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Report

Gladstone Area Water Board

Report on

Awoonga Dam Boyne River Dam Break and Flood Modelling Study

Volume I

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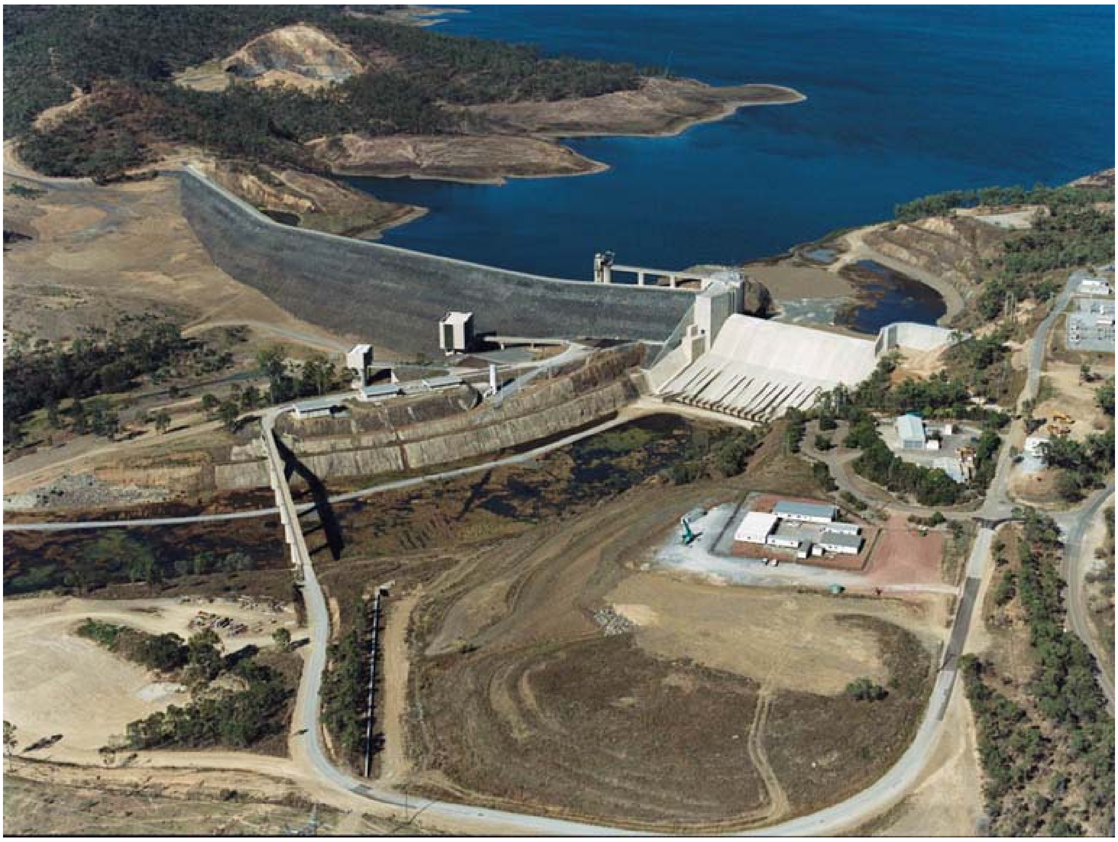
AWOONGA DAM

BOYNE RIVER DAM BREAK AND FLOOD MODELLING STUDY

VOLUME I



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EXECUTIVE SUMMARY

Awoonga Dam is a concrete faced rockfill structure located on the Boyne River approximately 26km south west of Gladstone. It has a capacity of 777,000Ml and is situated upstream of several residential development areas including Benaraby, Tannum Sands, and Boyne Island.

Awoonga Dam is a major source of water supply for the Gladstone area. Extensive raw and treated water distribution networks provide supplies from the dam to urban and industrial water users including the Gladstone City Council and Calliope Shire Council. Water is also supplied to the Callide Power Station to the west of Gladstone.

The objectives of this study are:

- For the purpose of the declaration of 1 in 100 AEP flood regulation lines (as required by the Calliope Shire Council), identify the effects of 1 in 100 flood flows out of and downstream of Awoonga Dam and delineate the extent and levels of potential flooding impacts to properties.
- For the purpose of developing updated Emergency Action and Counter Disaster Plans for the raised Awoonga Dam (as required by the Gladstone Area Water Board), establish the extent, level and timing of the potential flood inundation that would result from significant flood events, as well as dam crest failure and sunny day dam break flood.

The study not only considered the dam in its current configuration, FSL40, but also considered the effects of possible future raisings of the dam to FSL 45 and FSL 55

For FSL 45, the only modifications required would be in the spillway area, where 5 metre high gates would be installed. For the raising to FSL55, 15 metre high gates would be installed, along with post tensioning within the spillway monoliths. A 3.2 metre high wave wall would also be added to the embankment.

This report details the nature and extent of the flooding downstream of Awoonga Dam to its outfall at Tannum Sands. A MIKE-11 model (DHI, 2002) was established to simulate these effects.

For all flood events considered, initial conditions included the assumption that the reservoir was at Full Supply Level.

Also, for the cases where Full Supply Level (FSL) was at EL 45 and EL 55, the spillway rating curve was based on the assumption that the gates (5m high for FSL45, 15m high for FSL55) would open fully once reservoir level rose above the FSL. That is there was no attempt to attenuate the inflow into the reservoir in order to reduce flood effects downstream. This was done in accordance with a previous directive from the Gladstone Area Water Board during the recent raising of the dam.

An indication of the various dam break flood events can be given by comparing the times of inundation for the Bruce Highway Road Bridge. This structure is inundated for 48hrs, 53hrs, and 61hrs for the FSL40, 45 and 55 cases respectively with inundation commencing at least 13hrs after the first outflow from the dam.

For a Sunny Day Failure (SDF) however, although inundation times are much shorter (16hrs, 18hrs, & 24hrs), the commencement of inundation is very close in time to the initiation of failure at the dam. Times between 4.5 and 5 hrs have been recorded as the time when water reaches bridge deck level at the Bruce Highway Bridge.

For the 1 in 100 Annual Exceedence Probability (AEP) flood, no bridges were inundated for the FSL40, 45 and 55 cases. However, significant flooding was evident in the low-lying areas of Wurdong Heights, Benaraby, Boyne Island and Tannum Sands.

Such extent and time of flooding may be reduced for the FSL45 and 55 cases with the provision of some level of flood attenuation by introducing a more complex gate opening sequence.

Volume II of this report shows flood maps and tabulated data for the Boyne River and all nominated tributaries downstream of Awoonga Dam.

1.0 INTRODUCTION

The Awoonga Dam is located near the town of Gladstone in central Queensland. The dam is on the Boyne River, and was constructed for the purpose of supplying water for domestic and industrial use in the Gladstone area.

Industry in the area includes power stations, an alumina refinery, an aluminium smelter, a cement plant, chemical plants and other process industries.

The urban population of the region is approximately 40,000 people (1997), of whom 27,000 reside in Gladstone.

The Gladstone Area Water Board (GAWB) own and operate Awoonga Dam. In 1999, an agreement was made to raise the existing structure using a staged construction program.

As part of the construction program, and to fulfil the requirements of current legislation, a dam break analysis was required for the Awoonga Dam. The analysis is to be used as supporting documentation in the preparation of an Emergency Action Plan and for submission to the Department of Natural Resources and Mines.

In 2001, Awoonga Dam was raised from a Full Supply Level of EL 30.0m (FSL30) to EL 40.0m (FSL40.0). Further raisings are proposed to accommodate a FSL 45 and FSL 55.

This dam break analysis was carried out for the current full supply level, FSL40, and the two proposed raisings, FSL45 and FSL55.

In addition to the dam break analysis, Calliope Shire Council required that 1 in 100 Annual Exceedence Probability (AEP) flood levels be determined for the Boyne River from Awoonga Dam to its mouth at Tannum Sands. Flood levels were also required in a number of tributaries including the South Trees Inlet.

This report summarises the results of the flood model study for the Boyne River, from the Awoonga Dam to its outfall adjacent to Tannum Sands.

1.1 Objectives

The objectives of the flood model study are:

- For the purpose of the declaration of 1 in 100 Flood regulation Lines, for the Calliope Shire Council, establish 1 in 100 flood flows out of and downstream of Awoonga Dam and delineate the extent and levels of potential flooding impacts to properties

- For the purpose of developing updated Emergency Action and counter Disaster Plans for the raised Awoonga Dam, establish, for the Gladstone Area Water Board, the extent, level and timing of the potential flood inundation that would result from significant flood events, including dam break.

1.2 Purpose

The purpose of this report and study is to satisfy the objectives listed above. That is, the modelling of the Awoonga Dam and dam break under the various scenarios and the evaluation of the extent and nature of flooding along the river and creek systems downstream of the dam to the outfall of the river, adjacent to Tannum Sands.

The study incorporates the requirements of both the 1 in 100 flood regulation line required by the Calliope Shire Council, and the dam break analysis required by GAWB.

Based on the results of this study, flood maps showing the areas of inundation for each scenario have been prepared. The various flood and dam break scenarios that were examined are detailed in Table 1.1 below.

Table 1.1 Flood and Dam Break Scenarios

FULL SUPPLY LEVEL	1 in 100AEP Flood Event (No Dam Failure)	PMF event No Dam Failure	PMF event Dam Failure	SDF event Dam Failure
EL 30	✓	N/A	N/A	N/A
EL 40	✓	✓	✓	✓
EL 45	✓	✓	✓	✓
EL 55	✓	✓	✓	✓

(Refer Section 1.4 for definition of PM & SDF)

With all flood cases, the storm durations of 6hr, 12hr, 24hr and 48 hour were considered. In all, over fifty two (52) base flood events were considered, with additional analysis undertaken to examine the sensitivity to downstream river channel roughness, breach formation time and size.

To evaluate the extent and nature of flooding, several aspects were considered, including:

- Maximum depth, discharge and velocity of flow.
- Time travel of the flood wave along the river and creek systems downstream of the dam.
- Flood levels at selected locations downstream of the dam.

1.3 Outline Of Report

This report details the dam break and flood modelling study undertaken for the Awoonga Dam. A review of previous flood model studies is given in Chapter 2 followed by a description of Awoonga Dam and the study area in Chapter 3.

A description of the model and its set-up is given in Chapter 4, while the results of the various flood cases, including failure and non-failure, is given in Chapter 5.

The approach to the sensitivity analysis and the results from that analysis are described in Chapter 6.

1.4 Flood Modelling Definitions

Imminent Failure Flood (IFF)
The flood event which when routed through the reservoir just threatens failure of the dam.

> NOTE:
> The ANCOLD guidelines on Selection of Acceptable Flood Capacity for Dams (ANCOLD, 2000) no longer recommend the use of the IFF, and have replaced it with the Dam Crest Flood (DCF) on the basis that the IFF 'was not strictly correct and inconsistent in application'.
>
> However, for the purposes of this study, the DCF event is not applicable as the spillway has been designed to pass the PMF.

Probable Maximum Precipitation (PMP)
The theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin.

Probable Maximum Flood (PMF)
The flood resulting from the PMP coupled with the worst flood producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.

Sunny Day Failure (SDF)
The dam fails under a no inflow situation. Any flood inundation that eventuates downstream from such a failure would result solely from the water held in the storage. Such a situation could occur if, for example, an earthquake caused structural damage to the dam.

2.0 REVIEW OF PREVIOUS STUDIES

Previous flood and dam break studies have been carried out for Awoonga Dam. A flood study was undertaken in 1984 by Cameron McNamara Consultants which looked at both the 1 in 50AEP and the 1 in 100AEP floods in conjunction with the raising of the Awoonga Dam to EL 30.0

The hydrology used at the time had a level of uncertainty, and this was emphasised in their report. Detailed hydrologic analysis was not part of their brief, and consequently some basic hydrologic analysis was carried out.

The flood study was subsequently based on a peak discharge of 7000m^3/sec for the 1 in 100AEP return period.

More recent hydrology studies have been carried out as part of the Awoonga raising project. This work shows that a peak discharge of 4384m^3/sec is determined for the 1 in 100AEP event (24hr duration). This is approximately a 40% reduction in the peak discharge estimated in the Cameron McNamara report. Consequently, little comparison could be made between the results of this work, and the study by Cameron McNamara Consultants in 1984.

Previous dam break studies were undertaken in 1994 and 1999.

The 1994 study was undertaken as part of a Dam Safety Review carried out for the Gladstone Area Water Board by Engineering Services Group (then part of the Department of Primary Industries, Water Resources). This study looked at the structure at its then current full supply level of EL30m.

The 1999 study, also carried out by Engineering Services (then part of the Department of Natural Resources) looked at three full supply levels, EL43.5, EL53.5, and EL62.0. These levels were the proposed full supply levels for the next and subsequent raisings of Awoonga Dam.

The 1999 study included SDF and PMF failure events for the various full supply levels. Discharge hydrographs, flood times and peak levels were determined for significant points of interest from the dam to the outfall at Tannum Sands.

However, survey data at that time was limited to 1:10 000 orthophoto maps with 5.0m contour intervals. As the survey data was fairly coarse, the results of the flood studies using this information were considered as preliminary only, and therefore provide only basic calibration data for this analysis.

3.0 AWOONGA DAM AND STUDY AREA

3.1 Awoonga Dam

Awoonga Dam is located in the central coastal portion of Queensland, and is approximately 25km south west of Gladstone. The dam is at 22.7km AMTD on the Boyne River.

The dam was built to supply water for domestic and industrial use in the Gladstone area. The dam is a concrete faced rockfill structure, with the following characteristics:

Table 3.1 Awoonga Dam – General Layout

DESCRIPTION	DETAILS
Embankment	Concrete faced, zoned rockfill structure with maximum particle size ranging from 100mm, Zone 3A (transition zone), to 900mm Zone 3D (bulk) material.
Materials	Predominately argillites and sandstones
Crest Elevation	EL55.4m
Crest Width	6m
Embankment Slopes	1.3 H **:** 1.0 V, both U/S and D/S slopes
Embankment Length	658metres
Height of Embankment Crest above River Bed Level (max)	53m
Spillway Type	Reinforced concrete structure with an uncontrolled ogee crest
Spillway Width	110.95m
Spillway Crest	EL 40m AHD
Width of Spillway Approach Channel	120m
Floor Level of Approach Channel	EL25m
Catchment Area	2,230km^2
Storage Capacity (at FSL40)	777,000Ml

3.2 Study Area

The study area extends from Awoonga Dam on the Boyne River to its mouth at Tannum Sands.

It also includes the South Trees inlet which connects with the Boyne River approximately 5km upstream from the mouth of the Boyne River.

The study also required that the model include the effects of the following tributaries downstream of the dam:

- Coomal Creek
- Tucker Creek
- Station Creek
- Machine Creek
- Yunka Creek
- Cattle Creek
- Wurdong Creek
- Wapentake Creek

The extent of the study area was therefore based on catchment areas of these tributaries, as well as potential flood areas that may be affected by the largest flood wave from a dam break scenario.

Several townships, major road and rail crossings are located downstream of the dam, and include:

- Townships of Benaraby, Boyne Island and Tannum Sands
- North Coast Rail Crossing – on the Boyne River
- Bruce Highway Road Bridge – Boyne River
- John Oxley Bridge – Boyne River
- Boyne Island Road Bridge – South Trees Inlet

These also were considered in the model, and the report includes information on maximum flood depth, time of maximum flood depth, maximum discharge and velocity at significant locations downstream of the dam.

Drawings A220483 & A220732 (Volume II, Section 1) show graphically the location townships, bridges etc that are referred to in the study.

Levels used and quoted in this report for rail and road bridges were confirmed from information retrieved from the relevant authorities. The levels used at these locations are the lowest rail and bridge deck level for that particular structure.

4.0 HYDRAULIC MODEL

4.1 General

The dam break and flood modelling was carried out using the MIKE-11 hydraulic modelling package. MIKE-11 is recognised as an appropriate model for such an application as it includes the capability to represent branched networks and the dynamic conditions encountered with dam failure analysis. The use of this software package complies with the requirements of *'Guidelines for Failure Impact Assessment of Water Dams'* (Ref. No 5).

Two main models were constructed for this review:

- The 1 in 100 AEP flood line
- The dam break flood line

4.2 Survey Data

The survey data used in the hydraulic model study included aerial photography, digital mapping and hydrographic survey data. This data was supplied by the Principal in both AMG84 and MGA94 format. (Digital data used and created from this model study has been supplied in AMG84 as per the project brief.)

4.3 River and Channel Network

The model set up consists of the main branch, (Boyne River), a sub-branch, (South Trees Inlet) and 17 other creeks and overland flood channels. Over 64,000 co-ordinate points were used to create the model. An overview of the river and channel network system is included in drawing A220483 (Volume II Section 1) of this report.

4.4 Cross Sections

The sections considered in the model were extracted from the digital terrain model and selected so as provide a comprehensive representation of the area for both channel and overbank flow. The data from the hydrographic survey was also incorporated into the model .

Over 200 sections were used to create the model, with additional sections at specific points such as road and rail crossings and other significant features. (Drawing 220483 contained in Volume II Section 1 of this report shows the locations of the main cross sections used in the model). Each section is identified by an Adopted Overland Flow Distance (AOFD) in the MIKE 11 model, and where necessary a section identifier is also used. These identifiers are shown in the tabulated data contained in Volume II of this report.

The relative resistances for the cross sections was modelled in MIKE 11 using the triple zone approach. This facility allows the use of different resistance coefficients for bed, bank, and overflow conditions.

Resistance values used for the main channel, banks and over flow ranged from 0.05 to 0.08, and 0.11 respectively. These values were determined from field reconnaissance, and aerial photography. Although these values are considered appropriate for this type of terrain, a sensitivity analysis was also carried out on the values adopted for the various zones.

The location and orientation of the main cross sections (these have a section identifier in the Mike 11 model) are shown graphically in Volume II of this report.

4.5 Downstream Boundary Conditions

For all models, the downstream boundary conditions adopted were the Highest Astronomical Tide (HAT) EL2.42m. This condition was set at the downstream end of both the South Trees Inlet and the Boyne River.

4.6 Upstream Boundary Conditions

The upstream boundary conditions at Awoonga Dam were either the outflow hydrographs generated from the spillway discharge data, or the dam break module. The actual values used in each model were dictated by the flood case under consideration. The outflow hydrographs adopted were those as generated and used for the recent raising of Awoonga Dam. (This information is supplied in electronic form).

The upstream boundary conditions for the tributaries were the respective inflow hydrographs for the 1 in 100 AEP. This was the case for both the Calliope and GAWB model.

As required in the *Guidelines for Failure Impact Assessment of Water Dams* (Ref No.5), concurrent rainfall information is to be considered for downstream tributary flows when assessing the impacts of potential dam failures. The document also suggests that the flood events in the downstream tributaries should be in the order of 1/1,000 of the PMP magnitude for the dam break analysis. This equates to the 1 in 100 year average recurrence interval (ARI) event.

