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Milestone Report 4: Fast Model Results and Design Events Selection

Comprehensive Hydraulic Assessment

Brisbane River Catchment Flood Study

DRAFT FINAL

Prepared for the State of Queensland

August 2016

Comprehensive Hydraulic Assessment
as part of the
Brisbane River Catchment Flood Study

Milestone Report 4:
Fast Model Results and Design Events Selection

Prepared for:	State of Queensland
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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- Department of Infrastructure, Local Government and Planning (Client)
- Department of Natural Resources and Mines (Project Manager on behalf of Client)
- Department of Science, Information Technology and Innovation
- Department of Energy and Water Supply
- Seqwater
- Brisbane City Council
- Ipswich City Council
- Somerset Regional Council
- Lockyer Valley Regional Council
- Bureau of Meteorology
- Queensland Reconstruction Authority (post June 2016).

Executive Summary

The State of Queensland, acting through the Department of Infrastructure, Local Government and Planning (DILGP) (formerly Department of State Development, Infrastructure and Planning, DILGP), and project managed through the Department of Natural Resources and Mines, is undertaking a Comprehensive Hydraulic Assessment (this assessment) to deliver a fully calibrated detailed hydraulic model that accurately defines the flood behaviour of the lower Brisbane River including major tributaries downstream of Wivenhoe Dam. This assessment is a component of a broader framework of the Brisbane River Catchment Floodplain Studies (BRCFS) currently being undertaken by the Queensland Government in response to the Queensland Floods Commission of Inquiry to provide a comprehensive plan to manage Brisbane River flood risk.

This Milestone Report 4: *Fast Model Results* is the fourth[1] in a series of milestone reports to be delivered as part of the BRCFS Hydraulic Assessment. The purpose of this report is to provide details on the:

- Simulation and checking of 11,340[2] Monte Carlo events provided by the Hydrologic Assessment through the Fast Model.
- Undertaking of a level frequency analysis at 28 Reporting Locations to estimate the flood levels for a range of Annual Exceedance Probabilities (AEP) varying from the 1 in 2 (50%) to 1 in 100,000 (0.001%).
- Selection of groups of Monte Carlo events for each AEP (AEP ensembles) that when combined are representative of the AEP levels at the Reporting Locations. These AEP Ensembles are to be used in the Detailed Model for simulating the AEP design floods and producing flood maps.

Key observations and conclusions are:

- The Fast Model simulated all 11,340 events producing estimated peak water levels and flows, and water level and flow hydrographs at the 28 Reporting Locations. The results were checked and in a very small percentage of cases, corrected to remove numerical instabilities. Of the 317,520 sets of outputs (11,340 events times 28 Reporting Locations), 6 peak water levels and 152 peak flows (0.05% of peak flows) were corrected.
- The peak water level and flow frequency analyses used a statistical approach that minimised the bias in the associated expected probabilities. The approach used the exceedance probabilities of total catchment rainfalls as the conditioning variate. Consideration was given to the use of upstream streamflows and local catchment rainfalls as an alternative conditioning variate, though it was found that the results at all but four sites (in the vicinity of Ipswich) were insensitive to the adopted choice. The results obtained using alternative conditioning variates at these four sites were found to be inconsistent with expected hydraulic behaviour and did not adequately reflect the influence of Brisbane River on upstream levels. Accordingly, the results based on the use of total catchment rainfalls were adopted as the best estimate of the required expected probabilities. Estimated AEP flood levels from the Fast Model simulation of the 11,340 events were produced at each of the 28 Reporting Locations.

[1] The first report being BMT WBM (2014) - Milestone Report 1: Data Review and Modelling Methodology, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final - 29 October 2014. The second report being BMT WBM (2015a) - Milestone Report 2: Fast Model Development and Calibration, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final – April 2015, The third report being BMT WBM (2015b) – Milestone Report 3 – Detailed Model Development and Calibration, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final – August 2015.

[2] The Hydrologic Assessment considered 60 AEPs per event duration with 21 simulations performed per AEP. Thus the Hydrology Assessment simulated 1260 Monte Carlo events per duration. For the purpose of the Hydraulic Assessment, nine event durations were required (12 hours to 168 hours), leading to a total of 11,340 (9 x 1260) Monte Carlo events.

- The frequency analysis results are consistent with the flow quantiles derived during the Hydrologic Assessment. They are also consistent with expectations based on historical evidence and with expected hydraulic behaviour.
- It needs to be recognised that a longitudinal flood profile joining the AEP levels (i.e. a vertical section through the curves shown in Figure 4-6) does not represent the flood behaviour from any single event, and it cannot be expected that any single flood will conform to this profile. For example, the 1% AEP flood levels at each location represent the best estimate of flood risk based on the analysis of 11,340 events: it cannot be expected that any single hydraulic simulation will reproduce these levels at all reporting sites. While the AEP levels for the Reporting Locations in the vicinity of Ipswich are considered to provide the best available estimate of flood risk at those locations, the assumptions required to minimise bias in these estimates are perhaps less easily satisfied than those required for locations on the mainstream of the Brisbane River. Accordingly, while the nature of the hydrology and hydraulic simulation preclude a formal assessment of uncertainty, it is likely that the level AEP estimates in the tributary sites are more uncertain than those along the mainstream.
- Sensitivity assessments were undertaken for the AEP level frequency results, as detailed in Appendix E. In reality, the notional 1% uncertainty identified by these sensitivity tests due to the discretisation of the sample size of this aspect of the study is of negligible importance compared to the uncertainty in the estimation of the design rainfalls, their conversion to flood hydrographs, and the uncertainty inherent in the sample of events contained in a historic record that is very much shorter than the extrapolated extremes of interest. However, given that there is some sensitivity demonstrated to differing sampling approaches; it is recommended that the same threshold and bin discretisation sampling strategies used in this assessment are also used in potential future assessments to provide consistency. Should there be a justifiable reason to change the future sampling strategy, any issues associated with possible inconsistencies in results need to be considered and addressed as appropriate.
- Event ensembles for each of the 11 AEPs have been compiled that produce peak levels at each Reporting Location within the desired design flood tolerances specified in the ITO (DILGP, 2014). The AEPs where the desired accuracies are not met at all Reporting Locations is the 1 in 2 (50%) AEP, which is discussed further below, and at one location for the 1 in 10,000 AEP event.

- A total of 60 events have been selected to achieve the desired accuracy tolerances outlined in the ITO (DILGP, 2014). The number of events per ensemble varies as follows:

AEP	% AEP	Number of Events in Ensemble
1 in 2	50%	7
1 in 5	20%	6
1 in 10	10%	5
1 in 20	5%	6
1 in 50	2%	6
1 in 100	1%	5
1 in 200	0.5%	7
1 in 500	0.2%	5
1 in 2,000	0.05%	5
1 in 10,000	0.01%	4
1 in 100,000	0.001%	4
	Total	60

- The AEP Ensembles typically include a wide range of durations, reflecting the differing hydraulic responses of different Reporting Locations. The 1% AEP Ensemble of five events has five different durations: 12, 18, 48, 96 and 120 hours with some correlation between local catchment size and duration (ie. the smaller the local catchment area, the shorter the duration).
- Simulation of potential events using the calibrated Detailed Model allowed consistency between events to be checked. Flood levels are required to increase as event magnitude increases. Use of the Detailed Model allowed this requirement to be checked and fine tuning of event selection undertaken as required. This provided additional guidance on the final selection of events in areas not represented by the Reporting Locations. Such areas include:
  - Locations further upstream from the most upstream reporting locations on major tributaries (e.g. upstream of the Lyons Bridge Reporting Location on Lockyer Creek);
  - Locations further downstream from the most downstream Reporting Location on the Brisbane River (Gateway Bridge); and
  - Floodplains where the hydraulic behaviour is not controlled by the main waterways on which the Reporting Locations are located.
- It is recommended that the 1 in 2 AEP not be considered (ie. removed), at least for Lockyer Creek and the Bremer River catchment upstream of the tidal influence as the Monte Carlo AEP levels effectively reflect a dry bed at Reporting Locations along these tributaries that is further exacerbated by the use of LiDAR for in-bank topography. 1 in 2 AEP levels along the main Brisbane River and lower Bremer are also of questionable value but are considered useable, especially in the tidal reaches where accurate in-bank topography exists.

To summarise the outcomes of the selection of the AEP Ensemble events, a series of plots and tables are provided along with discussion for interpreting these media.

Of note is that the process of deriving AEP levels and selecting design event ensembles is a stepping stone to producing the final design levels using the Detailed Model. The AEP levels presented in this report are not the final AEP design levels, but levels statistically derived from the 11,340 Monte Carlo events simulated using the Fast Model. The final AEP design levels, as 3D flood surfaces, will be produced by simulating the design event ensembles through the Detailed Model and presented in Milestone Report 5.

