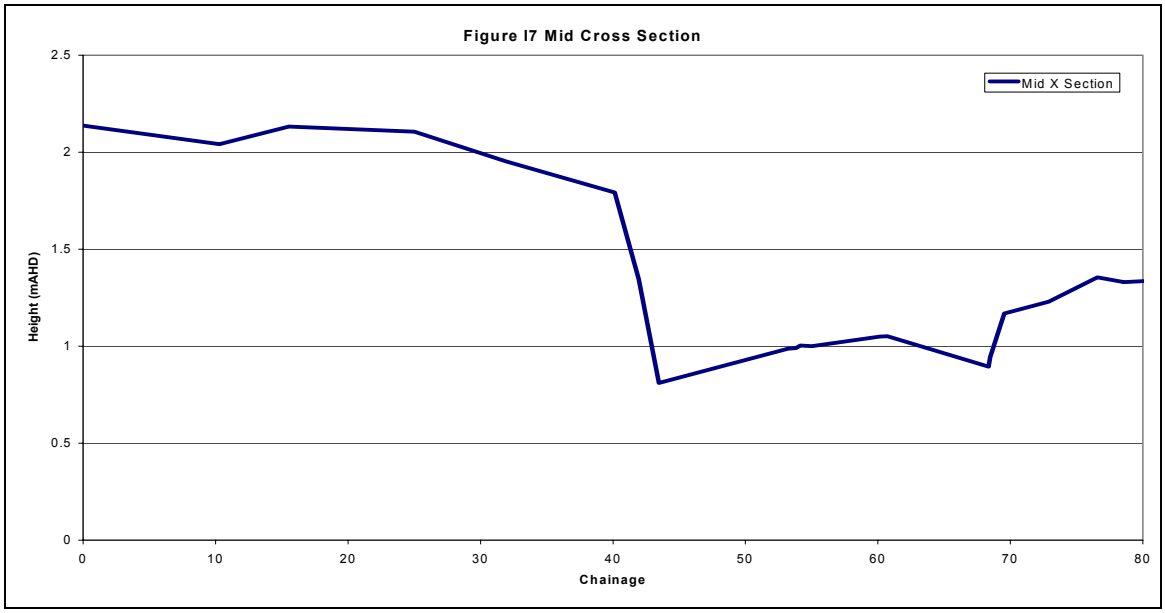


Figure I7 Mid Cross Section
Mid X Section
Height (mAHD)
Chainage
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
80

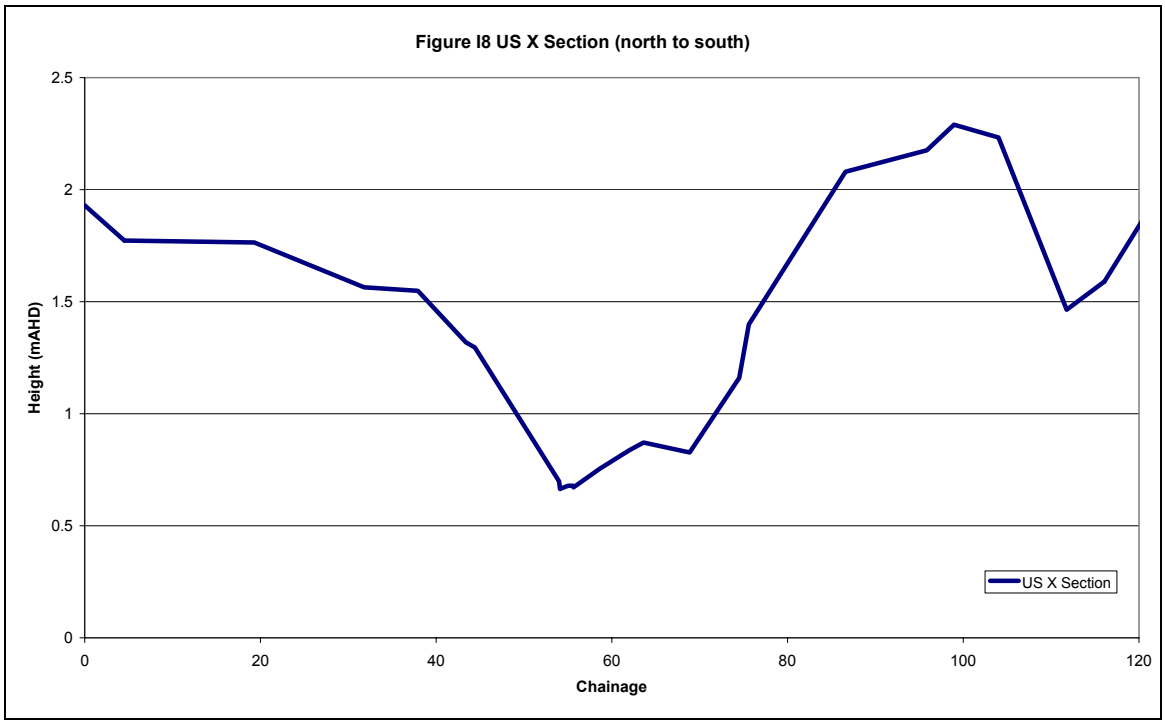


Figure I8 US X Section (north to south)
US X Section
Height (mAHD)
Chainage
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120