As a consequence of this requirement, 1 in 100 flood hydrographs were developed for all sub-catchments between Awoonga Dam and the river mouth. Table 4.1 defines the sub-catchments used for this study.

Table 4.1 Catchment Data downstream of Awoonga Dam

Creek Name	Catchment Area (km^2)	Value of k_c
Tucker Creek	20.3	5.1
Coomal Creek	14.6	4.4
Little Oaky Creek	5.4	2.7
Yunka Creek	4.1	2.3
Station Creek	49.1	8.0
Machine Creek	18.5	4.9
Wurdong Creek	6.3	2.9
Cattle Creek	3.8	2.2
Ten Mile Creek	7.5	3.1
Eleven Mile Creek	11.4	3.9
Wappentake Creek	6.1	2.8

Using the runoff-routing techniques as defined in ARR (1987), RORB models for each sub-catchment were developed. As there were no gauging stations on any of the creeks, it was not possible to calibrate the RORB models. Hence, the parameter indicating catchment non-linearity, (m), was defined as 0.8, the recommended value for ungauged catchments. Based on the southern drainage division, covering basins 126 to 146, the relationship of the model parameter, k_c, was defined as:

$$k_c = 1.14 * (A)^{0.5}$$

Where A = catchment area in km^2

The 1:100 year rainfall intensities for storm durations of 6, 12, 24 and 48 hours were derived using Chapter 2 of ARR (1987). Table 4.2 lists the input data derived from the rainfall intensity maps, while Table 4.3 shows the rainfall intensities and total depths for the range of durations.

Table 4.2 Downstream Sub-Catchments – Rainfall Input Data

Frequency	Duration	Intensity (mm/hr)
2 year	1 hr	46.0
2 year	12 hr	9.1
2 year	72 hr	2.7
50 year	1 hr	86.0
50 year	12 hr	21.0
50 year	72 hr	8.0
2 year	6 minute	Geographical factor = 4.28
50 year	6 minute	Geographical factor = 17.80

(Skewness 0.20, Latitude 25.05, Longitude 151.20)

Table 4.3 Downstream Sub-Catchments – Rainfall Intensity for Set Durations

Storm Duration (hours)	Intensity (mm/h)	Total Storm Depth (mm)
6	37.47	224.82
12	25.54	306.48
24	18.29	438.96
48	12.85	616.80

The rainfall temporal patterns were also obtained from ARR (1987), based on Zone 3 patterns. These temporal patterns were extracted in half hour periods and the total rainfall depths applied to them. Once this data was collated, the RORB models were run for each catchment for the four storm durations.

The respective hydrographs used were commensurate with the flood event at the dam (for example, in considering the 24hr PMF event at the dam, the 24hr, 1 in 100 event was used as the upstream boundary condition in the nominated tributaries).

The inflow and outflow hydrographs for the Awoonga Dam, and the inflow hydrographs for eleven tributaries downstream of the dam are included in the electronic data supplied with this report.

4.7 Base Inflows

For cases of steady state condition, and in particular the dam break case of Sunny Day Failure, base flows were used to maintain a stable model. Values of base inflow were kept to a minimum and ranged from $6m^3$/sec to $0.5m^3$/sec depending on the channel bed slopes (eg $6m^3$/sec was used in the upper reach of Coomal Ck which has steep terrain, while only $0.5m^3$/sec was required to maintain stability in creeks located in the flood plain area such as Station Ck)

4.8 Dam Break Model.

The dam break model is similar to the 1 in 100 model, with the main exception being the bridges were removed from the model.

This model incorporated two structures – a dam wall (or dam break structure) and a spillway structure. The dam wall was located 350m on the Boyne River Branch, while the spillway was located 250m on a ‘spillway branch’ that was connected and ran parallel to the Boyne River Branch. The configuration was such that the distance from the most upstream point of the Boyne River Branch to both structures was the same.

With the inclusion of the dam break structure, and with the retention of the bridges in the model, instabilities were encountered even for the lesser flood events.

It was also noted that for the floods under consideration, the bridges would have little or no influence on flood heights or flood inundation times. This was confirmed in the

1 in 100AEP model when comparisons were made between the models used. Consequently, all analyses for the dam break cases were undertaken without modelling the downstream bridges. However, additional cross sections were located close to or at bridge locations so as to provide a reliable estimate of flood heights.

Table 4.4 summarises the cases that were considered in the dam break analyses.

Table 4.4 Dam Break Flood Cases

Failure Mode and Duration	FSL 40	FSL 45	FSL 55
Sunny Day	✓	✓	✓
PMF No Dam Failure			
6hr storm	✓	✓	✓
12hr storm	✓	✓	✓
24hr storm	✓	✓	✓
48hr storm	✓	✓	✓
PMF Dam Failure			
6hr storm	✓	✓	✓
12hr storm	✓	✓	✓
24hr storm	✓	✓	✓
48hr storm	✓	✓	✓

With each of these cases, the storm durations were considered not only for the upstream catchment, but also the nominated downstream catchments.

In addition to these cases, sensitivity analyses were carried out on the models for the SDF and PMF dam failure events. The sensitivity analyses included variations to both breach formation time and breach width.

4.9 Breach Mechanism

The development of the breach used in the dam failure cases was assumed to occur by linear erosion, with a linear increase in breach dimensions developing over a specified length of time.

For the flood failure scenarios, breach development was initiated at the time of maximum reservoir level. (The time of initiation varied depending on the inflow hydrograph used for that particular FSL and flood case).

Breach widths were calculated initially based on the procedure described in the *Guidelines for Failure Impact Assessment of Water Dams,* (Ref No.5). The breach width and volume of material removed that was determined from this procedure however gave values in excess of the total volume of material in the embankment.

With consideration to the type of embankment (concrete faced rockfill) and surrounding topography, a breach width was estimated for the FSL 40 SDF case.

Using this as a base, additional estimates were made for the remaining combinations. Table 4.5 shows the breach base widths and formation times for the various full supply levels.

Table 4.5 Breach Base Widths and Formation Times

FSL	SDF		PMF	
	Base Width (m)	Formation Time (hrs)	Base Width (m)	Formation Time (hrs)
40	250	4.00	300	4.00
45	275	4.00	325	4.25
55	320	4.25	370	4.50

Volume II of this report includes a general arrangement of the Awoonga Dam including a typical breach profile. A table of breach widths for the various full supply levels is also included in the General Arrangement.

4.10 1 in 100 AEP Flood Event.

This model incorporated the bridges downstream of the dam, but did not model the dam structure itself. In this study, the outflow hydrograph from Awoonga dam was used as the upstream boundary condition.

Table 4.6 lists the cases that were considered for the 1 in 100AEP event.

Table 4.6 1 in 100 AEP Flood Cases

Duration	FSL 30	FSL 40	FSL 45	FSL 55
Model #1 (No bridges included)				
6hr	✓	✓	✓	✓
12hr	✓	✓	✓	✓
24hr	✓	✓	✓	✓
48hr	✓	✓	✓	✓
Model #2 (Bridges included)				
6hr	✓	✓	✓	✓
12hr	✓	✓	✓	✓
24hr	✓	✓	✓	✓
48hr	✓	✓	✓	✓

As in the case of the dam break analyses, the various storm durations were considered not only for the upstream catchment, but also the nominated downstream catchments.

4.11 Effects of Manns Weir

As part of the brief, this model study was to include, or give consideration to, the effects of Manns Weir. Manns Weir is a sand and gravel structure located approximately 5km downstream of Awoonga Dam.

Weirs of this type of construction are generally referred to as a rubble mound weir. Rubble mound weirs are generally defined as a weir made of natural sand, gravel and stone, with no particular gradation requirements. This type of weir is designed to restrict rather than prevent flow consequently it is permeable. The level of permeability is then dependent on particle size and gradation of materials used in their construction.

Research carried out on these structures found the following general configuration:

Side Slope of Weir:	1V:1.7H (minimum)
Height/Base length ratio:	1:10
Crest length: Base length:	1:1.5

(length measured parallel to flow)

These weirs are typically low height broad width structures. Failure mode of these structures is a combination of unravelling of the downstream slope along with the action of seepage forces within the structure.

The failure of these structures is usually not a continuous progression, rather the combination and cyclic collapse stage and stable stage. The failure moment is considered equivalent to a depth of water at the upstream edge of the structure equal to 20% of the height of the structure

A site inspection of Manns weir confirmed that the cross section is of similar configuration to a typical rubble mound weir.

Consequently, it is considered unlikely Manns Weir will have any impact on flood water levels. The height of the weir (approximately 2m) suggests that it will fail with no more than 0.4m depth of flow over the structure. Discussions with local residents confirmed that the weir is breached with approximately 0.3 to 0.5m of water over the structure.

5.0 DISCUSSION OF RESULTS

In order to analyse the impact of the flood wave resulting from both the dam break analysis of the Awoonga Dam, and the effects of the 1 in 100 AEP flood, several downstream locations were identified as being significant places of interest.

The number of locations has been limited, as suggested in the project brief, to those that represent significant interest to both the Gladstone Area Water Board and the Calliope Shire Council. The locations identified include:

- Immediately downstream of the Awoonga Dam
- Pikes Crossing
- The Queensland Rail Bridge across the Boyne River
- The Bruce Highway Bridge across the Boyne River
- The John Oxley Bridge – a road link connecting Boyne Is and Tannum Sands
- The South Trees Inlet and Boyne River bifurcate
- South Trees Inlet – Boyne Is Road Bridge

At these locations, several parameters were examined and the results from the analysis tabulated in the appendices of this report. They include values of maximum water level, discharge and velocity as well as time to maximum water level from the start of simulation. Volume II of this report contains similar tabulated data for most cross sections used in the model.

It should be noted at this point that all times are measured from the start of simulation “time zero”. That is, inflow into the reservoir and inflow into the sub-catchments downstream of the dam starts at “time zero”. For a dam failure during a flood event, the breach is initiated when the reservoir level reaches its peak elevation. For a sunny day failure, the breach is initiated at “time zero”.

5.1 SCENARIO COMPARISONS – GAWB Dam Break

The time from the commencement of the inflow event to the failure of the dam varied according to the magnitude of the inflow hydrograph. In all cases however, the reservoir was assumed full at the start of the modelling sequence.

The nine (9) scenarios for each full supply level are tabulated in Appendix 1, 2 & 3 for the FSL40, 45 and 55 cases respectively. Table 5.1 provides a summary of the cases considered for the dam break analyses, together with an indication (shaded cell) of those events that produced the highest values of flood level.

Table 5.1 Dam Break Flood Cases
(shaded cell indicates the flood case that produces the highest value for flood level)

Failure Mode and Duration	FSL 40	FSL 45	FSL 55
Sunny Day	✓	✓	✓
PMF No Dam Failure			
6hr storm	✓	✓	✓
12hr storm	✓	✓	✓
24hr storm	✓	✓	✓
48hr storm	✓	✓	✓
PMF Dam Failure			
6hr storm	✓	✓	✓
12hr storm	✓	✓	✓
24hr storm	✓	✓	✓
48hr storm	✓	✓	✓

Appendix 4, 5, & 6 contain the following graphical information:

- Discharge Hydrographs for the significant locations of interest.
- Stage Hydrographs for the significant locations of interest.
- Downstream Flood Profile for PMF Fail case for the 6, 12, 24 & 48hr durations.
- Maximum Flood Line for the PMF dam fail event, plus the respective PMF no dam fail event, and the SDF case.

As shown in Appendices in both tabular and graphical form, peak discharges varied most significantly in the areas of the QR Rail Bridge and the Bruce Highway Bridge. This is particularly evident for the maximum flood event. It should be noted that the model was set up to define the various channels downstream of the dam as per the requirements of the brief. These channels include un-named tributaries and anabranches. An anabranch is located downstream of the Rail Bridge on the right bank. (refer Drawing A220483 in Volume II). Once flood flow reaches a certain elevation, a significant portion of the discharge enters the anabranch from the main channel. The drop in the discharge hydrographs between the Rail Bridge and the Highway Bridge reflects this. It should be noted that the discharge hydrograph as shown in this report is for the Boyne River channel only, and at this location, the river channel cross sections are relatively narrow in width. The sections that define the anabranch and un-named tributaries make up the complete flood channel for this area.

The discharge hydrograph for a channel depicts the conditions in that particular channel, and not the flood plain, or other channels in that area. The stage hydrograph however does reflect the conditions in the general area, and hence will usually not reflect such variations as evident in the discharge hydrographs.

As a means of comparison, the peak discharge and maximum water level for the first and last significant downstream locations along the Boyne River are listed in Table 5.2.

Table 5.2 Comparison of Maximum Discharge and Water Levels

Full Supply Level	Flood Event	D/S Awoonga Dam		John Oxley Bridge	
EL (m)	Duration, Type	Maximum Discharge (m^3/sec)	Peak Level (m)	Maximum Discharge (m3/sec)	Peak Level (m)
FSL40	48hr, PMF, Fail	76975	45.87	24539	11.51
	48hr, PMF, No Fail	15502	27.76	8467	7.08
	SDF	51261	34.57	9235	7.31
FSL45	48hr, PMF, Fail	84264	47.37	26726	11.98
	48hr PMF, No Fail	15687	27.88	8607	7.06
	SDF	49914	38.94	12867	8.61
FSL55	24hr, PMF, Fail	104123	51.09	33002	13.02
	24hr, PMF, No Fail	19405	28.93	10099	7.65
	SDF	85724	47.31	24206	11.45

Also, critical levels have been identified for all bridges identified in the model. The times of start to finish of inundation are given in Table 5.3 below. It should be noted that for the FSL55 case, although the 24hr duration event causes the highest flood level, the 48hr event has the longest period of submergence. Consequently the values reported for the FSL55 case reflect the 48hr duration event.

Maps contained in Volume II of this report show the extent of flooding for the various cases considered. Flooding was extensive, and for all cases, the following areas were affected:

- The lower lying portions of Tannum Sands
- Development adjacent to Cattle Ck
- Township of Benaraby
- Low portion of Wurdong Heights
- Flooding of the Bruce Highway for a length exceeding 8.5km

Table 5.3 Inundation Times for Bridges downstream of Awoonga Dam

Location	Start (hrs)	Stop (hrs)	Start (hrs)	Stop (hrs)
FSL40	PMF Fail – 48hr		Sunny Day Failure	
QR Rail Bridge (EL19.0)	36.2	68.1	6.4	13.0
Bruce Highway (EL13.28)	26.1	74.3	5.0	21.0
John Oxley Bridge (EL11.47)	53.5	55.1	Not inundated	Not inundated
Boyne Is. Road Bridge (EL4.8)	25.6	79.5	7.5	25.0
FSL45	PMF Fail – 48hr		Sunny Day Failure	
QR Rail Bridge (EL19.0)	33.0	68.0	5.0	17.5
Bruce Highway (EL13.28)	22.0	75.0	5.0	23.5
John Oxley Bridge (EL11.47)	52.0	56.0	Not inundated	Not inundated
Boyne Is. Road Bridge (EL4.8)	22.0	80.0	6.5	28.4
FSL55	PMF Fail – 48hr		Sunny Day Failure	
QR Rail Bridge (EL19.0)	21.5	66.0	4.4	22.5
Bruce Highway (EL13.28)	13.0	73.8	4.5	29.0
John Oxley Bridge (EL11.47)	46.5	53.5	Not inundated	Not inundated
Boyne Is. Road Bridge (EL4.8)	13.5	78.0	5.0	33.5

5.2 Scenario Comparisons – 1 in 100 AEP Flood Study

As for the GAWB dam break model, the time from the commencement of the inflow event to the maximum water level at the various locations downstream varied according to the magnitude of the inflow hydrograph. In all cases however, the reservoir was assumed full at the start of the modelling sequence.

The model was prepared initially with no structures downstream of Awoonga Dam. With this as a base model 'no bridge model', modifications were made to the model to include the rail and road bridges 'bridge model'. However, instabilities were encountered in the area of the QR Rail Bridge and the Bruce Highway Bridge, not only because of the proximity of the two bridges, but also the significant change in flood channel profile as the flood wave progresses past the Bruce Highway Bridge.

Consequently two models were run for the 1 in 100 AEP flood event. The results from both models were similar, the execution time for the model which included the bridges however, was extended significantly with the inclusion of the structures.

Although the results from the 'bridge model' show some level of instability, the results are still consistent with the 'no bridge' model. Consequently, only the results from the 'bridge' are described and included here. However, for comparison purposes, tabulated results for the 'no bridge model' (Maximum Water Level only) has been included in accordance with the project requirements. Table 5.4 lists the flood cases considered.

Table 5.4 1 in 100 AEP Flood Cases
(shaded cell indicates the flood case that produces the highest value for flood level)

Duration	FSL 30	FSL 40	FSL 45	FSL 55
Model #1 (No bridges included)				
6hr	✓	✓	✓	✓
12hr	✓	✓	✓	✓
24hr	✓	✓	✓	✓
48hr	✓	✓	✓	✓
Model #2 (Bridges included)				
6hr	✓	✓	✓	✓
12hr	✓	✓	✓	✓
24hr	✓	✓	✓	✓
48hr	✓	✓	✓	✓

Appendix 7 lists the maximum values for water level, discharge and velocity at the significant locations of interest, while Appendix 8 & 9 contain the following graphical information:

- Discharge Hydrographs for the significant locations of interest
- Stage Hydrographs for the significant locations of interest
- Downstream flood profile for the maximum flood event for each full supply level
- Comparison of flood lines with that prepared from earlier flood studies

The bridges nominated in the report as significant sites were not inundated for full supply levels of 40, 45 and 55. For the old full supply level of EL30 however, the Boyne Island road bridge was inundated from 27.0 to 33.0 hours after the start of the modelling sequence.

Appendix 9 shows the maximum flood lines for the various floods, including a superimposed plot of the results from the Cameron McNamara report. There is a noticeable difference between the line representing the FSL30, 24hr duration case with the information retrieved from the Cameron McNamara report. However, with the recent reviews of hydrologic data, the peak discharge for this particular flood event has reduced from 7000m3/sec (used by Cameron McNamara) to the current value of 4384m^3/sec.

As a means of comparison, for the FSL55 case and 12hr duration event, the peak discharge is of the order of 8224m3/sec. Using these values for comparison, the Cameron McNamara flood line fits logically between the current FSL30 and FSL55 value. This is shown graphically in Appendix 9.

A tabulation of all flood levels, discharge and velocity is included in Volume II of this report.

6.0 SENSITIVITY ANALYSIS

Dam Break Study

Sensitivity analyses were performed on the dam break model, with particular attention to the breach base width and formation time. For each case considered, only one parameter was changed. This was necessary to ensure there was a good understanding of the implications of modifications to any variable used in the model.