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List of Abbreviations

1D	One dimensional
2D	Two dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Aerial Laser Survey
ARI	Australian Rivers Institute
AWRC	Australian Water Resources Council
BCC	Brisbane City Council
BCC (CPO)	Brisbane City Council (City Projects Office)
BoM	Bureau of Meteorology
BRCFMP	Brisbane River Catchment Floodplain Management Plan
BRCFMS	Brisbane River Catchment Floodplain Management Study
BRCFS	Brisbane River Catchment Flood Study
CBD	Central Business District
CET	Critical Event Tolerance
CPU	Central Processing Unit
DCS	Data Collection Study
DEM	Digital Elevation Model - a fixed grid of elevations sampled from a DTM
DM	Detailed Model
DMT	Disaster Management Tool
DNRM	Department of Natural Resources and Mines
DPI	Department of Primary Industries (former)
DS	Downstream
DILGP	Department of Infrastructure, Local Government and Planning DILGP (formerly the Department of State Development, Infrastructure and Planning, DILGP)
DTM	Digital Terrain Model – a triangulation of raw elevation data points
DTMR	Department of Transport and Main Roads
FCoI	Floods Commission of Inquiry (Qld)
FEWS	Flood Early Warning System
FM	Fast Model
FOSM	Flood Operations Simulation Model
GIS	Geographic Information System
GPU	Graphics Processing Unit
H&H	Hydrologic and Hydraulic
HDD	Hard Disk Drive
ICC	Ipswich City Council

ITO	Invitation to Offer, ie. the Hydraulic Assessment Brief (DILGP, 2014)
IPE	Independent Panel of Experts (for the current Study)
IRP	Independent Review Panel (commissioned by BCC in 2003)
LGA	Local Government Area
LiDAR	Light Detection and Ranging
LVRC	Lockyer Valley Regional Council
PMF	Probable Maximum Flood (Nominally 1 in 100,000 AEP)
PoB	Port of Brisbane
QGIS	Queensland Government Information Service
QR	Queensland Rail
RAM	Random Access Memory
SEQ	South East Queensland
SRC	Somerset Regional Council
SRTM	Shuttle Radar Topography Mission
TIN	Triangulated Irregular Network
TLPI	Temporary Local Planning Instrument
TWG	Technical Working Group
UDMT	Updated Disaster Management Tool
US	Upstream
WSDOS	Wivenhoe and Somerset Dams Optimisation Study

1 Introduction

1.1 Context

1.1.1 Brisbane River Catchment Floodplain Studies

The State of Queensland, acting through the Department of State Development, Infrastructure and Planning (DILGP) and the Department of Natural Resources and Mines (DNRM) as project manager, is undertaking a Comprehensive Hydraulic Assessment (this assessment) to deliver a fully calibrated hydraulic model that accurately defines the flood behaviour of the lower Brisbane River including major tributaries downstream of Wivenhoe Dam.

This assessment is a component of a broader framework of the Brisbane River Catchment Floodplain Studies (shown in Figure 1-1) currently being undertaken by the Queensland Government in response to Recommendation 2.2 of the Queensland Floods Commission of Inquiry[3] to provide a comprehensive plan to manage Brisbane River flood risk.

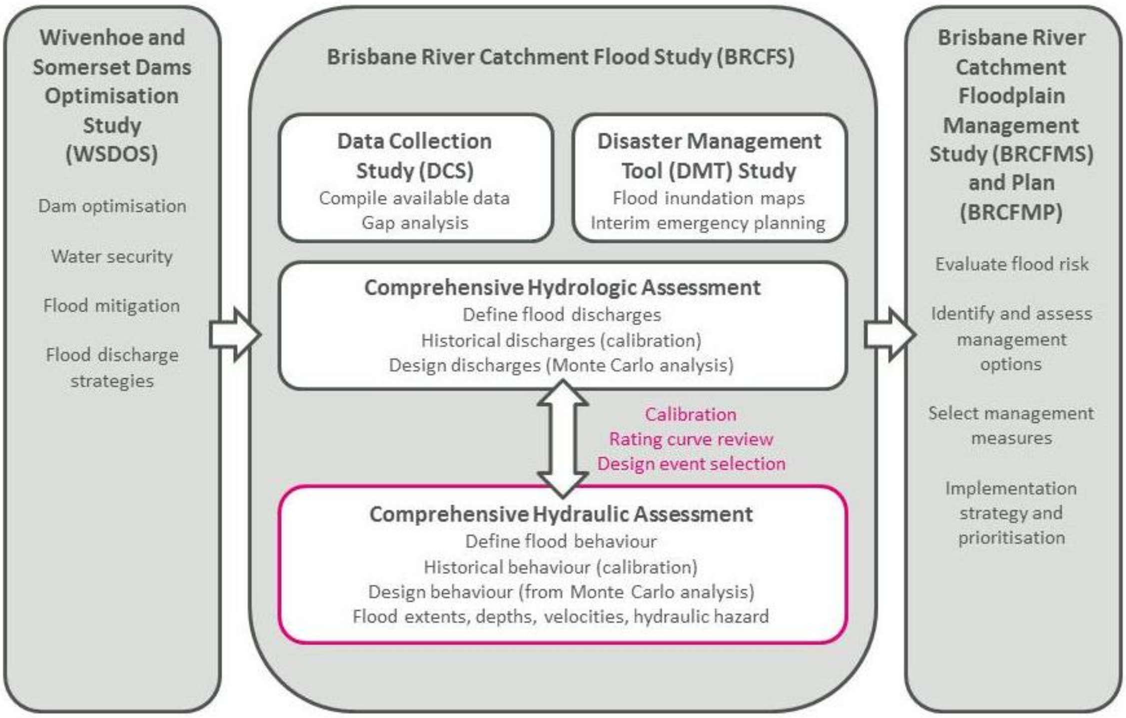

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Figure 1-1 Brisbane River Catchment Floodplain Studies

Based on Recommendation 2.2[3], this suite of studies follows the traditional and effective flood risk management framework endorsed as current best practice in Australia[4], which incorporates the following steps:

[3] Final Report, Queensland Floods Commission of Inquiry, March 2012.
[4] Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, Australian Emergency Management Handbook 7, Australian Government Attorney-General's Department, 2013.

- A Flood Study: The **Brisbane River Catchment Flood Study (BRCFS)** is presently underway to define flood behaviour. The BRCFS comprises a Data Collection Study (DCS), Comprehensive Hydrologic Assessment and Comprehensive Hydraulic Assessment (see Section 1.1.2).
- A Floodplain Management Study: The **Brisbane River Catchment Floodplain Management Study (BRCFMS)** will subsequently evaluate flood risk based on the flood behaviour defined in the BRCFS and identify and assess a range of flood risk management options. Options that involve changes in hydrologic and/or hydraulic conditions will be assessed using the models developed for the BRCFS.
- A Floodplain Management Plan: The **Brisbane River Catchment Floodplain Management Plan (BRCFMP)** will select a range of flood risk management measures based on the options assessed in the BRCFMS to guide the current and future management of flood risk. This will include a prioritised strategy outlining how the measures are to be implemented (including funding, responsibilities, actions, timeframes etc.).

The **Wivenhoe and Somerset Dams Optimisation Study** (WSDOS) has also been carried out in response to the Queensland Floods Commission of Inquiry to investigate potential options to improve dam operations and flood mitigation, taking into consideration water supply security, dam safety and erosion.

1.1.2 Brisbane River Catchment Flood Study (BRCFS)

The Brisbane River Catchment Flood Study (BRCFS) comprises the following stages:

- **Data Collection Study (Aurecon *et al*, 2013):** The Data Collection Study (DCS) was completed by Aurecon in August 2013 and identified, compiled and reviewed readily available data and metadata, including a gap analysis.
- **Comprehensive Hydrologic Assessment (Aurecon *et al*, 2015c):** The Hydrologic Assessment commenced in 2013 and was finalised in June 2015. It defines flood flows for the Brisbane River catchment based on flood frequency analysis, design event analysis and hydrologic modelling using a Monte Carlo approach to cater for temporal and spatial variations in rainfall patterns, operation of Wivenhoe Dam and other factors that affect catchment runoff. The Hydrologic Assessment also includes the configuration of a FEWS framework for data and simulation management.
- **Comprehensive Hydraulic Assessment:** The Hydraulic Assessment (this assessment) will define flood behaviour of the lower Brisbane River on the basis of, and in conjunction with, the Hydrologic Assessment. Specifically, this assessment will identify flood extents, depths, velocities and hydraulic hazard, across the full extent of the floodplain, for a range of events up to and including the 1 in 100,000 AEP. The components of the Hydraulic Assessment are outlined in Section 1.1.2.

In addition to the above stages, the **Disaster Management Tool (DMT) Study** (BCC, 2014a) has been undertaken by Brisbane City Council (City Projects Office) (BCC (CPO)) for the BRCFS Steering Committee for the purposes of providing flood inundation maps for interim emergency planning. The DMT also provides significant and useful background for the development of the hydraulic models for this assessment.

1.1.3 BRCFS Hydraulic Assessment

Key elements of the Hydraulic Assessment include the development of an integrated suite of hydraulic models, rigorous and defendable calibration to historical events, and modelling of a comprehensive range of design events to define flood behaviour.

The Hydraulic Assessment incorporates the following phases: data collation, site inspections, modelling, reporting and workshops (shown in Figure 1-2). Two models are developed and calibrated as part of the Hydraulic Assessment: the Fast Model and the Detailed Model. The development and calibration of the Fast Model is detailed in Milestone Report 2 (BMT WBM, 2015a) and an overview of the model provided in Section 1.1.4. The development and calibration of the Detailed Model is detailed in Milestone Report 3 (BMT WBM, 2015b) and an overview of the model provided in Section 1.1.6.

1.1.4 Fast Model Overview

The Fast Model is based on the established hydraulic modelling approach of using a network of 1D channels and storage nodes that was commonplace prior to 2D flood modelling. The network of channels gives a quasi 2D effect by conveying water through flowpaths representing both the rivers/creeks and floodplains. Spill channels connect the river/creek and floodplain flowpaths. The Fast Model has some 2,350 channels. The development and calibration of the Fast Model is described in Milestone Report 2 (BMT WBM, 2015a). The Fast Model is so-named because of its fast run times. A simulation of the Fast Model for one 10 day duration flood event takes approximately 5 minutes on a 2.7GHz i7 chip[5], compared to simulation times in the order of days for the 2D “Detailed Model”. The significantly faster simulation time of the Fast Model is essential in order for the Fast Model to meet its objectives, described as follows.

The primary purpose of the Fast Model is to simulate thousands of Monte Carlo events derived by the Hydrologic Assessment. The peak flows and peak water levels from these thousands of runs will be used to carry out flood frequency analyses (FFA) at 28 Reporting Locations along the main creeks and rivers. From these FFAs, preliminary flood level AEPs at the Reporting Locations will be derived, followed by selection of an estimated 50 of the Monte Carlo events that give a reasonable representation of the flood level AEPs derived from the FFA (refer to Section 1.1.5 for discussion the number of events selected).