Because of the volume of data generated from a sensitivity analysis on each duration storm for each FSL (potentially 72 flood cases) only those events that produced the maximum flood height downstream of the dam were considered.

Consequently, a total of twenty four (24) flood cases were considered for this sensitivity analysis. Table 6.1 lists the values adopted for each FSL. The variations from the original values were approximately plus or minus 10%. This was considered a reasonable approach for the sensitivity analysis and is in accordance with the *Guidelines for Failure Impact Assessment of Water Dams*. (Ref No5).

Table 6.1 Breach Parameters

Full Supply Level	Flood Model	Adopted Values		Sensitivity Values	
		Breach Width (m)	Breach Formation Time (hrs)	Breach Width (m)	Breach Formation Time (hrs)
FSL40	SDF	250	4.00	200	3.50
				275	4.50
	PMF (48hr)	300	4.00	250	3.50
				325	4.50
FSL45	SDF	275	4.00	250	3.50
				300	4.50
	PMF (48hr)	325	4.25	275	3.75
				350	4.75
FSL55	SDF	320	4.25	300	4.00
				350	4.50
	PMF (24hr)	370	4.50	350	4.00
				400	4.75

Results from the analyses show that at the Bruce Highway Bridge, shorter formation times and a larger breach base width generally produced a higher flood level, but the increase was no more than 0.1m. The effect was smaller again as the flood wave reached the John Oxley Bridge with variations no more than 0.05m (50mm). With such small variations in flood levels, the flood lines, when presented graphically, were indistinguishable, and consequently have not been included in the report.

However, tabular results for the cases as described have been included in Volume II.

1 in 100 AEP Flood Study

For this model study, a review on the roughness coefficients used in the base model was undertaken as a means of gauging the sensitivity of the model to such variations.

The model used for the sensitivity analysis was the ‘no bridge’ model. This was considered appropriate as there was little variation in flood values between the ‘bridge’ and ‘no bridge’models, and this model proved to be the more stable of the two. It therefore had a better capacity to accept significant variations in the roughness coefficient. (A comparison of flood levels for the ‘bridge’ and ‘no bridge’ models is included in Volume II of this report).

Table 6.2 1 in 100 AEP Sensitivity Analysis

Full Supply Level	Duration (hrs)	Sensitivity Analysis
FSL30	24	Mannings ‘n’ +/- 10%
FSL40	48	Mannings ‘n’ +/- 10%
FSL45	24	Mannings ‘n’ +/- 10%
FSL55	12	Mannings ‘n’ +/- 10%

The results of the sensitivity analysis included in this report represent the worst case, or maximum variation in flood levels. For this study, the FSL55, 12hr event produced the worst downstream effects.

The tabular results are presented in Volume II of this report, with Appendix 10 including a graphical representation of the flood height for the Boyne River.

Increasing the value of the roughness coefficient generally caused an increase in the flood level down to the South Trees bifurcate. From that point downstream, a slight decrease in the flood level was noted. For example, at the Bruce Highway Bridge, there was an increase of 0.46m while at the John Oxley Bridge, a decrease of 0.02 of a metre was recorded.

Such a pattern appears reasonable if we consider that by increasing the roughness, the flooding will increase in the upper reaches but assist in attenuating the flood in the downstream areas.

The reverse pattern can be seen for the case where the roughness coefficient is reduced. In this case, the flood level at the Bruce Highway Bridge is reduced by 0.51m while at the John Oxley Bridge, a slight increase of 0.1m was recorded.

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APPENDIX 1

SUMMARY OF HYDRAULIC ANALYSES – FSL40

SUMMARY OF HYDRAULIC ANALYSES – FSL 40

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 40 – 6hr PMF Dam Failure						
D/S Awoonga Dam	817	-	40.96	21:33	58634	4.2
Pikes Crossing	3313	-	34.23	22:06	51116	2.9
QR Rail Bridge	8050	19.0	27.47	25:06	26288	2.3
Bruce Hwy Road Bridge	10646	13.28	26.8	25:20	24464	3.4
John Oxley Bridge	21269	11.47	9.42	27:13	15652	3.5
South Trees – Boyne R. Bifurcate	217722	-	13.69	27:06	15454	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	12.58	27:33	15174	1.6
FSL 40 - 12hr PMF Dam Failure						
D/S Awoonga Dam	817	-	43.78	22:53	69253	4.3
Pikes Crossing	3313	-	36.72	23:26	61650	3.1
QR Rail Bridge	8050	19.0	30.45	26:13	29269	2.0
Bruce Hwy Road Bridge	10646	13.28	29.83	26:20	27383	3.1
John Oxley Bridge	21269	11.47	10.55	28:06	20192	3.9
South Trees – Boyne R. Bifurcate	217722	-	15.15	28:00	20143	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	14.10	28:20	19894	1.6

SUMMARY OF HYDRAULIC ANALYSES – FSL 40

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 40 - 24hr PMF Dam Failure						
D/S Awoonga Dam	817	-	45.42	30:46	75214	4.3
Pikes Crossing	3313	-	38.22	31:20	67994	3.2
QR Rail Bridge	8050	19.0	32.3	33:53	30758	2.0
Bruce Hwy Road Bridge	10646	13.28	31.68	34:00	28873	2.9
John Oxley Bridge	21269	11.47	11.25	35:40	23280	3.7
South Trees – Boyne R. Bifurcate	217722	-	16.06	35:33	23372	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	15.03	35:46	23145	1.6
FSL 40 - 48hr PMF Dam Failure						
D/S Awoonga Dam	817	-	45.87	49:13	76975	4.3
Pikes Crossing	3313	-	38.71	49:53	69913	3.2
QR Rail Bridge	8050	19.0	32.99	52:26	63261	3.5
Bruce Hwy Road Bridge	10646	13.28	32.37	52:33	29433	2.9
John Oxley Bridge	21269	11.47	11.51	54:13	24539	3.7
South Trees – Boyne R. Bifurcate	217722	-	16.41	54:06	24650	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	15.38	54:19	24446	1.6

SUMMARY OF HYDRAULIC ANALYSES – FSL 40

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 40 - 6hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	17.46	19:33	4161	2.0
Pikes Crossing	3313	-	15.55	20:33	4167	1.1
QR Rail Bridge	8050	19.0	12.38	22:39	4043	1.7
Bruce Hwy Road Bridge	10646	13.28	11.44	24:13	4043	1.9
John Oxley Bridge	21269	11.47	3.95	25:46	2788	1.7
South Trees – Boyne R. Bifurcate	217722	-	6.28	25:26	1179	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	4.58	26:26	1178	1.1
FSL 40 - 12hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	23.76	20:06	9847	2.4
Pikes Crossing	3313	-	21.12	20:46	9832	1.4
QR Rail Bridge	8050	19.0	16.88	23:56	7660	2.0
Bruce Hwy Road Bridge	10646	13.28	16.01	24:26	7547	1.6
John Oxley Bridge	21269	11.47	5.56	26:33	5365	2.4
South Trees – Boyne R. Bifurcate	217722	-	8.68	26:20	3555	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	7.03	27:26	3534	1.3

SUMMARY OF HYDRAULIC ANALYSES – FSL 40

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 40 - 24hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	27.13	27:39	14751	2.6
Pikes Crossing	3313	-	23.99	28:33	14640	1.6
QR Rail Bridge	8050	19.0	19.78	31:00	9756	2.0
Bruce Hwy Road Bridge	10646	13.28	19.05	31:20	9669	1.6
John Oxley Bridge	21269	11.47	6.68	33:13	7653	2.8
South Trees – Boyne R. Bifurcate	217722	-	10.18	33:06	6098	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	8.77	33:46	6077	1.3
FSL 40 - 48hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	27.76	45:53	15502	2.5
Pikes Crossing	3313	-	24.66	46:53	15533	1.6
QR Rail Bridge	8050	19.0	20.62	48:33	15545	1.9
Bruce Hwy Road Bridge	10646	13.28	19.91	48:49	10080	1.5
John Oxley Bridge	21269	11.47	7.08	50:26	8467	2.9
South Trees – Boyne R. Bifurcate	217722	-	10.62	50:19	10859	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	9.28	50:46	6950	1.3

SUMMARY OF HYDRAULIC ANALYSES – FSL 40

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 40 Sunny Day Failure						
D/S Awoonga Dam	817	-	34.57	5:00	51261	4.1
Pikes Crossing	3313	-	28.66	6:15	28941	2.4
QR Rail Bridge	8050	19.0	21.97	8:45	18201	2.4
Bruce Hwy Road Bridge	10646	13.28	21.23	8:45	17153	3.0
John Oxley Bridge	21269	11.47	7.31	11:15	9235	2.9
South Trees – Boyne R. Bifurcate	217722	-	11.0	11:15	8309	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	9.61	11:15	8012	1.4

APPENDIX 2

SUMMARY OF HYDRAULIC ANALYSES - FSL 45

SUMMARY OF HYDRAULIC ANALYSES – FSL 45

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 45 - 6hr PMF Dam Failure						
D/S Awoonga Dam	817	-	43.21	19:39	67368	4.2
Pikes Crossing	3313	-	36.21	20:13	59679	3.0
QR Rail Bridge	8050	19.0	29.68	23:06	29170	2.2
Bruce Hwy Road Bridge	10646	13.28	29.10	23:20	27236	3.4
John Oxley Bridge	21269	11.47	10.25	25:06	18927	3.5
South Trees – Boyne R. Bifurcate	217722	-	14.76	25:00	18887	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	13.70	25:20	18593	1.7
FSL 45 - 12hr PMF Dam Failure						
D/S Awoonga Dam	817	-	45.62	22:06	76996	4.3
Pikes Crossing	3313	-	38.37	22:39	69265	3.2
QR Rail Bridge	8050	19.0	32.25	25:13	31613	1.9
Bruce Hwy Road Bridge	10646	13.28	31.63	25:26	29526	3.1
John Oxley Bridge	21269	11.47	11.21	27:06	23129	3.7
South Trees – Boyne R. Bifurcate	217722	-	16.01	27:00	23279	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	14.98	27:13	23026	1.6

SUMMARY OF HYDRAULIC ANALYSES – FSL 45

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 45 - 24hr PMF Dam Failure						
D/S Awoonga Dam	817	-	47.34	28:36	84263	4.4
Pikes Crossing	3313	-	39.87	29:20	76290	3.3
QR Rail Bridge	8050	19.0	34.07	31:46	33677	1.9
Bruce Hwy Road Bridge	10646	13.28	33.44	31:53	31603	3.1
John Oxley Bridge	21269	11.47	11.91	33:30	26378	3.8
South Trees – Boyne R. Bifurcate	217722	-	16.90	33:23	26680	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	15.88	33:36	26446	1.7
FSL 45 - 48hr PMF Dam Failure						
D/S Awoonga Dam	817	-	47.37	48:49	84264	4.4
Pikes Crossing	3313	-	39.44	49:40	76181	3.3
QR Rail Bridge	8050	19.0	34.24	52:00	33590	1.8
Bruce Hwy Road Bridge	10646	13.28	33.61	52:10	31578	3.0
John Oxley Bridge	21269	11.47	11.98	53:43	26726	3.8
South Trees – Boyne R. Bifurcate	217722	-	16.99	53:36	27011	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	15.97	53:49	26794	1.6

SUMMARY OF HYDRAULIC ANALYSES – FSL 45

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 45 - 6hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	19.9	16:53	5855	2.2
Pikes Crossing	3313	-	17.8	18:00	5873	1.2
QR Rail Bridge	8050	19.0	14.1	20:13	5431	1.8
Bruce Hwy Road Bridge	10646	13.28	13.1	21:00	5393	1.3
John Oxley Bridge	21269	11.47	4.5	23:13	3555	1.9
South Trees – Boyne R. Bifurcate	217722	-	7.1	22:53	1926	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	5.5	24:20	1919	1.2
FSL 45 - 12hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	25.24	19:33	11888	2.5
Pikes Crossing	3313	-	22.44	19:26	12558	1.5
QR Rail Bridge	8050	19.0	18.04	22:13	8597	1.9
Bruce Hwy Road Bridge	10646	13.28	17.23	22:46	8488	1.6
John Oxley Bridge	21269	11.47	6.02	24:46	6242	2.6
South Trees – Boyne R. Bifurcate	217722	-	9.26	24:33	4450	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	7.69	25:33	4420	1.3

SUMMARY OF HYDRAULIC ANALYSES – FSL 45

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 45 - 24hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	27.74	27:13	15705	2.6
Pikes Crossing	3313	-	24.55	28:13	15623	1.6
QR Rail Bridge	8050	19.0	20.38	30:26	10135	1.8
Bruce Hwy Road Bridge	10646	13.28	19.67	30:46	10051	1.6
John Oxley Bridge	21269	11.47	6.91	32:40	8219	2.9
South Trees – Boyne R. Bifurcate	217722	-	10.48	32:26	6708	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	9.12	33:06	6692	1.3
FSL 45 - 48hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	27.88	45:40	15687	2.5
Pikes Crossing	3313	-	24.78	46:33	15734	1.6
QR Rail Bridge	8050	19.0	20.75	48:00	10147	1.8
Bruce Hwy Road Bridge	10646	13.28	20.06	48:19	10136	1.5
John Oxley Bridge	21269	11.47	7.06	49:46	8607	2.9
South Trees – Boyne R. Bifurcate	217722	-	10.69	49:40	7105	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	9.37	50:06	7102	1.7

SUMMARY OF HYDRAULIC ANALYSES – FSL 45

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 45 Sunny Day Failure						
D/S Awoonga Dam	817	-	38.94	5:00	49914	4.0
Pikes Crossing	3313	-	32.40	5:50	42495	2.7
QR Rail Bridge	8050	19.0	25.31	8:19	24218	2.9
Bruce Hwy Road Bridge	10646	13.28	24.68	9:10	22542	3.4
John Oxley Bridge	21269	11.47	8.61	10:49	12867	3.2
South Trees – Boyne R. Bifurcate	217722	-	12.64	10:49	12463	1.9
South Trees – Boyne Is. Road Bridge	-	4.8	11.44	11:40	12156	1.6

APPENDIX 3

SUMMARY OF HYDRAULIC ANALYSES - FSL 55

SUMMARY OF HYDRAULIC ANALYSES – FSL 55

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 55 - 6hr PMF Dam Failure						
D/S Awoonga Dam	817	-	49.22	15:19	94965	4.6
Pikes Crossing	3313	-	41.37	15:56	85298	3.5
QR Rail Bridge	8050	19.0	35.30	18:20	37203	2.4
Bruce Hwy Road Bridge	10646	13.28	34.66	18:30	34747	3.3
John Oxley Bridge	21269	11.47	12.37	20:03	28775	3.9
South Trees – Boyne R. Bifurcate	217722	-	17.50	19:56	29266	1.9
South Trees – Boyne Is. Road Bridge	-	4.8	16.48	20:06	29003	1.7
FSL 55 - 12hr PMF Dam Failure						
D/S Awoonga Dam	817	-	50.66	19:26	100941	4.6
Pikes Crossing	3313	-	42.65	20:00	91203	3.6
QR Rail Bridge	8050	19.0	36.86	22:21	38889	2.4
Bruce Hwy Road Bridge	10646	13.28	36.20	22:38	36520	3.2
John Oxley Bridge	21269	11.47	12.86	24:01	31925	4.0
South Trees – Boyne R. Bifurcate	217722	-	18.23	23:53	32473	1.9
South Trees – Boyne Is. Road Bridge	-	4.8	17.22	24:09	32233	1.8

SUMMARY OF HYDRAULIC ANALYSES – FSL 55

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 55 - 24hr PMF Dam Failure						
D/S Awoonga Dam	817	-	51.09	28:50	104123	4.6
Pikes Crossing	3313	-	43.06	29:23	93328	3.6
QR Rail Bridge	8050	19.0	37.37	31:46	84196	3.8
Bruce Hwy Road Bridge	10646	13.28	36.71	31:53	37058	3.1
John Oxley Bridge	21269	11.47	13.02	33:19	33002	4.1
South Trees – Boyne R. Bifurcate	217722	-	18.47	33:13	33572	1.9
South Trees – Boyne Is. Road Bridge	-	4.8	17.46	33:23	33344	1.8
FSL 55 - 48hr PMF Dam Failure						
D/S Awoonga Dam	817	-	50.78	44:10	102296	4.6
Pikes Crossing	3313	-	42.79	45:00	92019	3.6
QR Rail Bridge	8050	19.0	37.22	47:30	39157	2.1
Bruce Hwy Road Bridge	10646	13.28	36.56	47:36	36769	3.2
John Oxley Bridge	21269	11.47	12.99	49:03	32783	4.0
South Trees – Boyne R. Bifurcate	217722	-	18.43	48:56	33276	1.9
South Trees – Boyne Is. Road Bridge	-	4.8	17.42	49:06	33072	1.8

SUMMARY OF HYDRAULIC ANALYSES – FSL 55

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 55 - 6hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	26.25	12:00	13391	2.7
Pikes Crossing	3313	-	23.21	13:06	13275	1.6
QR Rail Bridge	8050	19.0	18.96	16:00	9287	2.4
Bruce Hwy Road Bridge	10646	13.28	18.19	16:20	9111	1.9
John Oxley Bridge	21269	11.47	6.38	18:20	6971	2.7
South Trees – Boyne R. Bifurcate	217722	-	9.77	18:13	5314	1.9
South Trees – Boyne Is. Road Bridge	-	4.8	8.28	18:53	5290	1.4
FSL 55 - 12hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	28.92	16:13	17945	2.7
Pikes Crossing	3313	-	25.52	17:13	17804	1.7
QR Rail Bridge	8050	19.0	21.28	19:26	11056	2.4
Bruce Hwy Road Bridge	10646	13.28	20.59	19:53	10930	1.9
John Oxley Bridge	21269	11.47	7.25	21:46	9079	2.9
South Trees – Boyne R. Bifurcate	217722	-	10.93	21:33	7671	1.9
South Trees – Boyne Is. Road Bridge	-	4.8	9.63	22:06	7648	1.4

SUMMARY OF HYDRAULIC ANALYSES – FSL 55

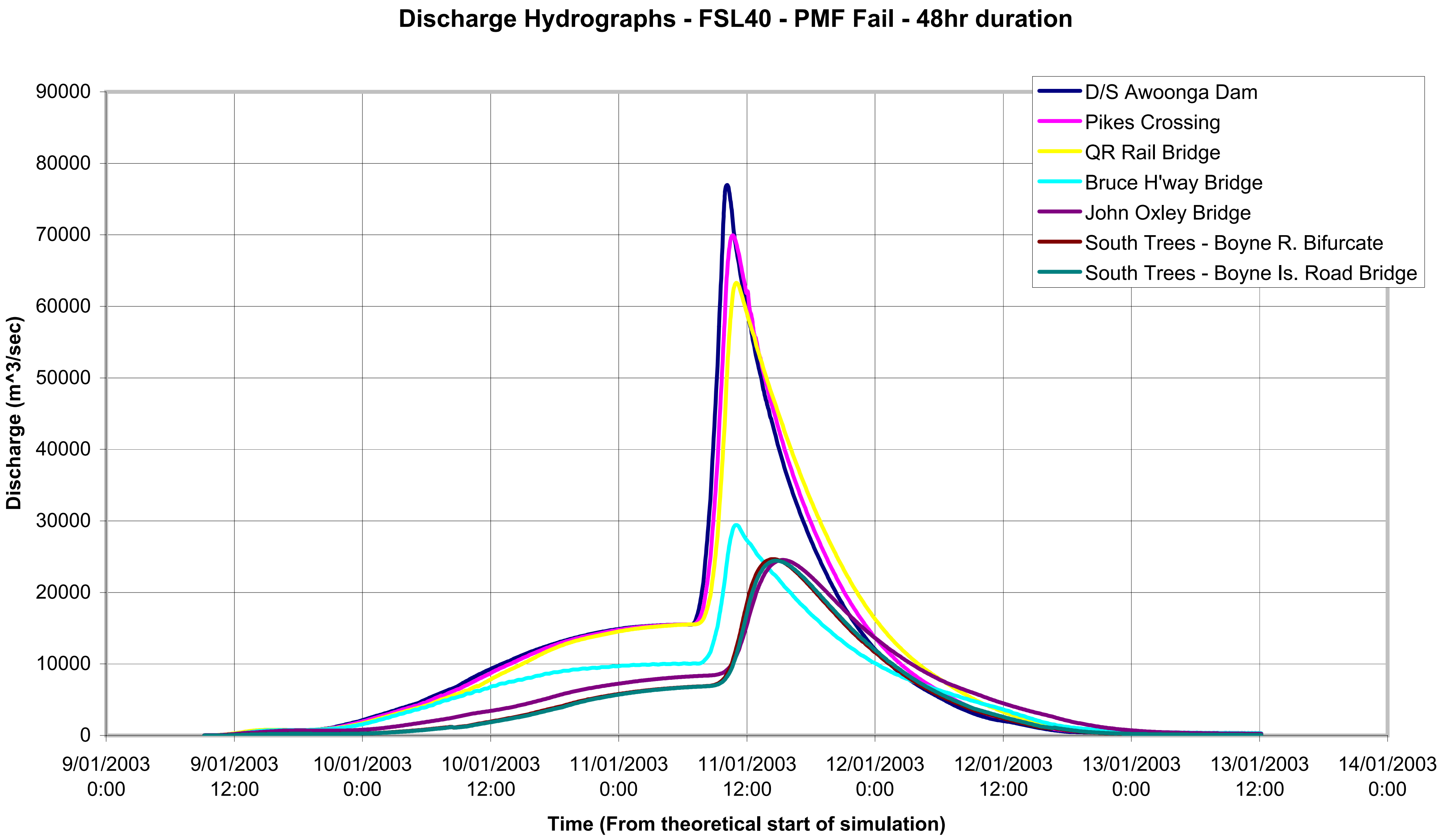
Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 55 - 24hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	29.83	25:00	19405	2.7
Pikes Crossing	3313	-	26.41	25:46	19371	1.7
QR Rail Bridge	8050	19.0	22.25	27:33	19182	2.2
Bruce Hwy Road Bridge	10646	13.28	21.58	27:46	11554	1.8
John Oxley Bridge	21269	11.47	7.65	29:26	10099	3.0
South Trees – Boyne R. Bifurcate	217722	-	11.43	29:20	8748	1.9
South Trees – Boyne Is. Road Bridge	-	4.8	10.19	29:46	8736	1.4
FSL 55 - 48hr PMF No Dam Failure						
D/S Awoonga Dam	817	-	28.67	40:19	17034	2.6
Pikes Crossing	3313	-	25.47	40:53	17091	1.6
QR Rail Bridge	8050	19.0	21.43	42:40	10720	2.1
Bruce Hwy Road Bridge	10646	13.28	20.75	43:13	10712	1.7
John Oxley Bridge	21269	11.47	7.35	45:19	9319	2.9
South Trees – Boyne R. Bifurcate	217722	-	11.05	45:13	7875	1.8
South Trees – Boyne Is. Road Bridge	-	4.8	9.78	45:33	7873	1.3

SUMMARY OF HYDRAULIC ANALYSES – FSL 55

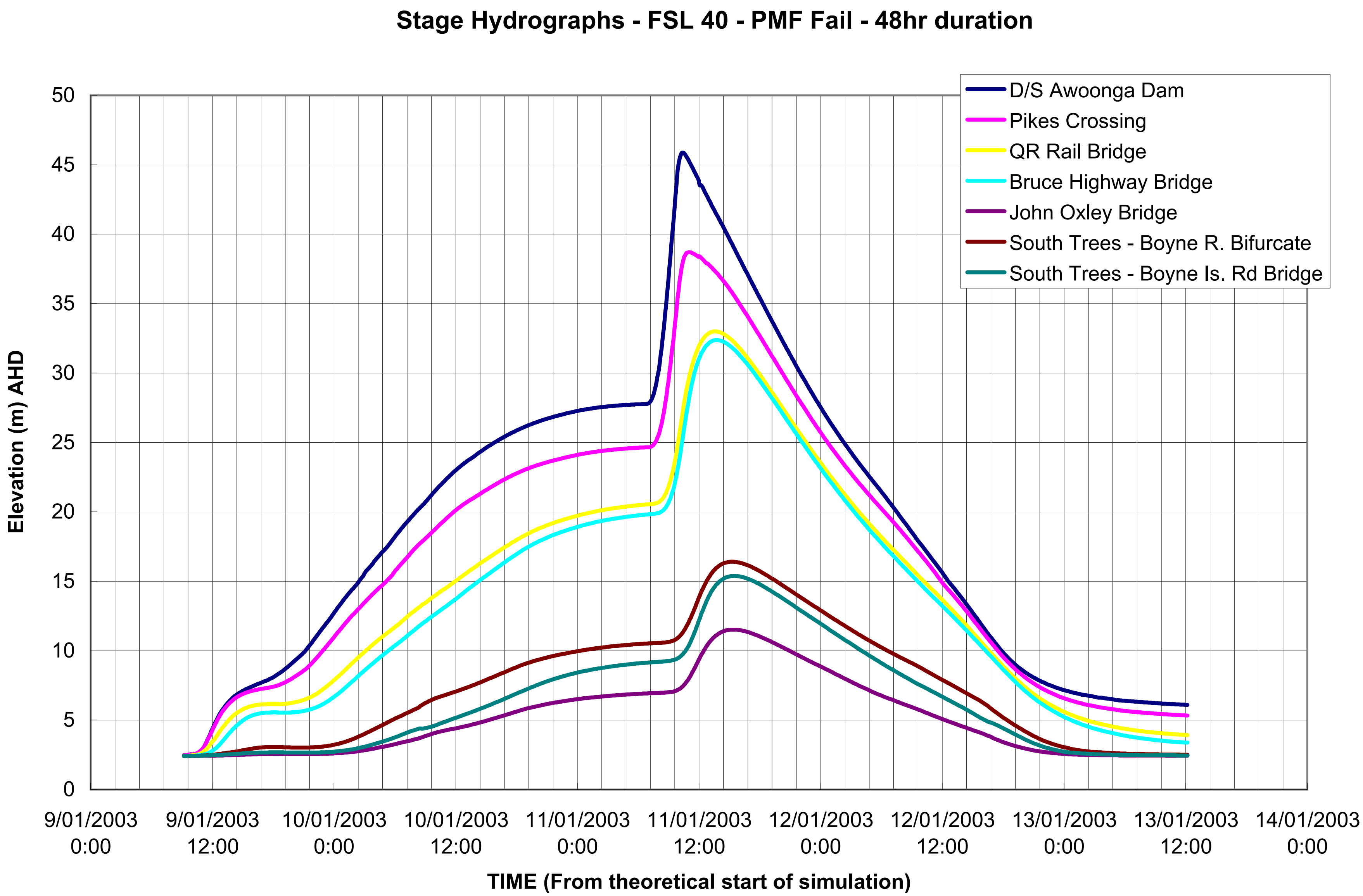
Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level, from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 55 Sunny Day Failure						
D/S Awoonga Dam	817	-	47.31	5:00	85724	4.4
Pikes Crossing	3313	-	39.56	5:50	75685	3.3
QR Rail Bridge	8050	19.0	32.88	8:19	36412	2.7
Bruce Hwy Road Bridge	10646	13.28	32.24	9:10	34231	4.1
John Oxley Bridge	21269	11.47	11.45	10:49	24206	3.7
South Trees – Boyne R. Bifurcate	217722	-	16.31	10:49	24587	2.0
South Trees – Boyne Is. Road Bridge	-	4.8	15.30	10:49	24318	1.9

APPENDIX 4

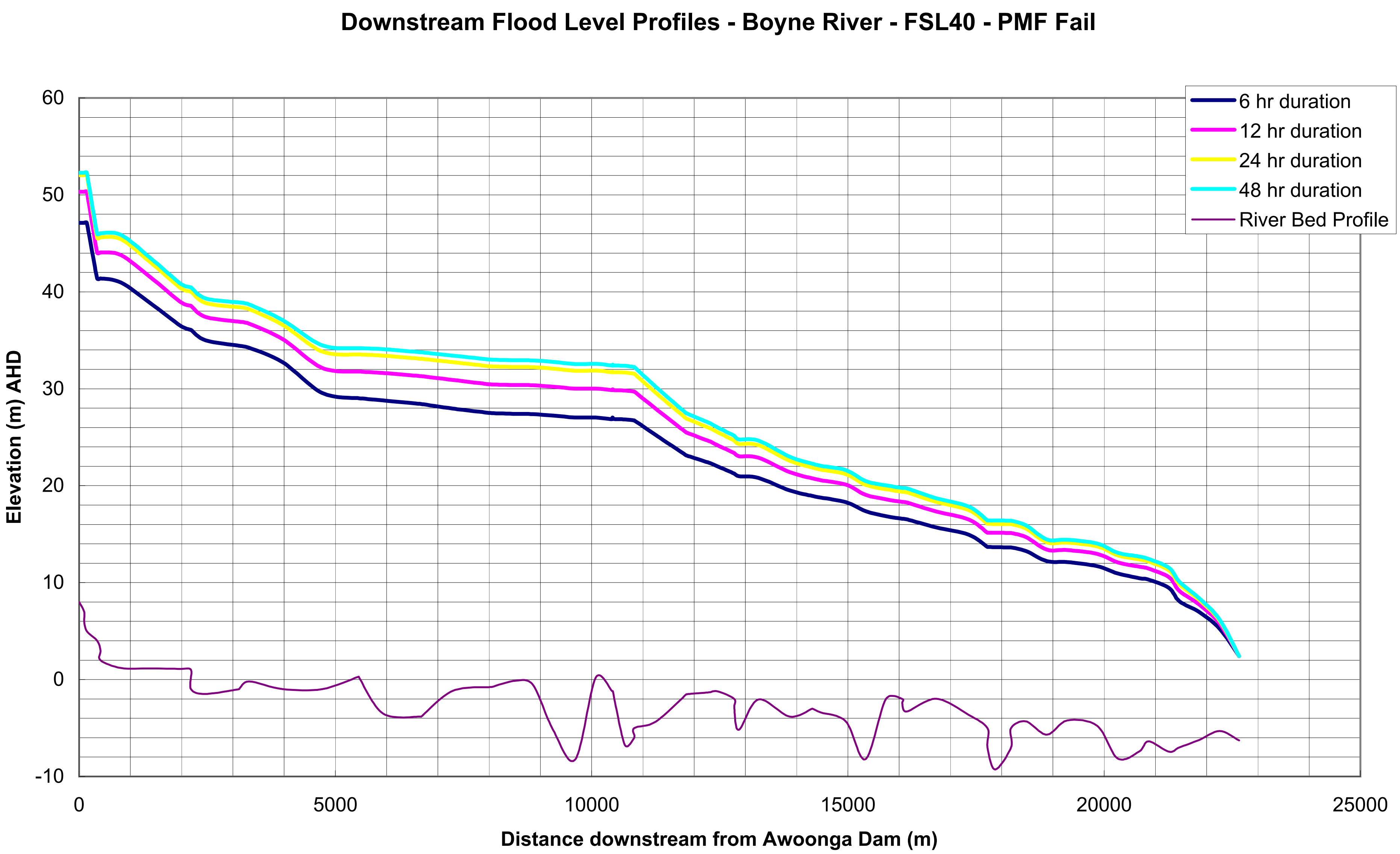
FSL 40 Discharge Hydrograph
Stage Hydrograph
Downstream Flood Profile
Maximum Flood Lines