The Fast Model is best viewed as a stepping stone to the selection of the estimated 50 events to define the design flood events for the Detailed Model. The events are to be selected from the thousands of Monte Carlo Events produced by the Hydrologic Assessment. The long run-times of the Detailed Model prohibit using the Detailed Model for the Monte Carlo analysis to derive peak water level AEPs, hence the need for the Fast Model.

The Fast Model must also be able to reliably reproduce the hydraulics of the Brisbane River Catchment downstream of Wivenhoe Dam, particularly along the main creeks and rivers where the

[5] The ITO (Invitation to Offer) (DILGP, 2014) specifies that a simulation time of less than 15minutes is required for the Fast Model.

Reporting Locations are situated. Therefore, the Fast Model has been calibrated and verified to a range of historical events as documented in BMT WBM (2015a). It has also been shown to produce consistent results for extreme events through comparison with other models/analyses as discussed in BMT WBM (2015a).

Importantly, the Fast Model is not used to calculate the final peak water levels for different AEPs – this will be an output of the Detailed Model. The Fast Model is solely used to help select a small sub-set (estimated at around 50) of the Monte Carlo events that produce consistent results with the Fast Model Monte Carlo AEP analysis.

This report presents the methodology and results leading to the selection of these events.

1.1.5 Number of Selected Events Overview

The ITO (DILGP, 2014) specifies the number of events to be selected as "approximately 50". It has been acknowledged throughout the course of the Hydraulics Assessment that the number of events selected was estimated to be 50 for the purposes of costing and implementing the study, but the actual number would be dependent upon the selection criteria used and the nature of the events themselves in being able to satisfy key criteria. Based on the methodology used for the selection process (as detailed in Section 5), the actual number of events selected is 61.

1.1.6 Detailed Model Overview

The Detailed Model is a 1D/2D hydraulic model that is designed to reproduce the hydraulic behaviour of the rivers, creeks and floodplains at a much higher resolution than the Fast Model. The Detailed Model, whilst substantially slower to simulate a flood event than the Fast Model, is far superior for producing flood maps and 3D surfaces of flood depths, water levels, hazard, risk categories and other useful data for floodplain management planning measures. The model will also more accurately predict changes in flood levels and flow patterns due to past and proposed works, including flood mitigation measures and future developments.

The functions of the Detailed Model are to:

- Accurately reproduce the flood behaviour of the Brisbane River, Lockyer Creek and Bremer River at a sufficiently high resolution to produce mapping of flood levels, depths and hazard for whole-of-catchment (below Wivenhoe Dam) planning purposes as per the requirements specified in the ITO.
- Use the model into the future to quantify the impacts or changes in flood levels, depths and hazard due to:
  - Flood mitigation measures, urban developments, road and rail infrastructure, dredging and quarry operations, and other works that change or alter the flood behaviour; and
  - Changes in climate, land-use, sedimentation and erosion, or other factors that may or may not influence the flood behaviour into the future so that planning instruments can accommodate these effects.

1.2 This Report

1.2.1 Purpose and Scope

This Milestone Report 4: Fast Model Results is the fourth[6] in a series of milestone reports to be delivered as part of the BRCFS Hydraulic Assessment. The purpose of this report is to provide details on the:

- Fast Model simulation of Monte Carlo events generated by the Hydrologic Assessment (Aurecon *et al,* 2015a,b).
- Peak flood level AEP frequency analysis at the Reporting Locations using the results from the Fast Model Monte Carlo event simulations.
- Selection of an estimated 50 of the Monte Carlo events that are representative of the AEP peak levels at the Reporting Locations.

This report incorporates comments from the IPE (Appendix F) and the TWG on the Draft version.

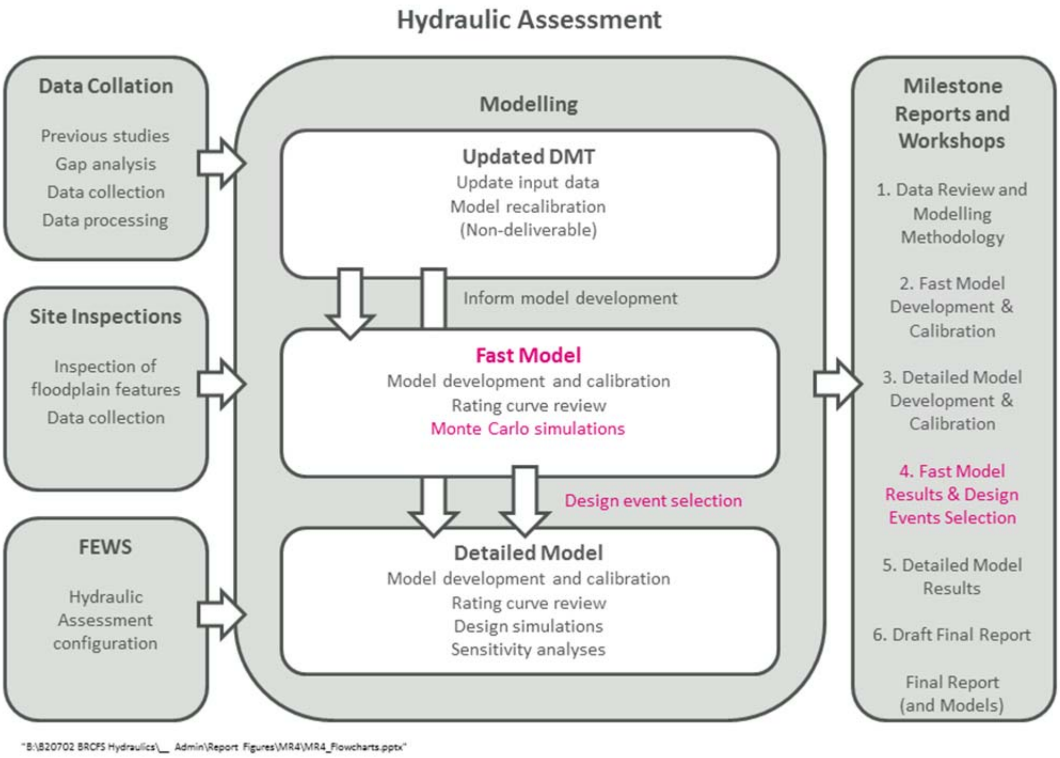


Figure 1-2 BRCFS Hydraulic Assessment

[6] The first report being BMT WBM (2014) - Milestone Report 1: Data Review and Modelling Methodology, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final - 29 October 2014. The second report being BMT WBM (2015a) - Milestone Report 2: Fast Model Development and Calibration, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final – April 2015. The third report being BMT WBM (2015b) – Milestone Report 3: Detailed Model Development and Calibration, BMT WBM for Department of State Development, Infrastructure and Planning, Draft Final – August 2015.

1.2.2 Invitation to Offer (the Brief)

This Milestone Report 4: Fast Model Results, addresses the relevant components of the following tasks as outlined in the Invitation to Offer (ITO) (DILGP, 2014):

"3.10.4.2 Fast model Monte Carlo Simulations

The fast hydraulic model will be used to route numerous combinations of event hydrographs from the catchment upstream of Wivenhoe dam and catchments of the tributary streams downstream of Wivenhoe Dam, and tide level scenarios. These scenarios (approximate 500) will be outcomes of the Monte Carlo Simulation component of the Hydrology Study. The results of approx. 500 model runs will be compiled and summarised for each location listed in Section 3.9.5. The results will be analysed (as part of the interaction process) to determine at each location and for each AEP, the particular storm runoff and tailwater combination(s) to be modelled using the detailed model.

3.10.4.3 Fast Model Quality Assurance and reporting

….

A report on flood estimation using the fast model will also be required. This report will describe the use of the model for flood routing as part of the Monte Carlo Simulation, the analysis of the results, and selection of design events for detailed modelling."

….

*"**Optional Item #A – Hydraulic Consultant to undertake extra Monte-Carlo analysis and interpretation***

Whilst the successful hydraulics consultant is expected to play a key part in the proposed interaction process (see Section 3.4), Offerors are to provide a separate firm price for greater involvement and additional work as follows:

1. To analyse and interpret the results of the approximate 500 fast hydraulic model runs as input to the proposed interaction process in order to finalise the Monte-Carlo analysis (see Section 3.4, Interface#1 Item#3). Approval of the process and results will be required by the client, before further stages of the study

2. Based on the results from the 500 fast hydraulic model Monte-Carlo simulations, to draw a subset of approximately 50 'events' as input to the client interaction process (see Section 3.4, Interface#3 Item#1). Selection of the subset will form part of the Monte Carlo analysis and, as such, should be undertaken in line with the objectives of the previously completed analysis. Approval from the client is required prior to the use of these 50 events in the detailed 2D hydraulic modelling."

Revisions to this methodology were found to be necessary during the Hydrology-Hydraulics interfacing process. The overall methodology is known as the "Option 5" methodology and this is documented in Appendix A. The Option 5 methodology incorporates the Option G/H methodology, which is documented in Appendix B. Further details are provided in Section 3.1 and the Appendices.

"3.4 Interaction with BRCFS Hydrology Study (part)

…..

Interface #1: Events from the Monte-Carlo Analysis to be used in the fast hydraulic model

1. The hydrology study is to produce a subset of the results (approximate 500 scenarios) from the Monte-Carlo analysis as input for use in the fast hydraulic model (approximately 500 model runs). These results will be comprised of scenarios defining sets of boundary condition inflow hydrographs and downstream tide levels, and will be provided to the hydraulics consultant at the proposed interaction session in September 2014.

2. The fast hydraulic study is to input this data and produce results from the model runs, including of level, flow and stage-discharge relationships at selected locations throughout the modelled domain, compile the results and provide them back to the client. The locations are given in Section 3.9.5.