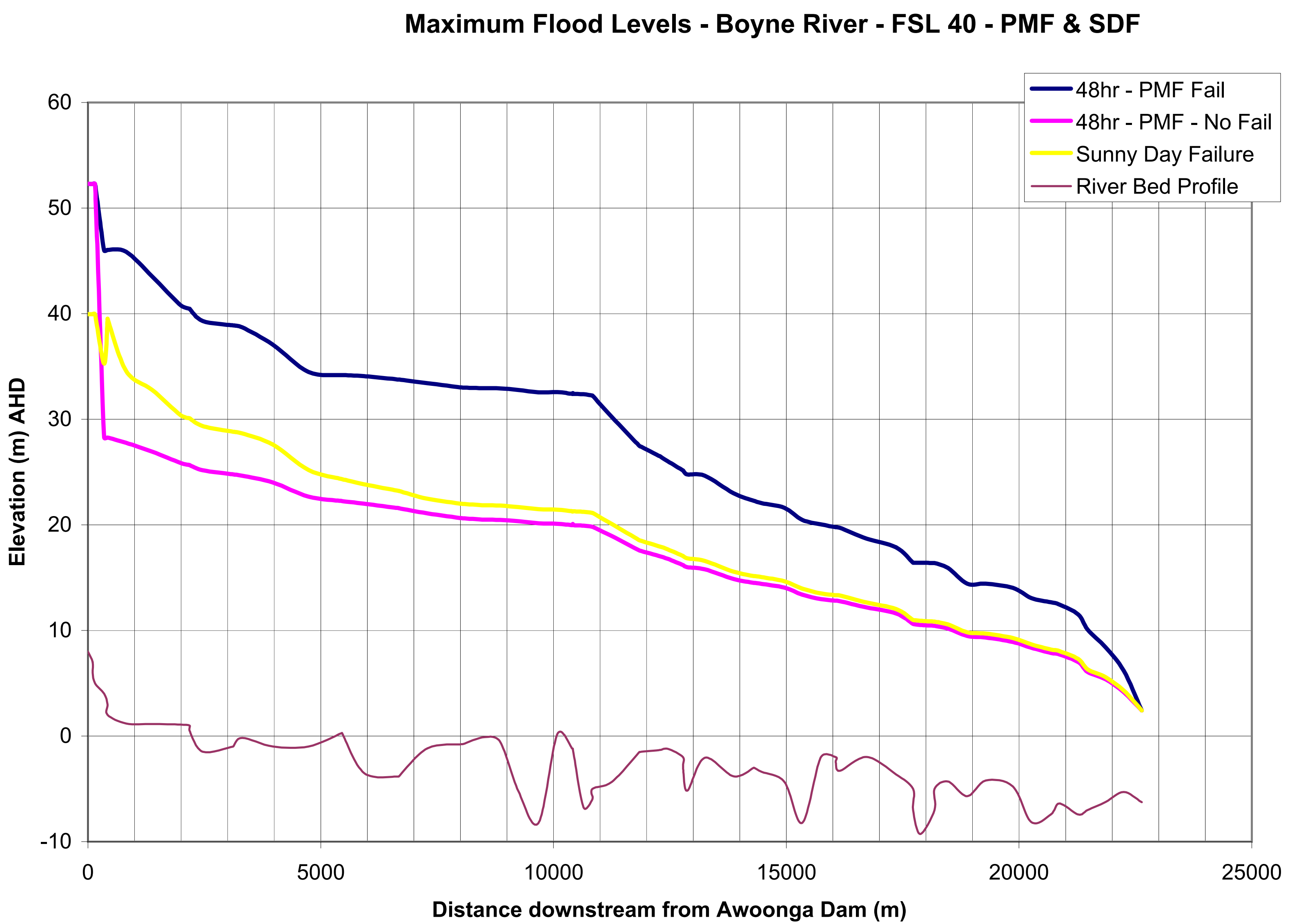
Appendix 4 Fig. 1



Appendix 4 Fig. 2



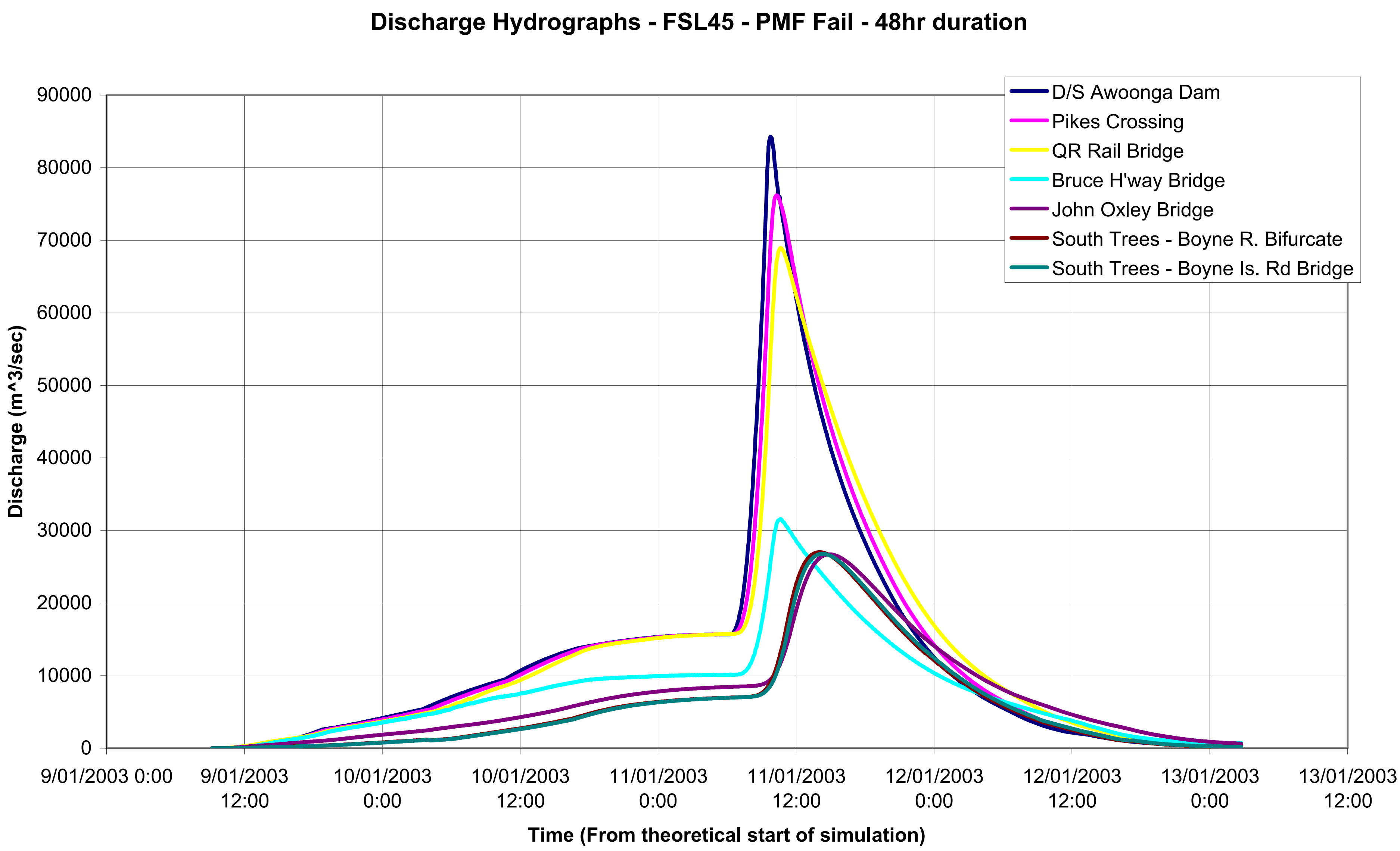
Appendix 4 Fig 3



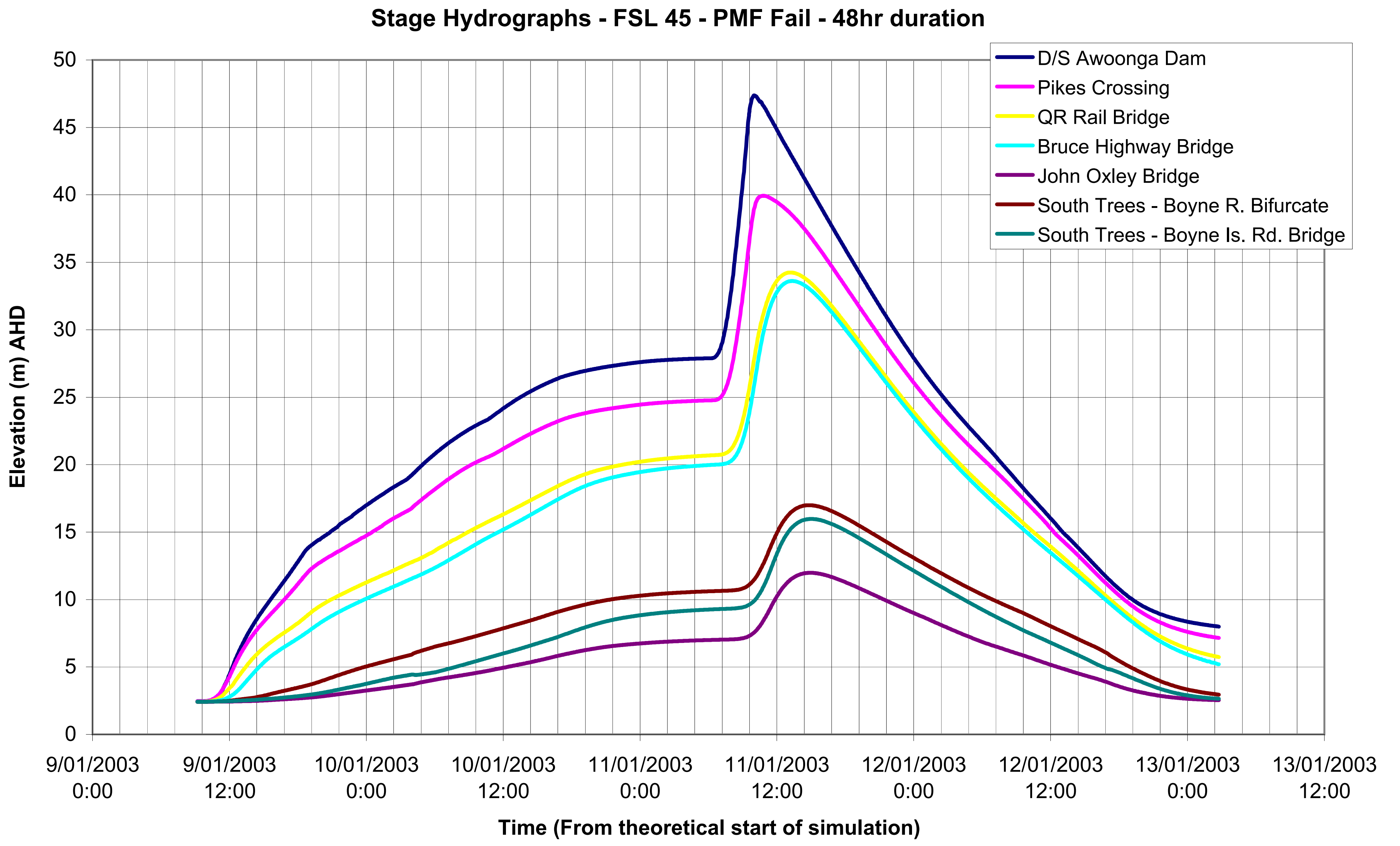
Appendix 4 Fig 4.

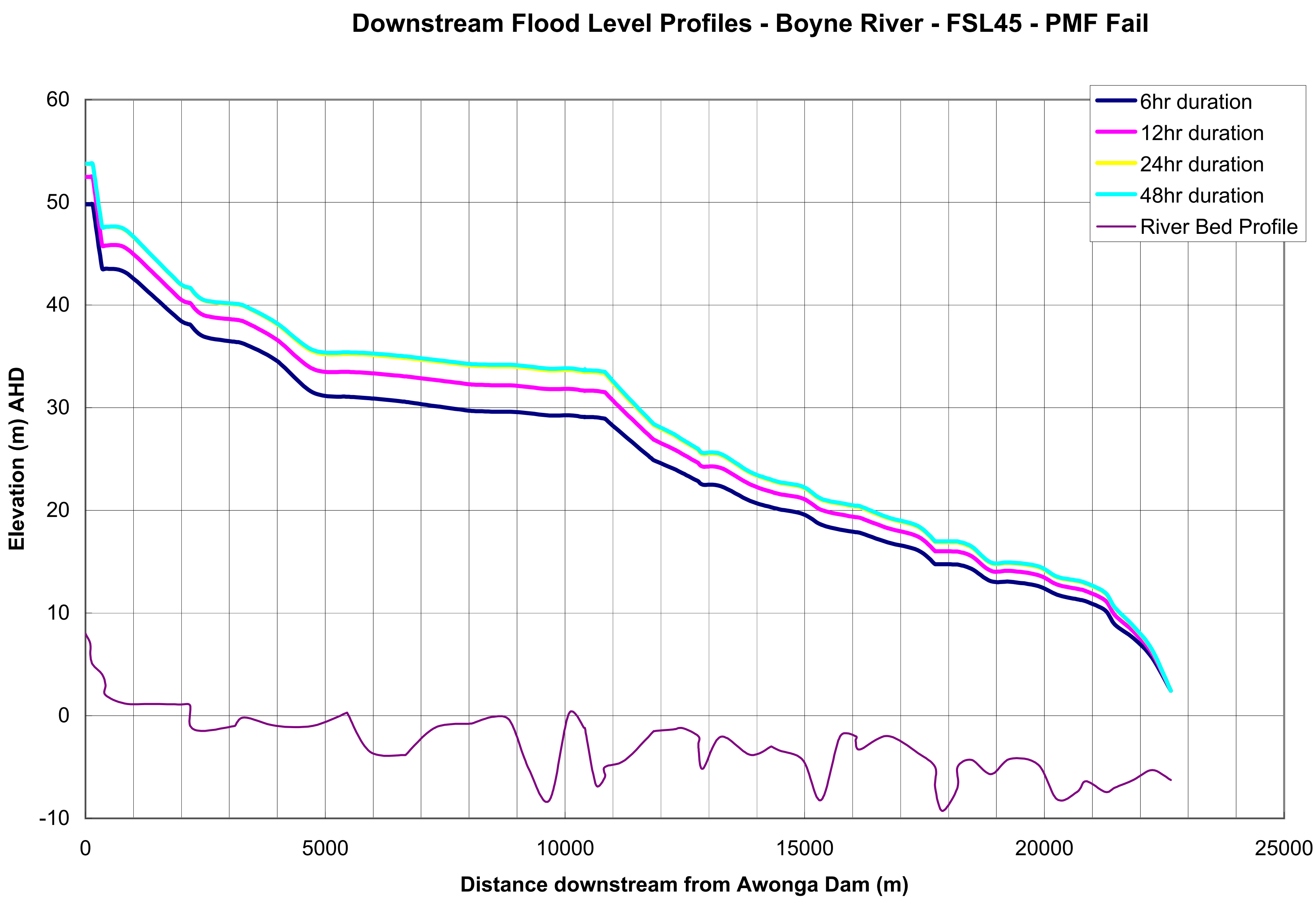
APPENDIX 5

FSL 45 Discharge Hydrograph
Stage Hydrograph
Downstream Flood Profile
Maximum Flood Lines

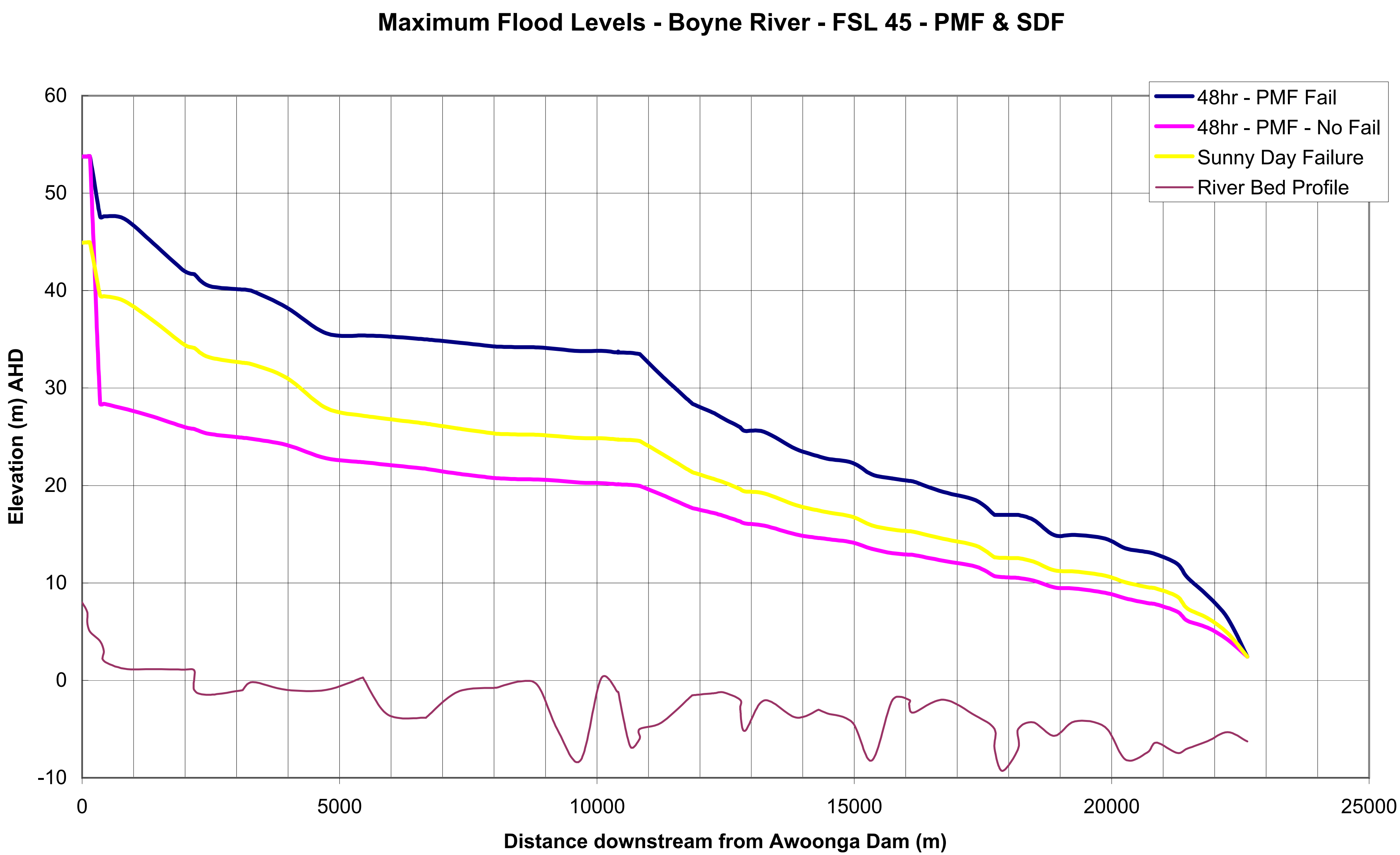


Appendix 5 Fig 1


Stage Hydrographs - FSL 45 - PMF Fail - 48hr duration
D/S Awoonga Dam
Pikes Crossing
QR Rail Bridge
Bruce Highway Bridge
John Oxley Bridge
South Trees - Boyne R. Bifurcate
South Trees - Boyne Is. Rd. Bridge
Elevation (m) AHD
50
45
40
35
30
25
20
15
10
5
0
9/01/2003 0:00
9/01/2003 12:00
10/01/2003 0:00
10/01/2003 12:00
11/01/2003 0:00
11/01/2003 12:00
12/01/2003 0:00
12/01/2003 12:00
13/01/2003 0:00
13/01/2003 12:00
Time (From theoretical start of simulation)



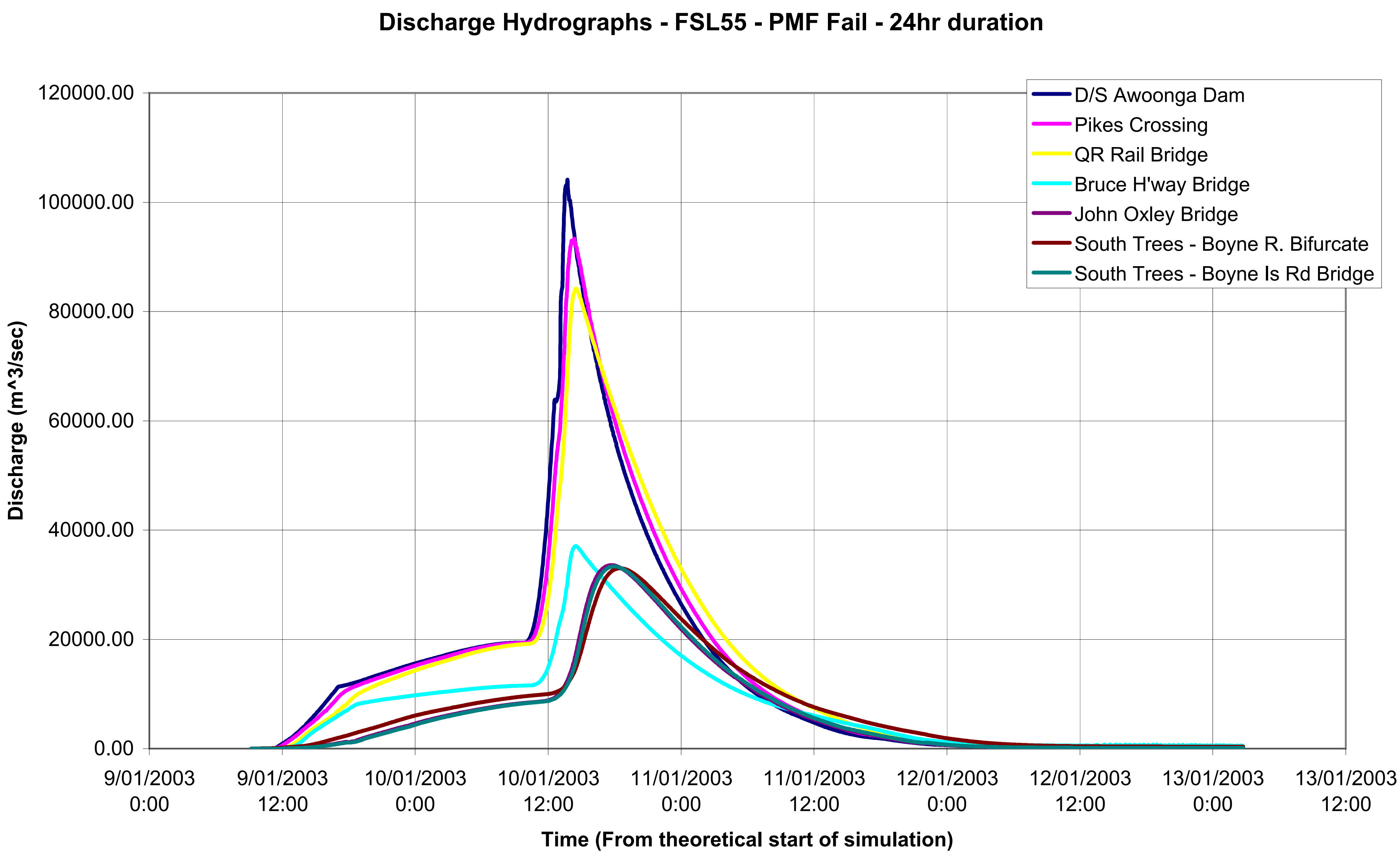
Downstream Flood Level Profiles - Boyne River - FSL45 - PMF Fail
Elevation (m) AHD
60
50
40
30
20
10
0
-10
0
5000
10000
15000
20000
25000
Distance downstream from Awonga Dam (m)
6hr duration
12hr duration
24hr duration
48hr duration
River Bed Profile

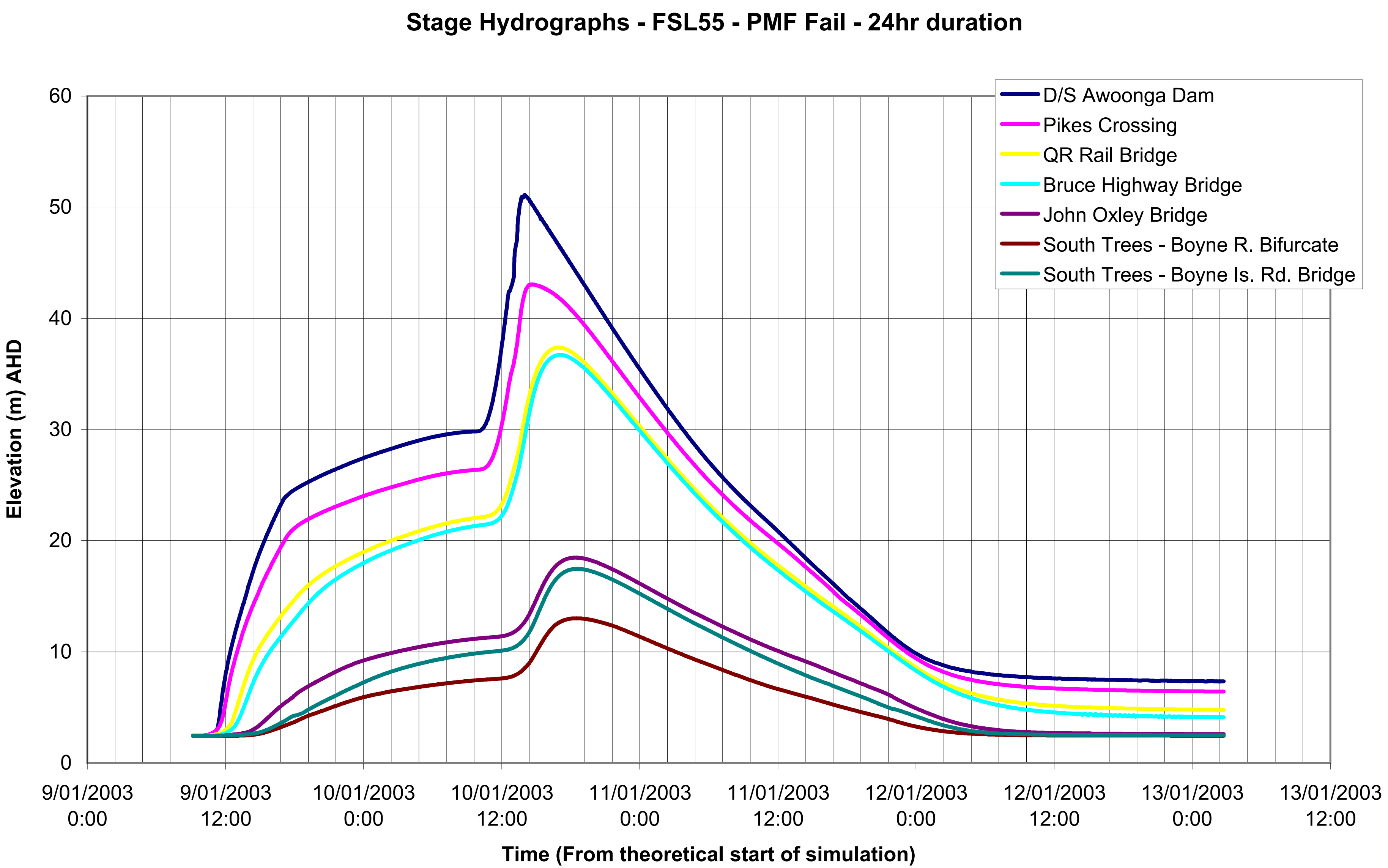


Appendix 5 Fig 4

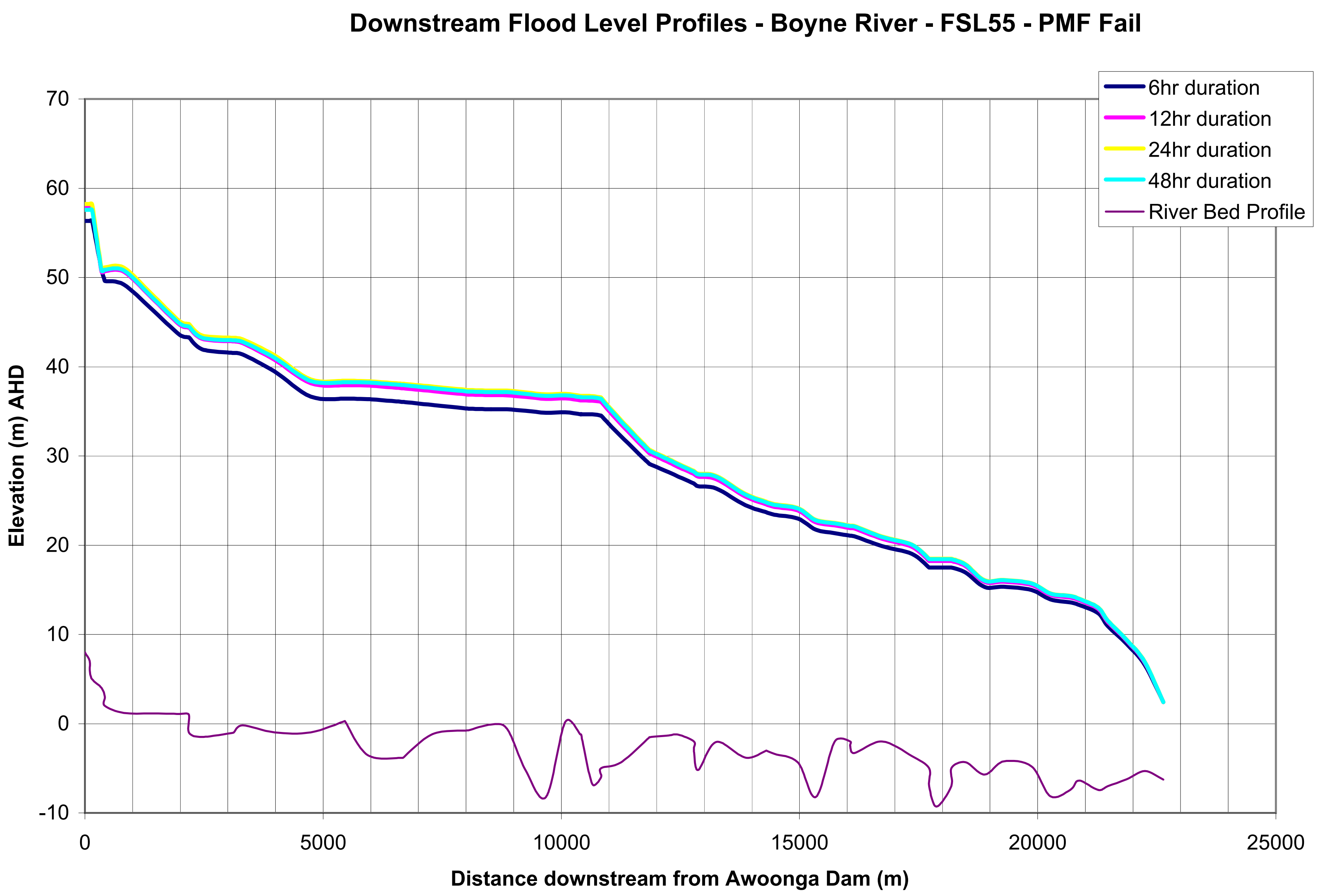
APPENDIX 6

FSL 55 Discharge Hydrograph
Stage Hydrograph
Downstream Flood Profile
Maximum Flood Lines

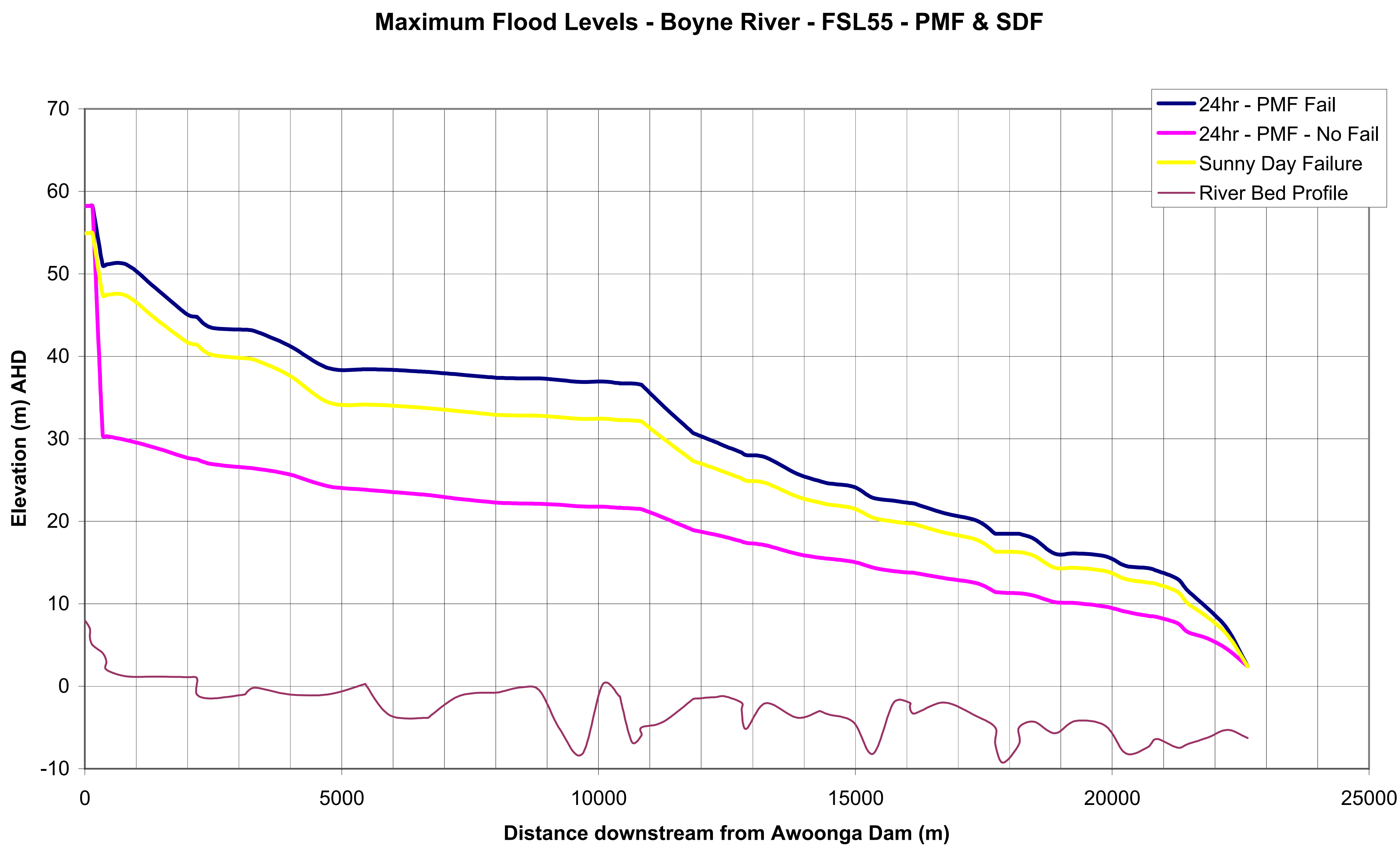

Discharge Hydrographs - FSL55 - PMF Fail - 24hr duration
Discharge (m^3/sec)
120000.00
100000.00
80000.00
60000.00
40000.00
20000.00
0.00
9/01/2003 0:00
9/01/2003 12:00
10/01/2003 0:00
10/01/2003 12:00
11/01/2003 0:00
11/01/2003 12:00
12/01/2003 0:00
12/01/2003 12:00
13/01/2003 0:00
13/01/2003 12:00
Time (From theoretical start of simulation)
D/S Awoonga Dam
Pikes Crossing
QR Rail Bridge
Bruce H'way Bridge
John Oxley Bridge
South Trees - Boyne R. Bifurcate
South Trees - Boyne Is Rd Bridge



Appendix 6 Fig 2



Downstream Flood Level Profiles - Boyne River - FSL55 - PMF Fail
6hr duration
12hr duration
24hr duration
48hr duration
River Bed Profile
Elevation (m) AHD
70
60
50
40
30
20
10
0
-10
0
5000
10000
15000
20000
25000
Distance downstream from Awoonga Dam (m)



Maximum Flood Levels - Boyne River - FSL55 - PMF & SDF
24hr - PMF Fail
24hr - PMF - No Fail
Sunny Day Failure
River Bed Profile
Elevation (m) AHD
70
60
50
40
30
20
10
0
-10
0
5000
10000
15000
20000
25000
Distance downstream from Awoonga Dam (m)

APPENDIX 7

SUMMARY OF HYDRAULIC ANALYSES - 1 in 100 AEP

SUMMARY OF HYDRAULIC ANALYSES – 1 in 100 AEP

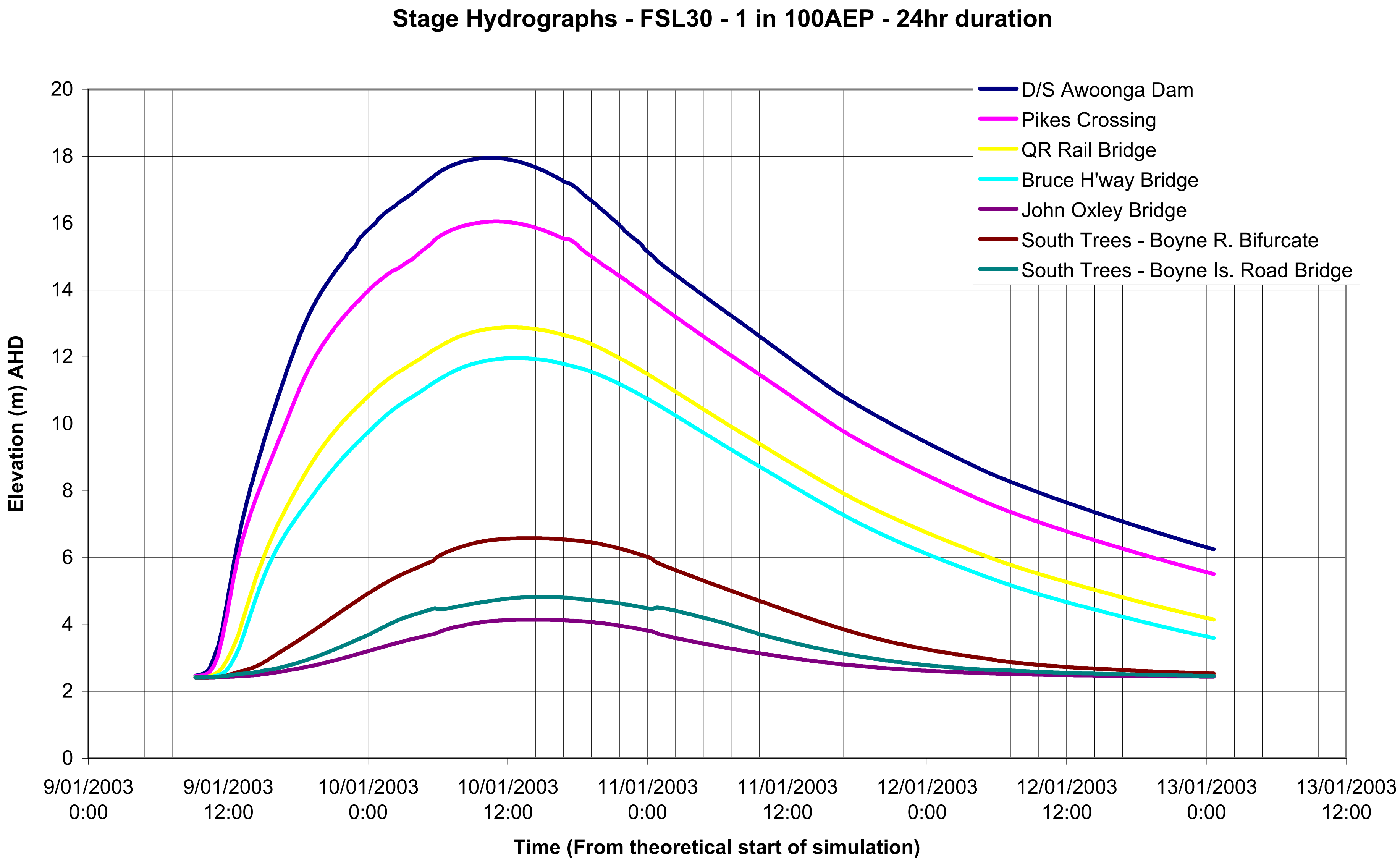
Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 30 – 24hr duration						
D/S Awoonga Dam	817	-	17.96	25:20	4383	2.0
Pikes Crossing	3313	-	16.06	26:00	4418	1.1
QR Rail Bridge	8050	19.0	12.93	27:13	4308	1.7
Bruce Hwy Road Bridge	10646	13.28	11.97	27:35	4303	1.2
John Oxley Bridge	21269	11.47	4.52	29:28	3017	1.7
South Trees – Boyne R. Bifurcate	217722	-	6.68	29:00	1388	1.7
South Trees – Boyne Is. Road Bridge	-	4.8	4.82	30:00	1385	1.2
FSL 40 – 48hr duration						
D/S Awoonga Dam	817	-	14.56	46:30	2640	1.6
Pikes Crossing	3313	-	13.16	46:40	2693	0.9
QR Rail Bridge	8050	19.0	10.61	47:30	2770	1.4
Bruce Hwy Road Bridge	10646	13.28	9.73	48:40	2579	0.9
John Oxley Bridge	21269	11.47	3.51	49:30	1994	1.4
South Trees – Boyne R. Bifurcate	217722	-	5.24	49:20	795	1.5
South Trees – Boyne Is. Road Bridge	-	4.8	3.93	50:00	793	0.9