3. The client is then to make arrangements for these results to be reviewed, analysed, and interpreted jointly (by the IPE, TWG, the hydrology consultant, and the hydraulics consultant) as part of the interaction process in order to finalise the Monte-Carlo analysis. The methodology and processes developed during the hydrology study phase of the BRCFS will be used for this analysis. Approval of the process and results will be required by the client, before further stages of the study.

…..

Interface #3: 2D model design runs

1. A subset will be drawn from the fast hydraulic model Monte Carlo simulation results of approximately 500 scenarios, for use in the detailed 2D hydraulic model as boundary conditions, including downstream ocean levels. This subset will consist of approximately 50 'events', covering a range of design probabilities, for different river reaches and for pre- and post-dam scenarios, and will be the final output of the Monte-Carlo analysis. Selection of the subset will form part of the Monte Carlo analysis and, as such, should be undertaken in line with the objectives of the previously completed analysis. Again, the selection of approximately 50 'events' would be made based on the interaction process (involving the IPE, TWG, the hydrology consultant and the hydraulics consultant) to be facilitated by the client. Approval from the client is required prior to the use of these 50 events in the detailed hydraulic modelling.

2. This subset of approximately 50 runs is to be run in the 2D hydraulic model as part of the hydraulic study.

3. The model results will be used to produce design flood levels and other final results. This would include analysis and interpretation of the approximate 50 detailed hydraulic model Monte-Carlo simulation results as part of the hydraulic study.

4. Feedback/input from the client through the proposed interaction process (involving the IPE, TWG and the hydrology consultant) will be required before the final results are produced."

2 Methodology

2.1 Stages for Selection of Design Flood Events

The process to select Monte Carlo events from the Hydrologic Assessment (Aurecon) that are representative of different design flood AEPs followed three stages:

(1) **Stage 1:** Run the 11,340[7] Hydrologic Assessment Monte Carlo events through the calibrated Fast Model retaining peak water levels and flows for each event at each Reporting Location (see Section 2.3 and Drawing 1 for a description of these locations).

(2) **Stage 2:** Carry out a Monte Carlo flood level frequency analysis of the 11,340 events using the peak water levels to produce initial estimates of AEP levels at the Reporting Locations. Importantly, the level frequency analysis focuses on peak water level to include the effects of backwater, hysteresis (rating curve looping) and the tide or storm tide, as the peak flow may not occur at the time of peak level.

(3) **Stage 3:** Select an estimated 50 of the Monte Carlo events that produce peak flood levels representative of the AEP levels derived in the previous stage. The expectation is that for any given AEP, an ensemble of events will be needed to match the AEP levels at all Reporting Locations.

Section 3, Section 4 and Section 5 present the approach and outcomes for each of the three stages above respectively. The following sections provide relevant background information referred to by these sections.

Of note is that the process of deriving AEP levels and selecting design event ensembles using the Fast Model is a stepping stone to producing the final design levels using the Detailed Model. The AEP levels presented in this report are not the final AEP levels, but AEP levels derived from 11,340 Monte Carlo events simulated using the Fast Model. The final AEP levels, as 3D flood surfaces, will be produced by simulating the design event ensembles through the Detailed Model.

[7] The Hydrologic Assessment considered 60 AEPs per event duration with 21 simulations performed per AEP. Thus the Hydrology Assessment simulated 1260 Monte Carlo events per duration. For the purpose of the Hydraulic Assessment, nine event durations were required (12 hours to 168 hours), leading to a total of 11,340 (9 x 1260) Monte Carlo events.

2.2 Design Flood AEPs

Design floods for eleven (11) Annual Exceedance Probabilities (AEPs) are to be derived based on Table 1 in the ITO (DILGP, 2014), and listed in Table 2-1 below. This includes the 1 in 100,000 AEP event as this is the rarest event that can be estimated in a consistent and defensible manner across all sites in the study area.

Table 2-1 Design Flood AEPs

AEP (%)	AEP (1 in ..)
50%	2
20%	5
10%	10
5%	20
2%	50
1%	100
0.5%	200
0.2%	500
0.05%	2,000
0.01%	10,000
0.001%	100,000

Councils via the TWG were asked whether they have a view on the priority or importance of the different AEPs in terms of their day-to-day operations. The response of the Councils to the survey is recorded in Table 2-2 and these are plotted as normalised rankings in Figure 2-1.

Table 2-2 AEP Priority Ranking Survey Responses

		Indicative Ranking (Highest Rank = 1)			
Annual Exceedance Probability AEP	AEP (1 in Y)	ICC	BCC	SRC	LVRC
50%	2	3	2	4	7
20%	5	3	1	4	5
10%	10	2	1	3	4
5%	20	2	1	2	7
2%	50	2	1	2	6
1%	100	1	1	1	1
0.50%	200	6	2	2	7
0.20%	500	5	1	2	7
0.05%	2,000	4	1	3	2
0.01%	10,000	6	3	4	7
0.001%	100,000	4	3	4	3

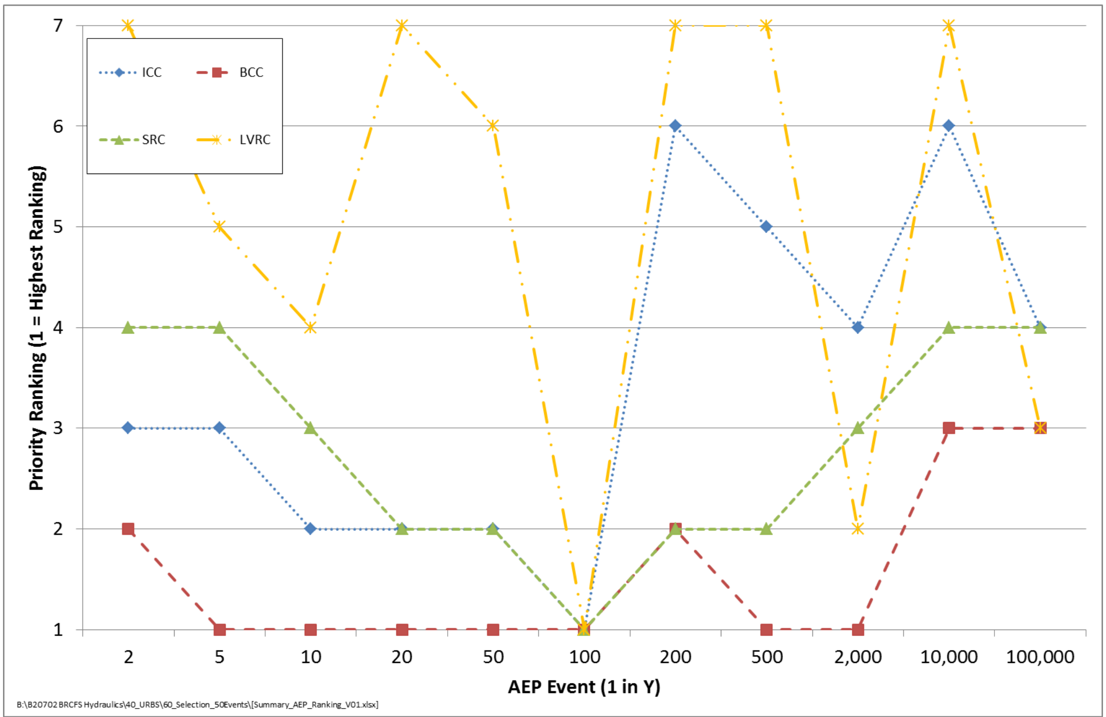


Figure 2-1 AEP Priority Ranking

In addition to the responses from the Councils, Seqwater advised that they have an interest in all levels of flooding that may pose a risk to Seqwater assets. For example, Seqwater has the following assets at which flood levels (and flood impacts) are important:

- A head office in Ipswich CBD, so understanding the risk to corporate operations during a flood is paramount.
- Major multi-billion dollar assets for potable water treatment plants at Mount Crosby plus small scale, but important water treatment facilities at Lowood.
- Major multi-billion dollar asset for the advanced recycled water plant near the lower reaches of the Bremer River, just upstream of the Warrego Highway.

2.3 Reporting Locations

The sites at which to carry out the hydraulic Monte Carlo AEP level frequency analysis and selection of 50 events for the design floods are referred to as the Reporting Locations. These locations were listed after Table 1 in the ITO (DILGP, 2014; pages 23 and 24) and were subjected to a final review/confirmation by the IPE and TWG as part of Workshop 1 and documented in Appendix F of Milestone Report 1 (BMT WBM, 2014). During this review "Brisbane River at City Gauge" was added as a Reporting Location.

For the purpose of the Monte Carlo analysis and selection of AEP ensemble events, the Reporting Location "Oxley Creek at Beatty Road" was removed due to its distant proximity to the Brisbane River, making the total number of locations 28 for this current assessment. Oxley Creek at Beatty Road was not used for the Monte Carlo Analysis and selection of AEP Ensemble events due to its hydraulic behaviour not being consistently representative of Brisbane River dominated flood levels because of its proximity well away from the Brisbane River and closeness to the upstream Oxley Creek inflow boundary.

Note that for the AEP analysis and selection of events, "Brisbane River at Port Office" is the same as "Brisbane River at City Gauge" in terms of results as they are both represented by the same 1D output node in the Fast Model. The two sites are on opposite sides of the river with the City Gauge being slightly further downstream, so any localised hydraulic effects such as superelevation while not possible to represent in the Fast Model, will be evident in the results from the Detailed Model for the design flood mapping stage.

The full 29 Reporting Locations are listed in Table 2-3 and their locations shown in Drawing 1, noting that Beatty Road is not used in the Monte Carlo analysis and selection of AEP ensembles bringing the number of Reporting Locations considered for this component of the assessment down to 28. Drawing 1 also shows the locations within the Hydraulic Assessment study area used by the Hydrologic Assessment (Aurecon et al, 2015b) for their Monte Carlo analyses.