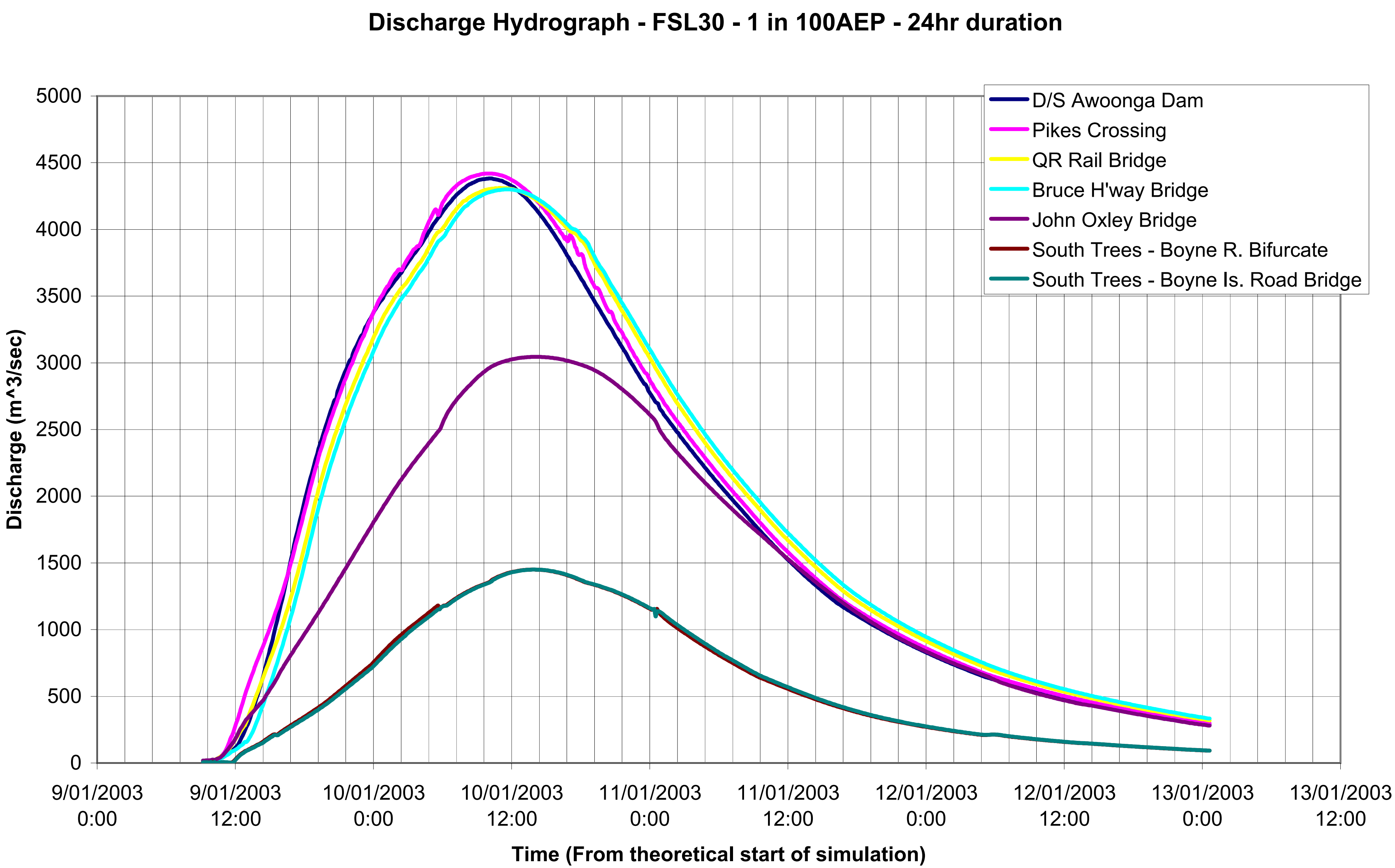
SUMMARY OF HYDRAULIC ANALYSES – 1 in 100 AEP

Location	Section Distance Downstream (m)	Elevation (m)	Maximum Water Level (m)	Time to Max Water Level from start of simulation(hrs:min)	Maximum Discharge (m^3/sec)	Maximum Velocity (m/sec)
FSL 45 - 24hr duration						
D/S Awoonga Dam	817	-	16.58	25:00	3570	1.8
Pikes Crossing	3313	-	14.79	25:20	3615	1.0
QR Rail Bridge	8050	19.0	12.04	25:30	3622	1.6
Bruce Hwy Road Bridge	10646	13.28	11.16	25:00	3606	1.1
John Oxley Bridge	21269	11.47	4.14	26:10	2654	1.6
South Trees – Boyne R. Bifurcate	217722	-	6.20	25:50	1123	1.7
South Trees – Boyne Is. Road Bridge	-	4.8	4.49	26:30	1117	1.1
FSL 55- 12hr duration						
D/S Awoonga Dam	817	-	22.33	12:30	8182	2.35
Pikes Crossing	3313	-	19.90	13:25	7708	1.31
QR Rail Bridge	8050	19.0	15.63	14:00	6121	1.78
Bruce Hwy Road Bridge	10646	13.28	14.09	16:15	6139	1.54
John Oxley Bridge	21269	11.47	5.72	18:30	4141	1.82
South Trees – Boyne R. Bifurcate	217722	-	7.94	18:25	2243	1.75
South Trees – Boyne Is. Road Bridge	-	4.8	5.58	19:30	2330	1.24

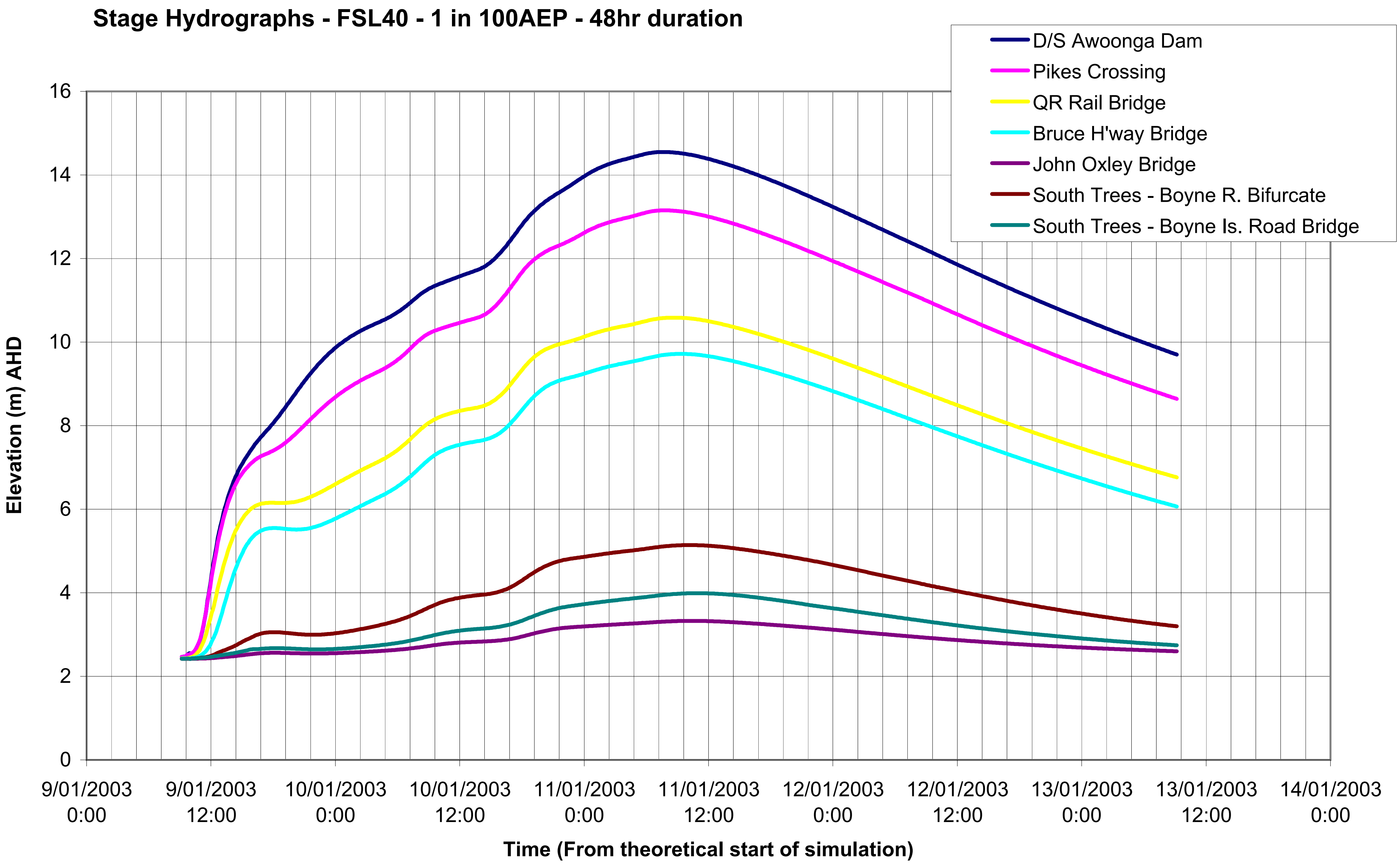
APPENDIX 8

1 in 100 AEP	FSL 30	Stage Hydrograph
		Discharge Hydrograph
	FSL 40	Stage Hydrograph
		Discharge Hydrograph
	FSL 45	Stage Hydrograph
		Discharge Hydrograph
	FSL 55	Stage Hydrograph
		Discharge Hydrograph

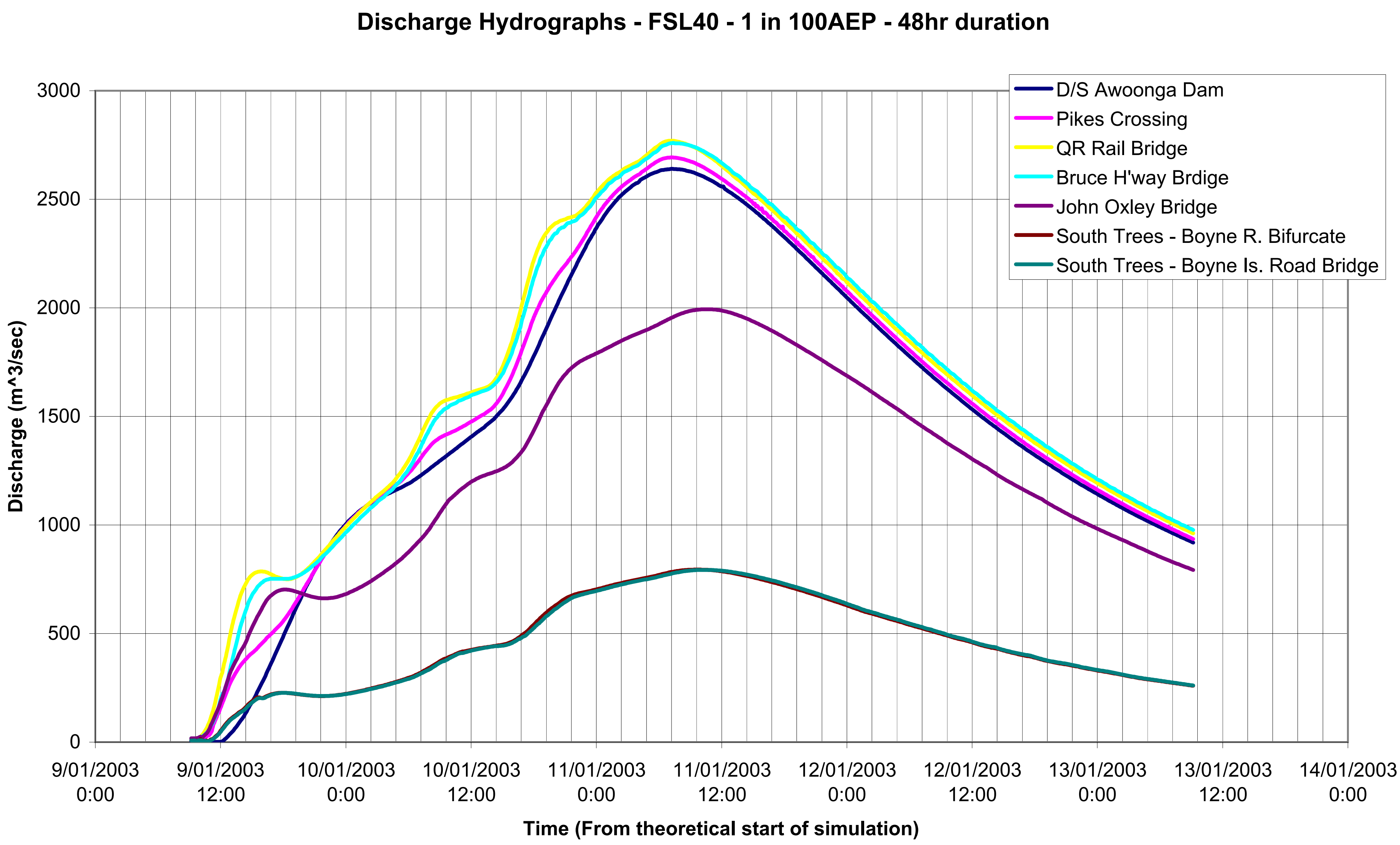

Stage Hydrographs - FSL30 - 1 in 100AEP - 24hr duration
D/S Awoonga Dam
Pikes Crossing
QR Rail Bridge
Bruce H'way Bridge
John Oxley Bridge
South Trees - Boyne R. Bifurcate
South Trees - Boyne Is. Road Bridge
Elevation (m) AHD
20
18
16
14
12
10
8
6
4
2
0
9/01/2003 0:00
9/01/2003 12:00
10/01/2003 0:00
10/01/2003 12:00
11/01/2003 0:00
11/01/2003 12:00
12/01/2003 0:00
12/01/2003 12:00
13/01/2003 0:00
13/01/2003 12:00
Time (From theoretical start of simulation)



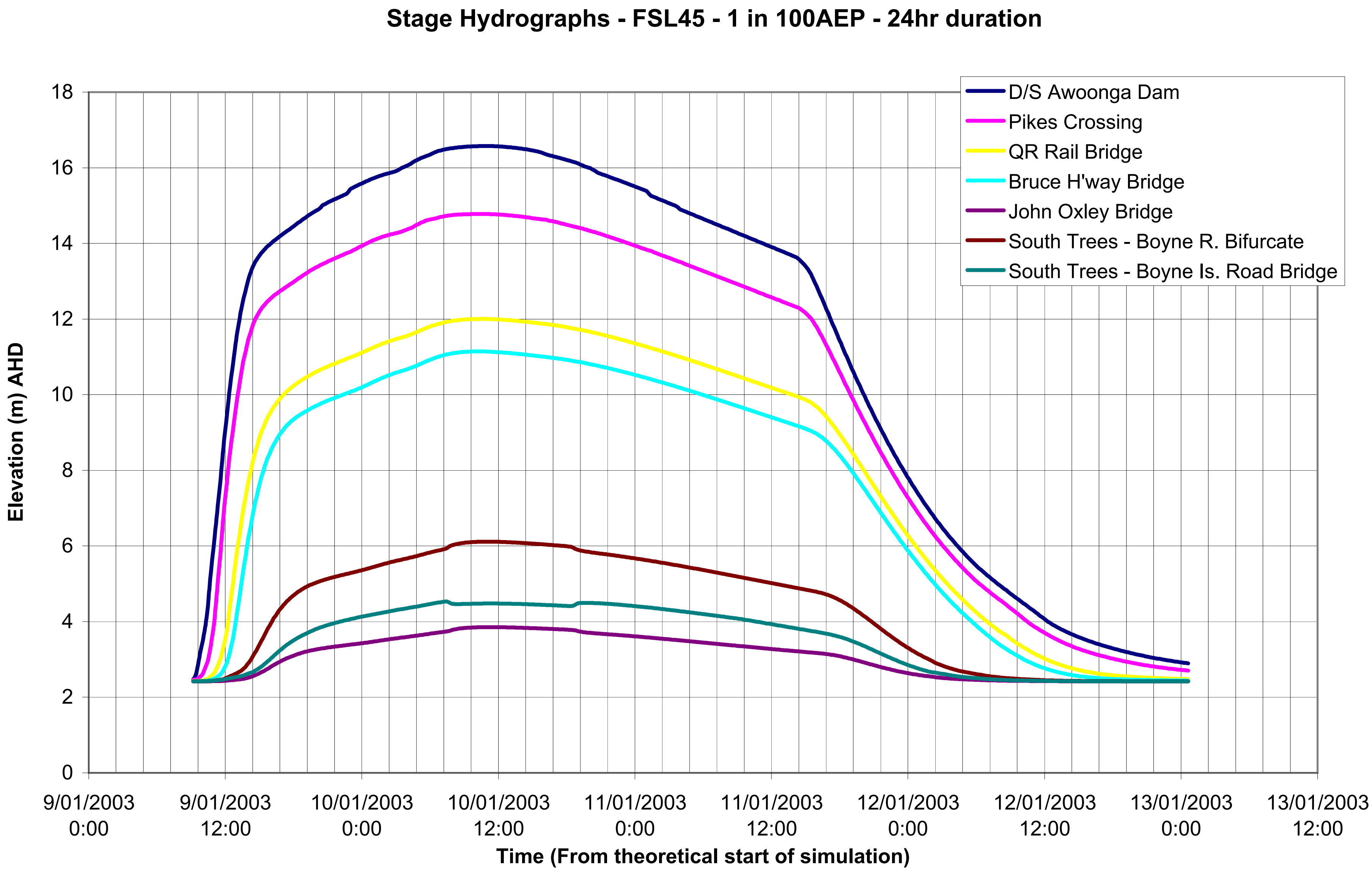
Appendix 8 Fig 2

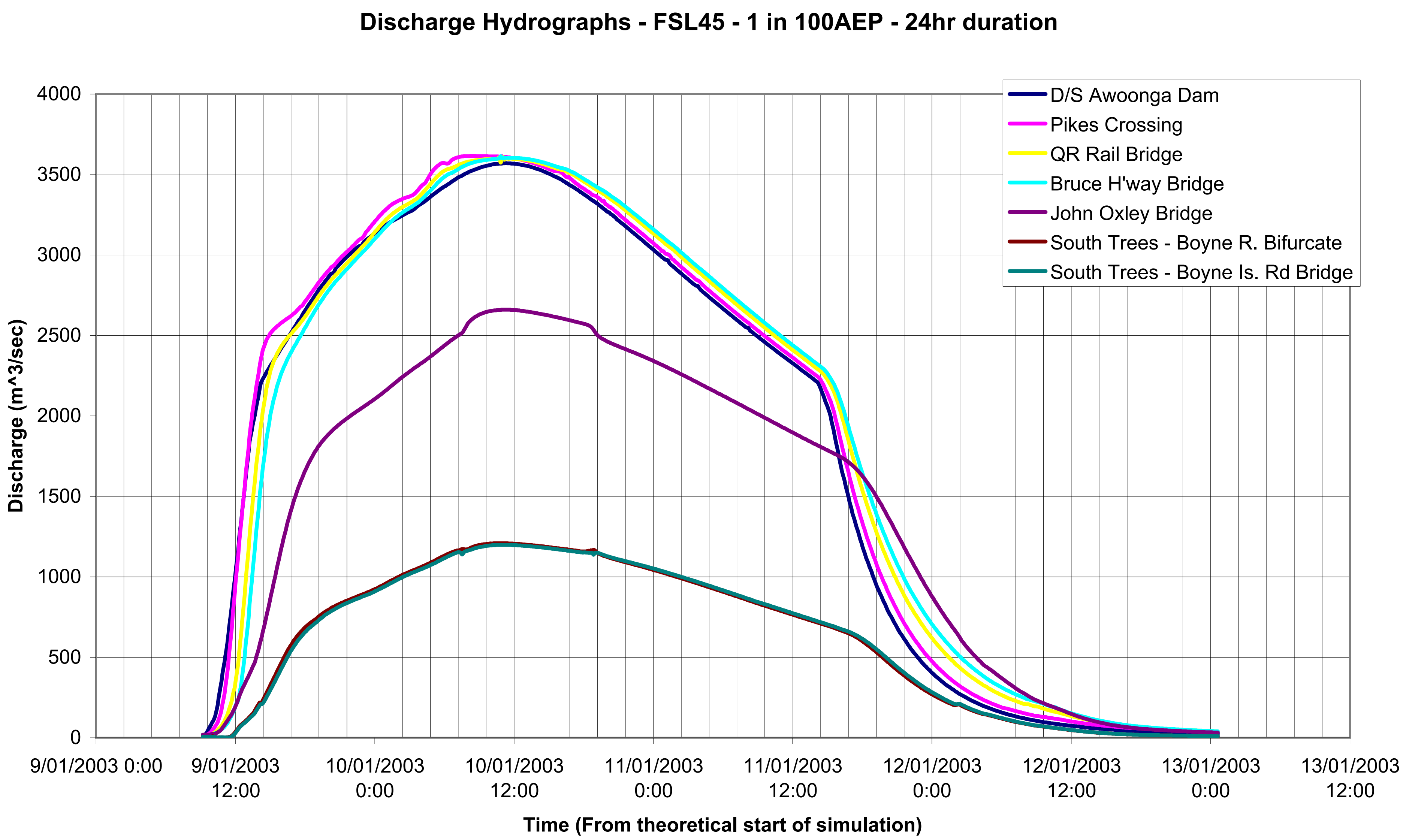


Stage Hydrographs - FSL40 - 1 in 100AEP - 48hr duration
D/S Awoonga Dam
Pikes Crossing
QR Rail Bridge
Bruce H'way Bridge
John Oxley Bridge
South Trees - Boyne R. Bifurcate
South Trees - Boyne Is. Road Bridge
Elevation (m) AHD
0
2
4
6
8
10
12
14
16
9/01/2003 0:00
9/01/2003 12:00
10/01/2003 0:00
10/01/2003 12:00
11/01/2003 0:00
11/01/2003 12:00
12/01/2003 0:00
12/01/2003 12:00
13/01/2003 0:00
13/01/2003 12:00
14/01/2003 0:00
Time (From theoretical start of simulation)

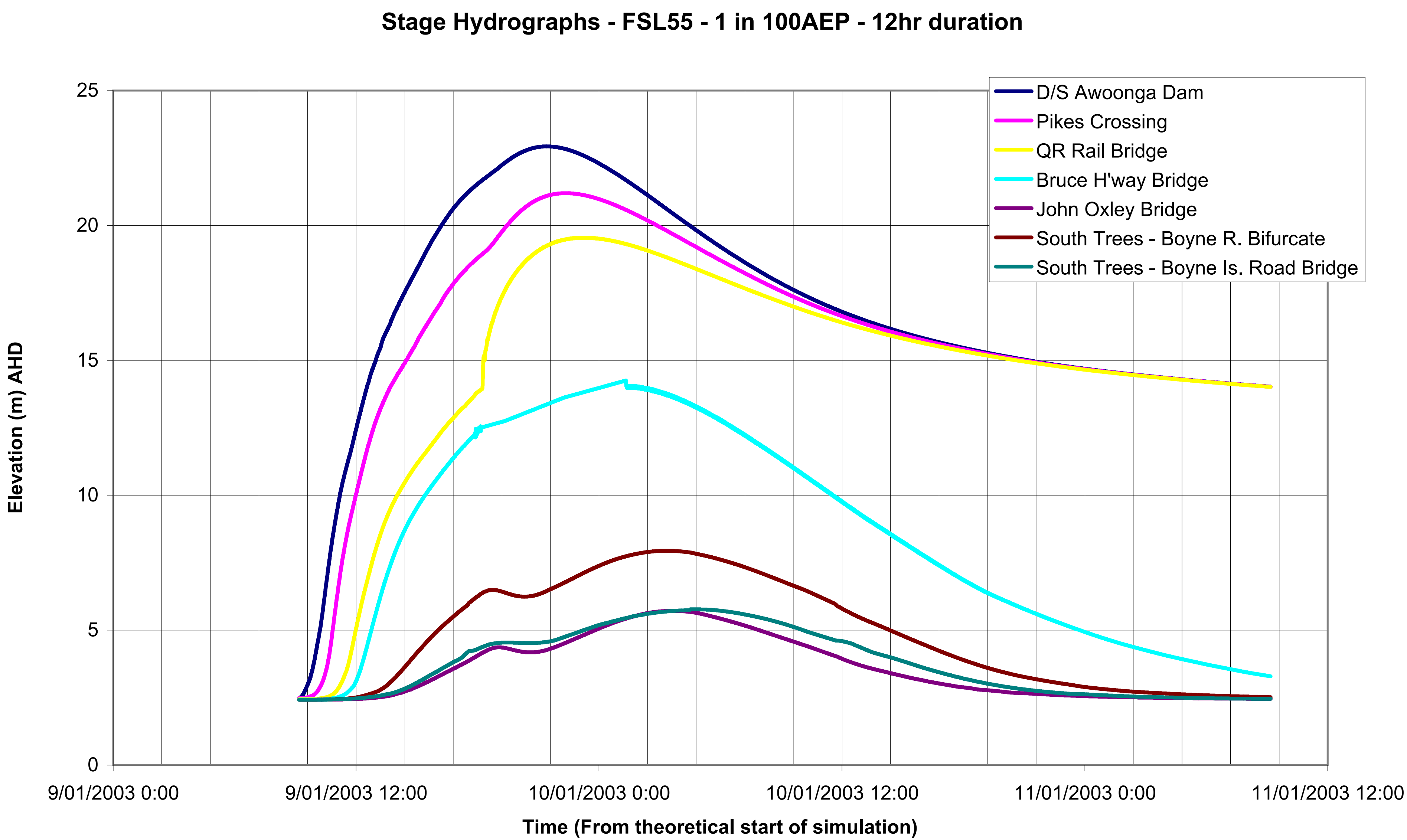


Discharge Hydrographs - FSL40 - 1 in 100AEP - 48hr duration
Discharge (m^3/sec)
3000
2500
2000
1500
1000
500
0
9/01/2003 0:00
9/01/2003 12:00
10/01/2003 0:00
10/01/2003 12:00
11/01/2003 0:00
11/01/2003 12:00
12/01/2003 0:00
12/01/2003 12:00
13/01/2003 0:00
13/01/2003 12:00
14/01/2003 0:00
Time (From theoretical start of simulation)
D/S Awoonga Dam
Pikes Crossing
QR Rail Bridge
Bruce H'way Brdige
John Oxley Bridge
South Trees - Boyne R. Bifurcate
South Trees - Boyne Is. Road Bridge

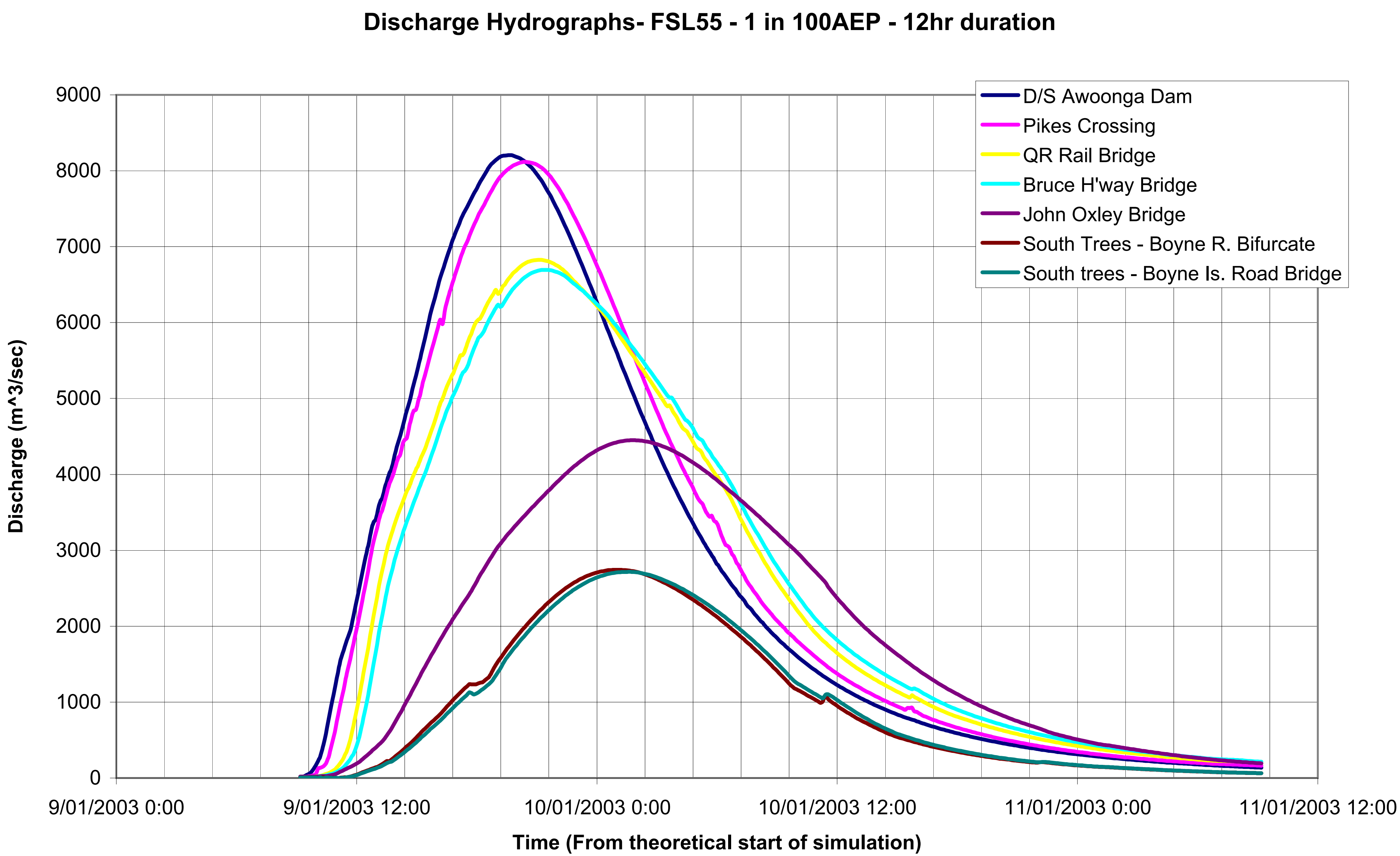

Stage Hydrographs - FSL45 - 1 in 100AEP - 24hr duration
Elevation (m) AHD
Time (From theoretical start of simulation)
0
2
4
6
8
10
12
14
16
18
9/01/2003 0:00
9/01/2003 12:00
10/01/2003 0:00
10/01/2003 12:00
11/01/2003 0:00
11/01/2003 12:00
12/01/2003 0:00
12/01/2003 12:00
13/01/2003 0:00
13/01/2003 12:00
D/S Awoonga Dam
Pikes Crossing
QR Rail Bridge
Bruce H'way Bridge
John Oxley Bridge
South Trees - Boyne R. Bifurcate
South Trees - Boyne Is. Road Bridge



Appendix 8 Fig 6



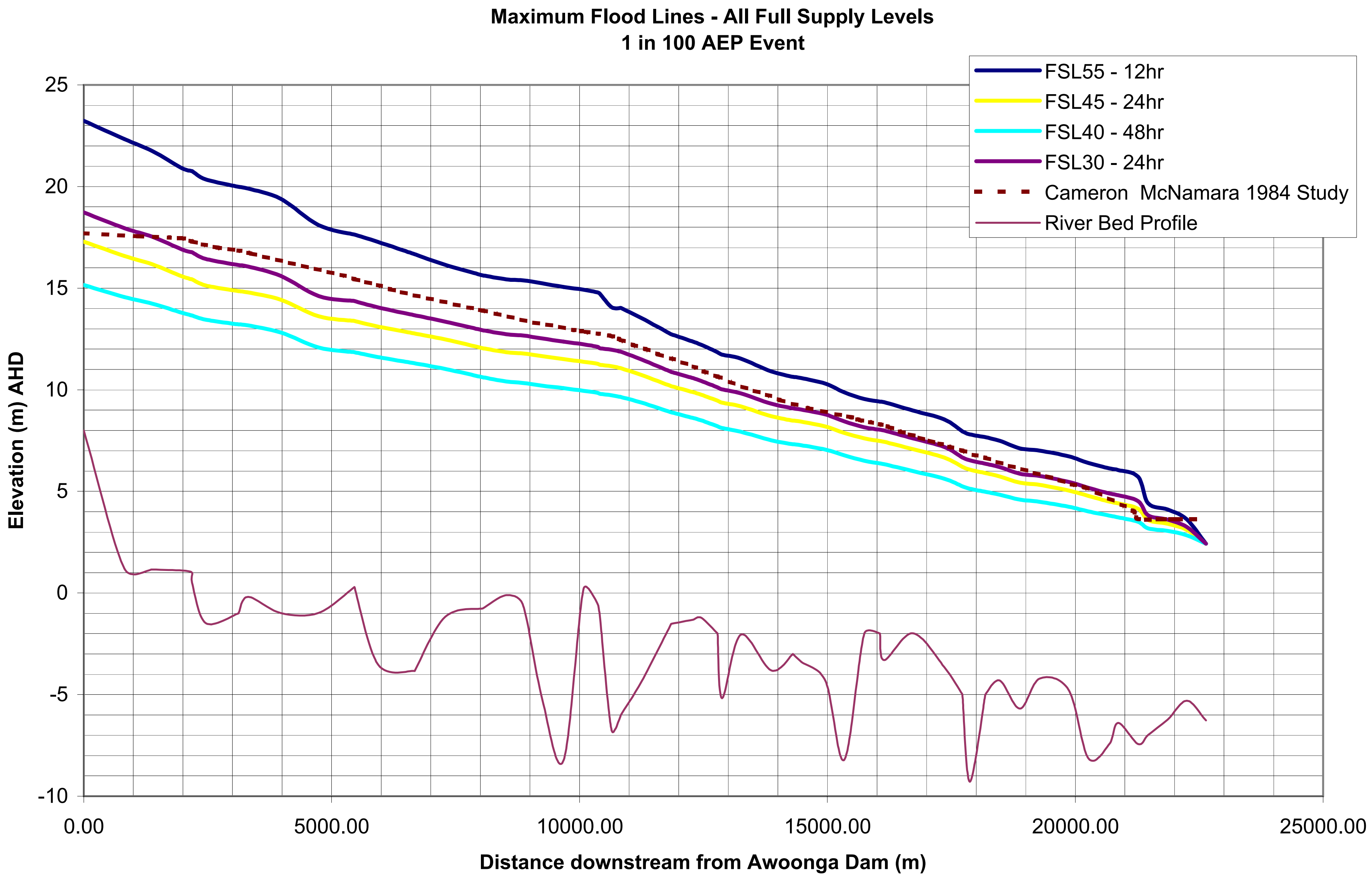
Appendix 8 Fig 7



Appendix 8 Fig 8

APPENDIX 9

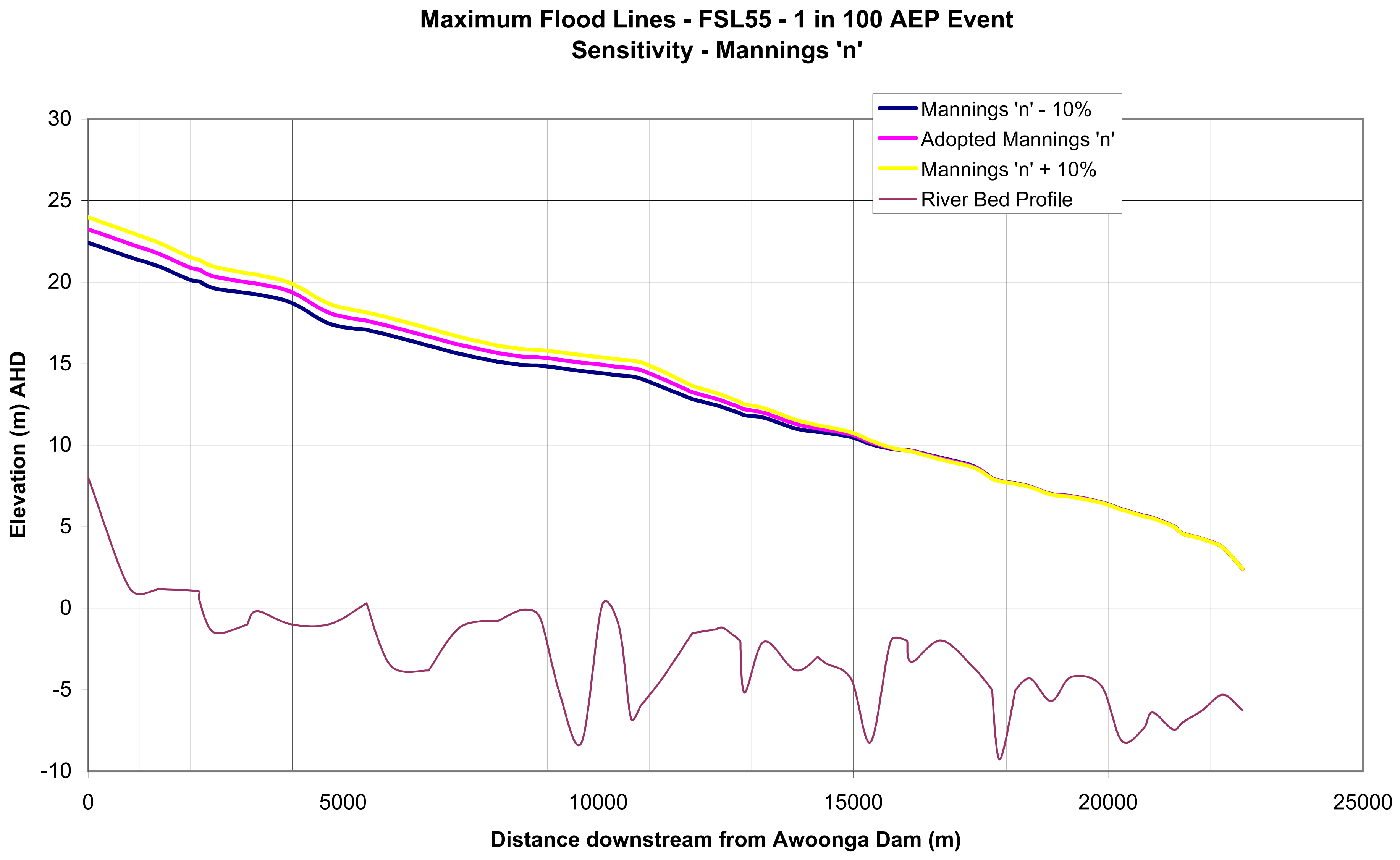
1 in 100 AEP – Maximum Flood Lines



Appendix 9 Fig 1

APPENDIX 10

1 in 100 AEP – Maximum Flood Lines Sensitivity Analysis



Appendix 10 Fig 1