Table 2-3 Reporting Locations

ID	Reporting Location	Description
RL_01	Lockyer Creek at Tarampa	At Rifle Range Road gauge
RL_02	Wivenhoe Dam Tailwater*	At gauge
RL_03	Lockyer Creek at Lyons Bridge	At gauge
RL_04	Brisbane River at Lowood Pump Station*	At gauge
RL_05	Brisbane River at Savages Crossing*	At gauge
RL_06	Brisbane River Upstream Mt Crosby Weir*	At gauge
RL_07	Brisbane River downstream Mt Crosby Weir	Downstream weir
RL_08	Brisbane River at Moggill*	Moggill ferry (mid river)
RL_09	Brisbane River at Jindalee*	Upstream Centenary Highway
RL_10	Brisbane River at Tennyson	Tennis Centre
RL_11	Brisbane River at Fairfield	Leyshon Park
RL_12	Brisbane River at Toowong	Regatta ferry terminal
RL_13	Port Office Gauge	At gauge (Edward Street)
RL_14	Brisbane City Gauge*	At gauge (Kangaroo Point)
RL_15	Brisbane River at Hawthorne	Hawthorne ferry terminal
RL_16	Brisbane River at Gateway Bridge	Upstream Gateway Bridge (mid river)
RL_17	Warrill Creek at Amberley*	At gauge
RL_18	Purga Creek at Loamside*	At gauge
RL_19	Bremer River at Walloon	At gauge
RL_20	Bremer River at Three Mile Bridge	Mid river
RL_21	Bremer River at One Mille Bridge	Mid river
RL_22	Bremer River at David Trumpy Bridge*	At gauge
RL_23	Bremer River at Hancock Bridge	At gauge
RL_24	Bremer River at Bundamba Confluence	Downstream confluence
RL_25	Bremer River at Warrego Highway	Upstream Warrego Highway (mid river)
RL_26	Bundamba Creek at Hanlon St Alert	At gauge
RL_27	Woogaroo Creek at Brisbane Road Alert	Downstream confluence
RL_28	Oxley Creek at Rocklea	Upstream Sherwood Road
RL_29[8]	Oxley Creek at Beatty Road (Not Used)[8]	Upstream Beatty Road

* These locations are also Hydrology Assessment Reporting Locations (Aurecon et al, 2015c)

[8] Oxley Creek at Beatty Road was not used for the Monte Carlo Analysis and selection of AEP Ensemble events due to its hydraulic behaviour not being consistently representative of Brisbane River dominated flood levels because of its proximity well away from the Brisbane River and closeness to the upstream Oxley Creek inflow boundary.

3 Fast Model Monte Carlo Events Simulation

3.1 Monte Carlo Events from Hydrologic Assessment

3.1.1 Background

The Hydrologic Assessment (Aurecon *et al*, 2015b) completed a Monte Carlo analysis at a range of locations throughout the Brisbane River Catchment to produce estimates of peak AEP flow rates at each location. The ITO (DILGP, 2014) envisaged that, due to the longer run times of hydraulic models, repeating this exercise to produce peak AEP flood levels using hydraulic modelling would not be practical, and that around 500 events selected from the tens of thousands generated by the Hydrologic Assessment would have to suffice. Through the Hydrology and Hydraulics interfacing discussions, this approach was reviewed with a strong preference, if feasible, to be able to run a much larger set of Monte Carlo events to remove the uncertainty associated with selecting a sub set of 500.

As agreed through the Hydrology and Hydraulics Interfacing process, the improved approach resulted in Option 5 (incorporating Option G/H) as documented in Appendix A and Appendix B respectively. Option G/H is specifically related to resolving the residual catchment rainfall issue as described further in Appendix B. It is noted that Option G represents the first pass and that Option H was only considered necessary should Option G not produce plausible results for the Lockyer Creek and Bremer River tributaries of the Brisbane River.

3.1.2 Provision of Hydrologic Assessment Hydrographs

Monte-Carlo hydraulic model simulations using the Fast Model were carried out using the Hydrologic Assessment Monte Carlo events generated for the Brisbane City Gauge (ie. for the whole of the catchment rainfall AEP scenarios) as agreed in the Option G/H approach. The Monte-Carlo event set **initially** identified consisted of a total of 7,560[9] separate events for the event durations of 24, 48, 72, 96, 120 and 168 hours. The Hydrologic Assessment team (Aurecon) generated the inflow hydrographs, via the Delft-FEWS framework, needed for the Fast Model based on the work specification provided by BMT WBM and reproduced in Appendix A. The inflow hydrographs are at the same locations as developed for the Fast Model calibration (BMT WBM, 2015a).

Whilst the work specification in Appendix A refers to 7,560 events, the number of events provided by the Hydrologic Assessment team and simulated through the Fast Model was increased to 11,340[9] due to inclusion of the additional durations of 12, 18 and 36 hours giving a total of 9 event durations. The inclusion of the additional durations was made after it became evident from initial trials that it was feasible to include these durations, thereby utilising all durations adopted in the Hydrologic Assessment without any delay to the study timeline. In addition to the URBS inflow hydrographs, the corresponding Wivenhoe Dam outflow and Moreton Bay Storm Tide hydrographs

[9] The Hydrologic Assessment considered 60 AEPs per event duration with 21 simulations performed per AEP. Thus the Hydrology Assessment simulated 1260 Monte Carlo events per duration. During the initial stages of Monte Carlo methodology development, only six durations were being considered, giving a total of 7,560 (6 x 1260) Monte Carlo events. However, the final adopted methodology included nine event durations (12, 18, 24, 36, 48, 72, 96, 120 & 168 hours), leading to a total of 11,340 (9 x 1260) Monte Carlo events.

for each event were also provided. In total, around 1.1 million hydrographs were provided (11,340 events times 100 inflow/boundary locations).

The hydrographs were generated by FEWS and provided in NetCDF format.

3.1.3 Proofing of Hydrologic Assessment Hydrographs

Generating the hydrographs required modifying the URBS model to produce local and total hydrographs as required by the Fast Model inflow locations, which are different to the locations used for the Hydrologic Assessment Monte Carlo Analysis. To ensure that the hydrologic calculations were not affected by these changes, checks were carried out by both the Hydrologic and Hydraulic Assessment teams before and after the changes. The testing showed that there was no change in results due to adding in the additional hydrograph output required for the Fast Model boundaries.

3.1.4 Comparison of Whole-of-Catchment versus Local Rainfall AEP

The AEP of the rainfall applied to the local catchment (ie. the catchment upstream of the Reporting Location) was compared with the whole-of-catchment rainfall (ie. the entire Brisbane River catchment). This was of interest as the Option G/H approach is to use the whole-of-catchment rainfall to assign a probability to each event, and appreciation of any differences with the local catchment rainfall AEP would assist in proofing and cross-checking the Option G/H approach.

Plot 1 to Plot 3 (contained in the separate Plot Addendum document) illustrate the relativity of local versus whole-of-catchment rainfall AEP at each Reporting Location for all 11,340 events. Figure 3-1 presents examples of these plots for Lockyer Creek at Tarampa, Savages Crossing, Ipswich at David Trumpy Bridge and Brisbane CBD. As would be expected, there is a substantially greater spread for the Lockyer Creek and Bremer River (Ipswich) sites, with some spread for Savages Crossing and no spread for Brisbane CBD. This reflects the fact that as the local catchment area at a location increases in magnitude toward the whole-of-catchment area, the AEPs of the local and whole-of-catchment become more closely aligned. Thus, the Reporting Locations with smaller local catchment areas have a greater variability in AEPs than the Reporting Locations with the larger local catchment areas.

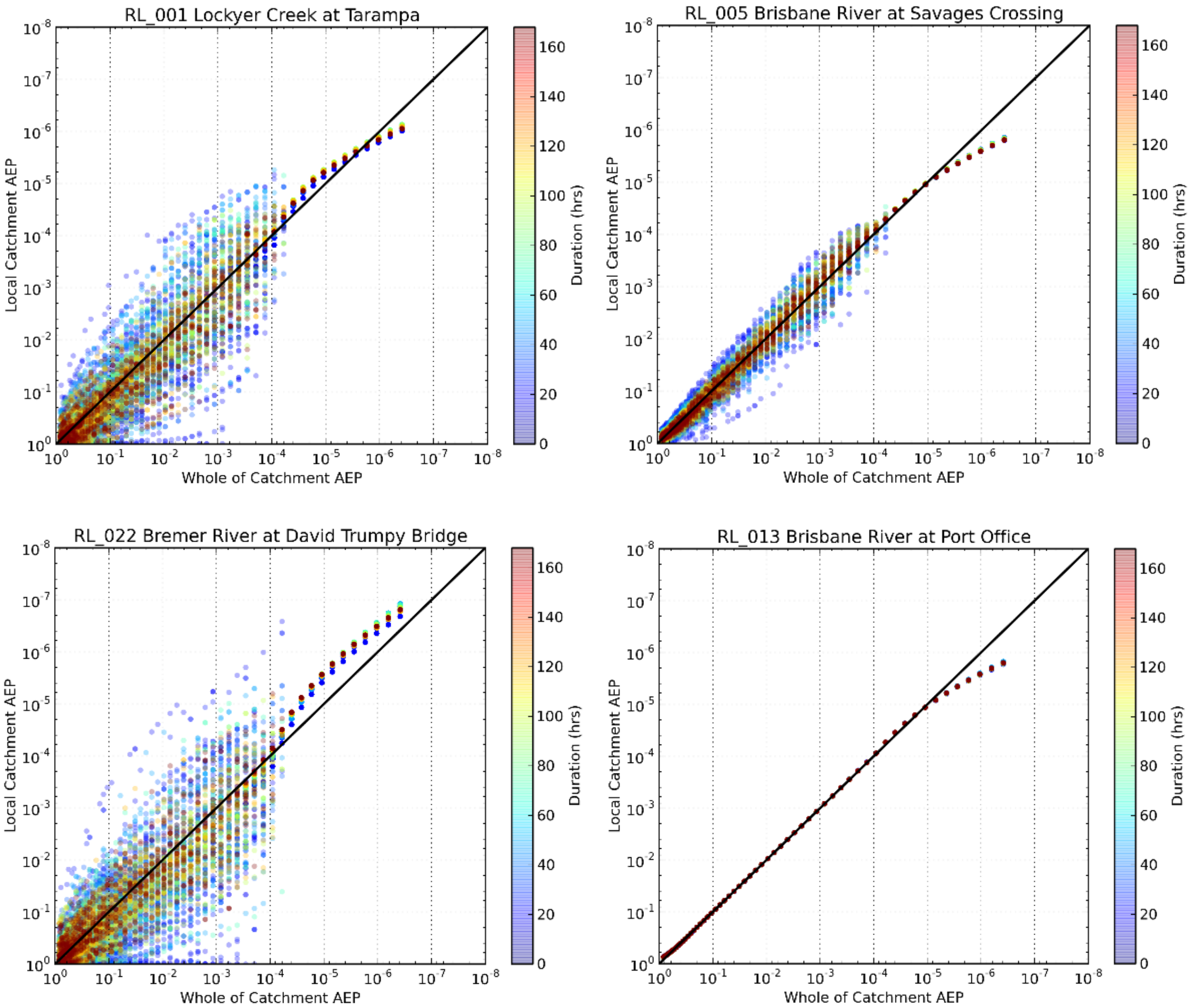


Figure 3-1 Examples of Local Catchment vs Whole-of-catchment Rainfall AEP Plots

3.2 Fast Model Simulation of 11,340 Events

The 11,340 events were simulated through the Fast Model by using an automatic batching script to push each simulation to available CPU cores across a network of office computers with varying CPU specifications. Depending on the availability of CPU cores, the process would take several days to a week.

The peak water levels and peak flows at each Reporting Location were tracked every computational timestep and written to a file at the completion of each simulation. In addition, other information to validate the model outputs was also tracked every timestep and reported within the same file.

The information retained included:

- Peak water level
- Peak flow
- Flow at peak water level
- Water level at peak flow
- Time of peak water level
- Time of peak flow
- Maximum change in water level during a computational timestep
- Maximum change in flow during a computational timestep.

To track the flow related values, the sum of the flows of all 1D channels that contribute to the total flow across the creek/river and its floodplains was calculated every timestep, and the total flow recorded if a maximum along with the time and water level for that maximum flow. These channels were identified by an intersection line for each Reporting Location extending across the entire floodplain. The tracking of water level was based on the nearest 1D node to the Reporting Location. The Reporting Locations' flow lines and 1D water level nodes are illustrated in Drawing 2.

The full time history output of flow and water level at each Reporting Location on an hourly interval was also retained for all 11,340 events. Retention of this information proved to be invaluable for proofing the model output for a small percentage of problematic events as discussed in Section 3.4.

Fundamental checks such as checking the model mass error is within standard bounds were also carried out. Figure 3-2 and Figure 3-3 present the cumulative % mass error and peak % mass error for all 11,340 events. These values are well within the 1% target (a cumulative mass error exceeding 1% can be a sign of a simulation not performing well in terms of numerical convergence and/or numerical instabilities).

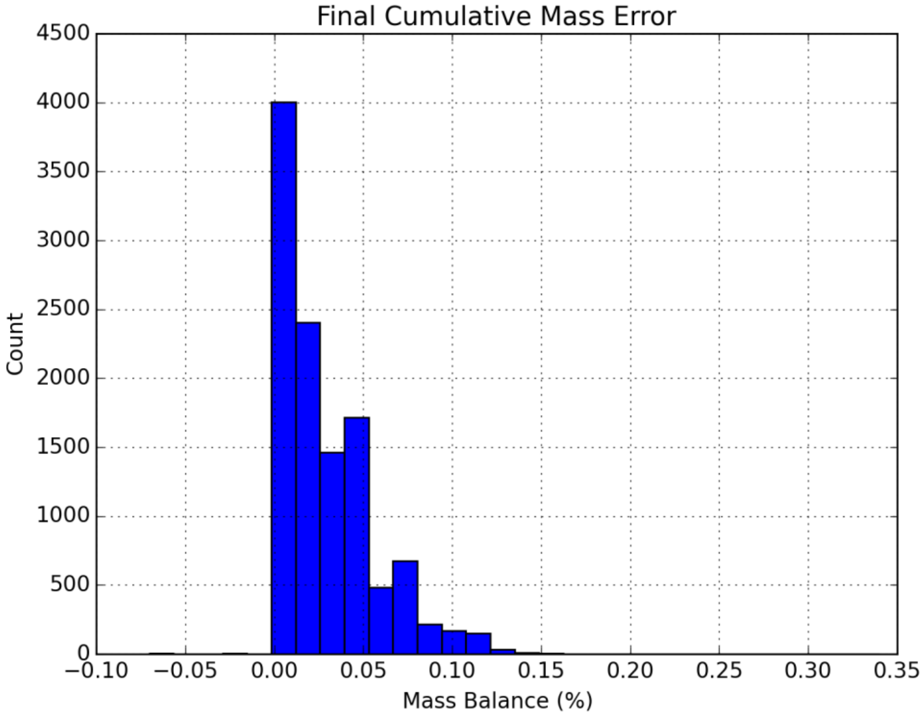


Figure 3-2 Cumulative % Mass Error across 11,340 Events

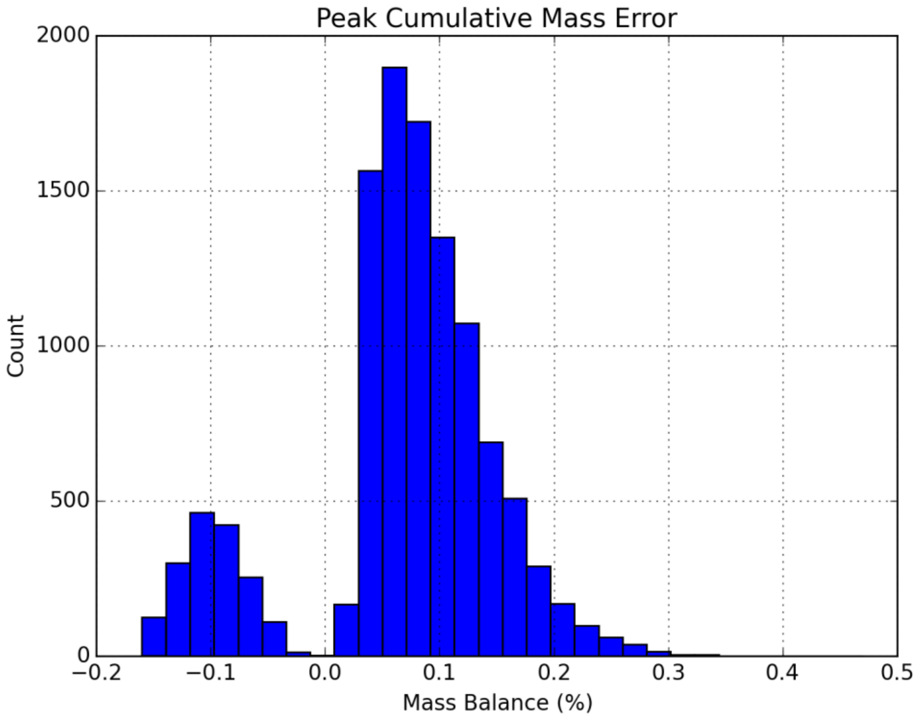


Figure 3-3 Peak Cumulative % Mass Error across 11,340 Events

3.3 Checking of Fast Model Results

The Fast Model simulations needed to be checked for any numerical instabilities causing unreliable peak flows and water levels. This was carried out using a range of statistical analyses and charts of the output from the 11,340 events. Comparisons with peak flows from the URBS model were also carried out. These outputs are discussed in the following sections.

3.3.1 Fast Model vs URBS Peak Flows

Plot 4 presents comparisons of the peak flow from the Fast Model and the URBS hydrologic modelling for the 11,340 events at Reporting Locations common to both the Hydraulic and Hydrologic Assessments (these locations are shown in Drawing 1). Extracts from Plot 4 are shown below in Figure 3-4. The events are colour shaded according to duration, with blue for short durations through to red for long durations. A perfect match between both models would see the peak flows aligned along the black line.

Observations from these plots are:

- At locations such as Amberley, Loamside and Walloon where the hydraulic model inflow boundary is near the Reporting Location, there tends to be a close correlation between the hydrologic and hydraulic models.
- As expected, for events up to 10,000 m^3/s in the Brisbane River, there is reasonable correlation between peak flows, as both models have been calibrated to events within this range. However, for extreme events, there is a significant departure and greater spread of results at locations along the Brisbane River. The significant hydraulic effects such as the influence of the large Lockyer Creek floodplains, particularly for extreme events, result in a greater attenuation of the flows causing a reduction in the flow peaks.
- David Trumpy Bridge (Ipswich) also sees greater attenuation of flows and lower peak flows due to the substantial Brisbane River backwater effects that are better represented in a hydraulic model than a hydrologic model. There is also a natural constriction in the vicinity of Berry's Lagoon that tends to choke flood flows, and for increasingly larger events, causes an attenuation of the flood wave due to the floodplain storages upstream.
- As would be expected, along the Brisbane River, the shorter duration events (blue) are significantly more attenuated by floodplain storage effects due to their lower volume than the longer duration, high volume events (red). This is not so apparent at David Trumpy Bridge, which is more influenced by backwater effects from the Brisbane River.

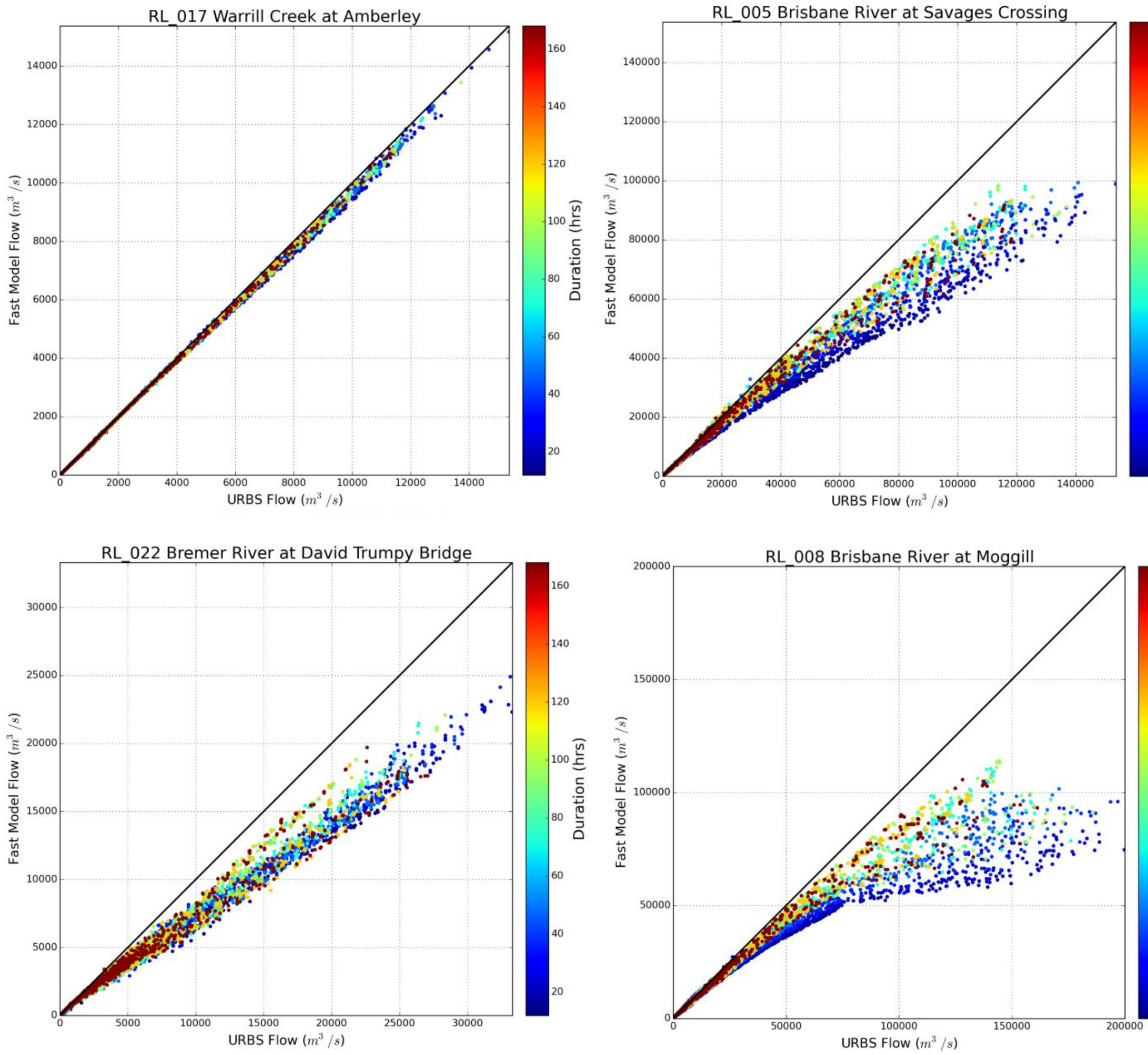


Figure 3-4 Examples of Fast Model vs URBS Peak Flow Plots

3.3.2 Peak Water Level vs Peak Flow

Plot 5 to Plot 7 illustrate charts of peak water level versus peak flow for each Reporting Location, in effect presenting the stage-discharge or rating curve relationship at all locations. Examples from these plots are shown in Figure 3-5 for Tarampa (Lockyer Creek), David Trumpy Bridge (Ipswich) and Moggill (Brisbane River). The 11,340 events are colour coded according to the rainfall AEP where blue is the most frequently occurring events and red the rarest events.

As can be seen, locations such as Moggill, where there is little backwater effect or hysteresis looping, show less spread in the results and a reliable relationship exists between peak level and peak flow.

For sites such as Tarampa that experience little backwater or storage effects for frequent, predominantly in-bank events there is a little spread, while for bigger events when the large Lockyer Creek floodplain storage effects have a strong influence, there is little correlation between peak water level and flow. For sites such as David Trumpy Bridge at Ipswich there is even a greater spread due to the substantial backwater effects of the Brisbane River on the lower Bremer reaches. These sites are not considered to be dependable rating curve locations as no reliable relationship between peak level and flow can be derived.

While these plots are useful in appreciating the sensitivity in the relationship between peak water level and flow at each of the Reporting Locations, they are only useful for identifying any model instabilities that may have caused unreliable results where there is little spread in the water level versus flow relationship. Of the locations where a close relationship exists (ie. little spread) there are some clues as to the presence of possible anomalies. A close examination of Tennyson indicates a handful of events are producing slightly higher peak flows, whereas at other nearby Brisbane River sites, eg. Jindalee, Fairfield and Toowong this is not the case. Issues relating to Tennyson are further discussed in Section 3.4.

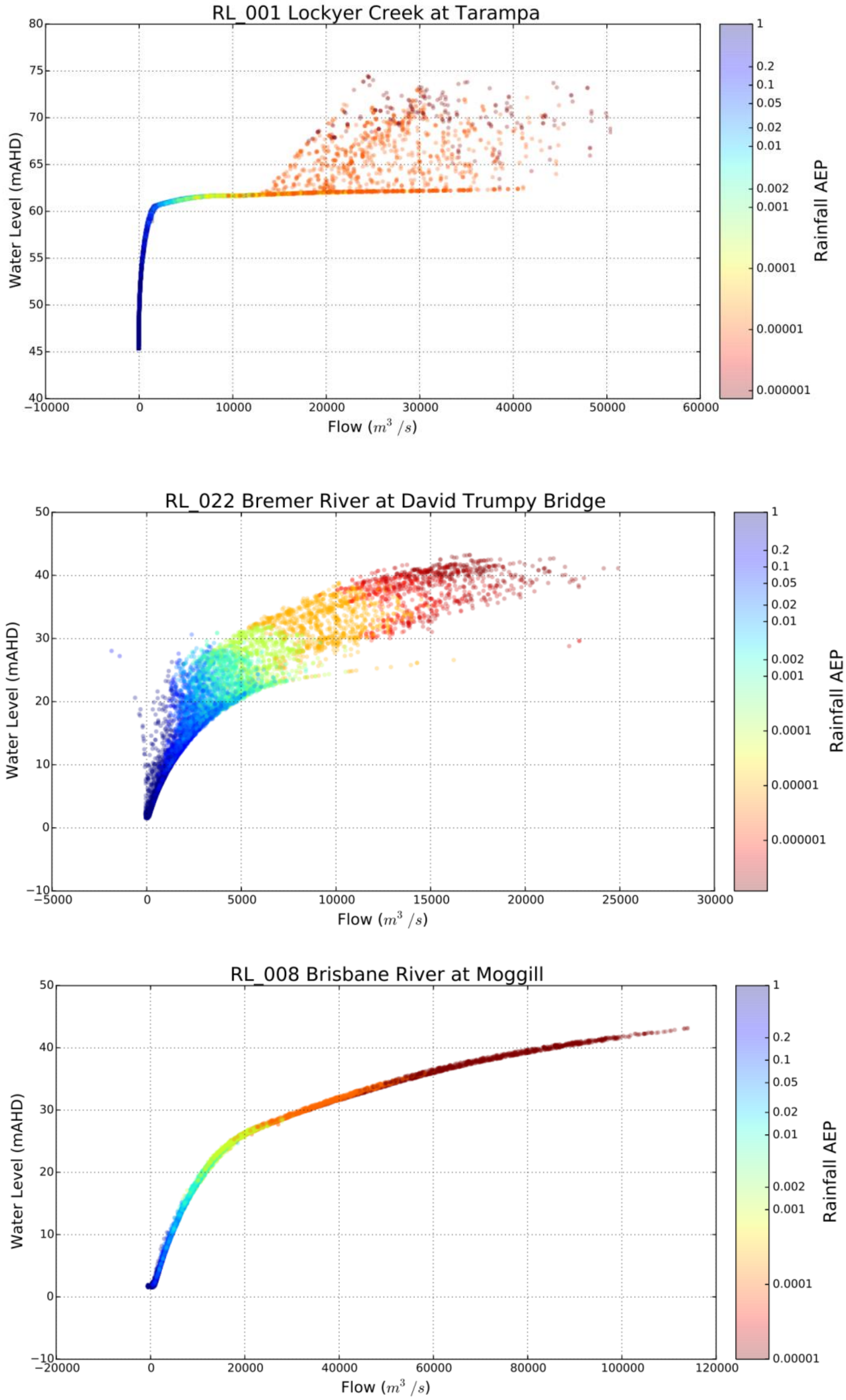


Figure 3-5 Examples of Peak Water Level vs Peak Flow Plots

3.3.3 Water Level versus Flow at Peak Level and Peak Flow

Plot 8 to Plot 10 also show the relationship between peak water level and peak flow as discussed in the previous section, this time as a blue colour. The plots also show the water level at peak flow (red) and the flow at peak water level (green). Figure 3-6 shows example extracts from these plots for the same locations as shown in Figure 3-5 in the previous section.

As would be expected, where there is little hysteresis there is little variation or spread in results; for example, at Moggill. Where backwater or other hydraulic variability occurs the spread can be substantial, as shown for Tarampa and David Trumpy Bridge.

These plots, whilst not particularly useful for identifying any problematic results, are beneficial in understanding whether the flood behaviour of the Fast Model at each Reporting Location is in accordance with expectations, and the plots indicate that this the case.

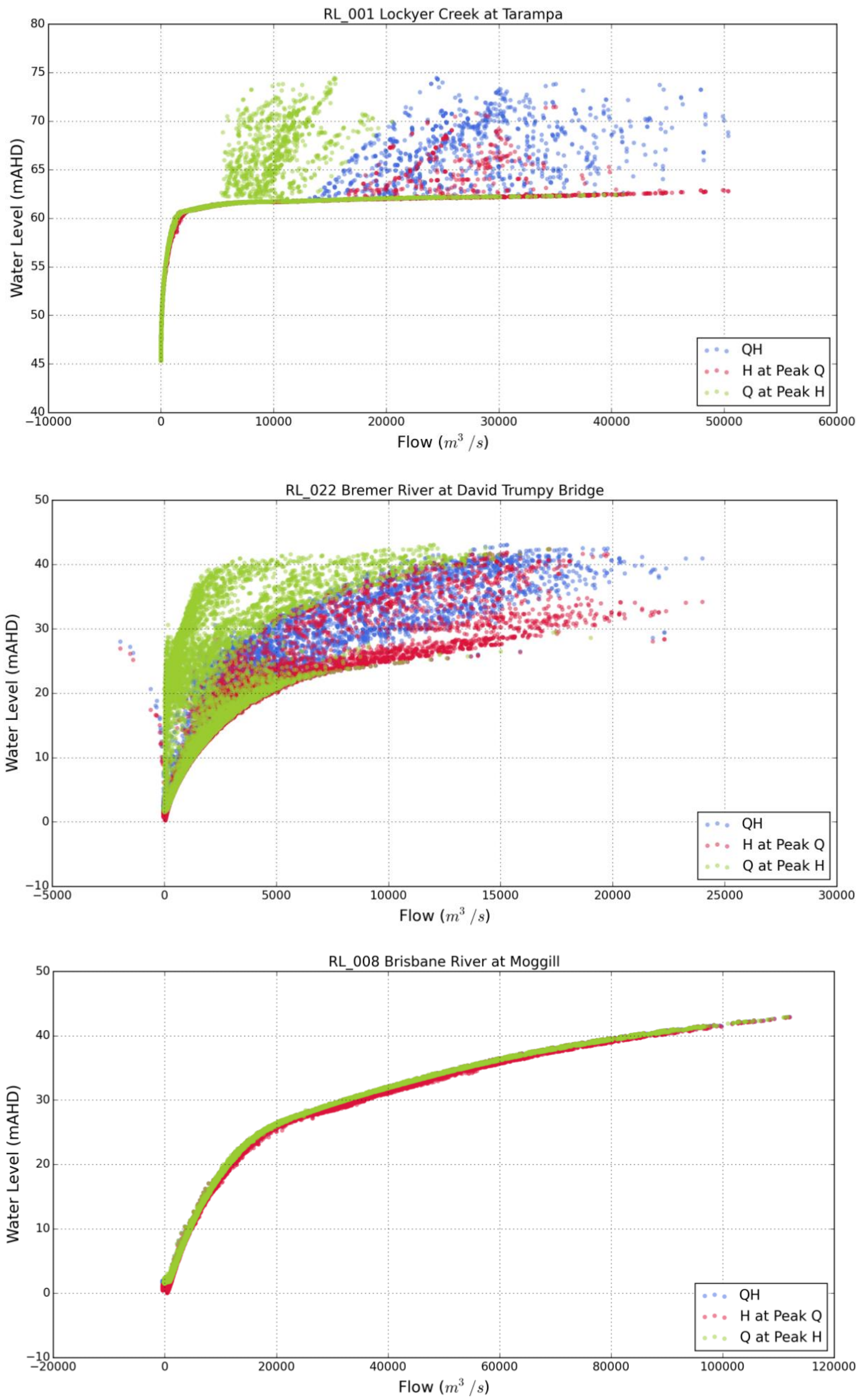


Figure 3-6 Examples of Water Level versus Flow at Peak Level and Peak Flow Plots

3.3.4 Maximum Change in Water Level over One Timestep

Plot 11 to Plot 13 chart the maximum change in water level (positive or negative) over one computational timestep that occurred during each of the 11,340 simulations at each of the Reporting Locations. The charts are shown as histograms with examples extracted from these plots for Tarampa, Tennyson and Brisbane City Gauge as presented in Figure 3-7.

The expected magnitude of the change in water level varies depending on the hydraulic characteristics of the location and the size of the event. Typically, upper catchment locations will experience greater maximum changes as the flood wave rises faster, than in the lower, slower rate of change locations such as would be expected in the Brisbane River. If an instability in the water level occurs, this will typically create a maximum value (positive or negative) in excess of the values from stable simulations.

Where there are no outliers forcing large values along the X-axis to occur, this indicates the model is running smoothly with no numerical instabilities. Conversely, where uncharacteristically large X-axis values occur, this is an indication that the model for the events causing these large values, may have experienced numerical instabilities and the peak water level values, if caused by the numerical instability, may be unrepresentative and needs to be investigated.

After the first pass of 11,340 simulations, several locations were identified as potentially being problematic, such as Tennyson where there are a handful of events that have caused the X-axis scale to be greater in extent than other Brisbane River locations – compare Tennyson with Brisbane City Gauge in Figure 3-7.

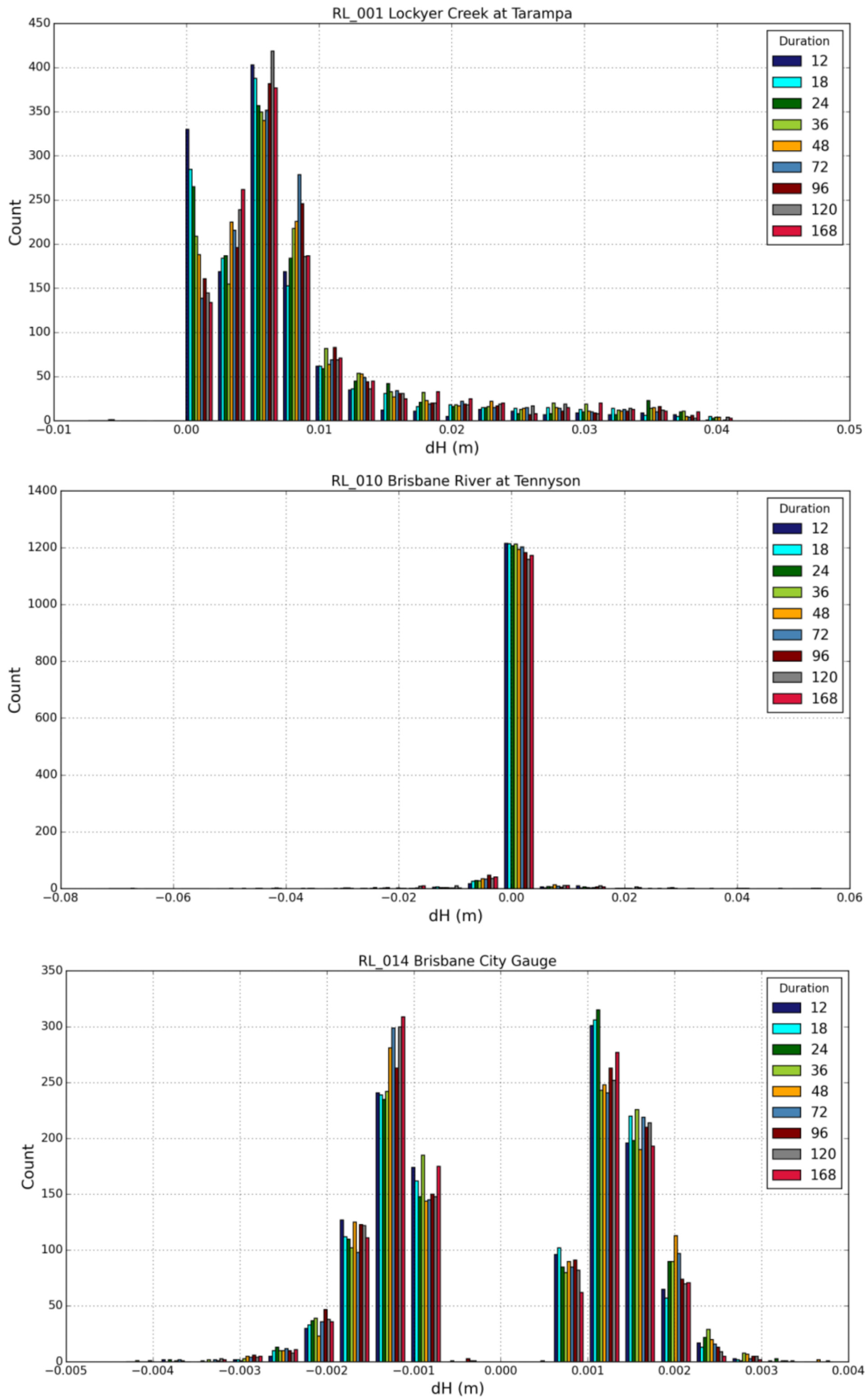


Figure 3-7 Examples of Maximum Change in Water Level over One Timestep Plots

3.3.5 Maximum Change in Flow over One Timestep

Similar to the previous section, Plot 14 to Plot 16 show the maximum change in flow (positive or negative) over one computational timestep that occurred during each of the 11,340 simulations at each of the Reporting Locations. The charts are shown as histograms with examples for the same locations as for maximum water level change presented in Figure 3-8.

As for the change in water level charts, where there are no outliers forcing large values along the X-axis to occur, this indicates the model is running smoothly with no numerical instabilities. Conversely, where uncharacteristically large X-axis values occur this is an indication that a numerical instability may have occurred and the peak flow, if caused by the instability, may be unrepresentative and needs to be investigated.

Examples of potentially problematic locations are Tarampa and Tennyson as shown in Figure 3-8, where the X-axis scale indicates there were events with substantial changes in flow over one timestep well beyond the norm, while for Brisbane City Gauge the magnitude of the X-axis scale indicates there were no instabilities of any note in the flow calculations. The process used to deal with these potentially problematic locations is discussed in Section 3.4.

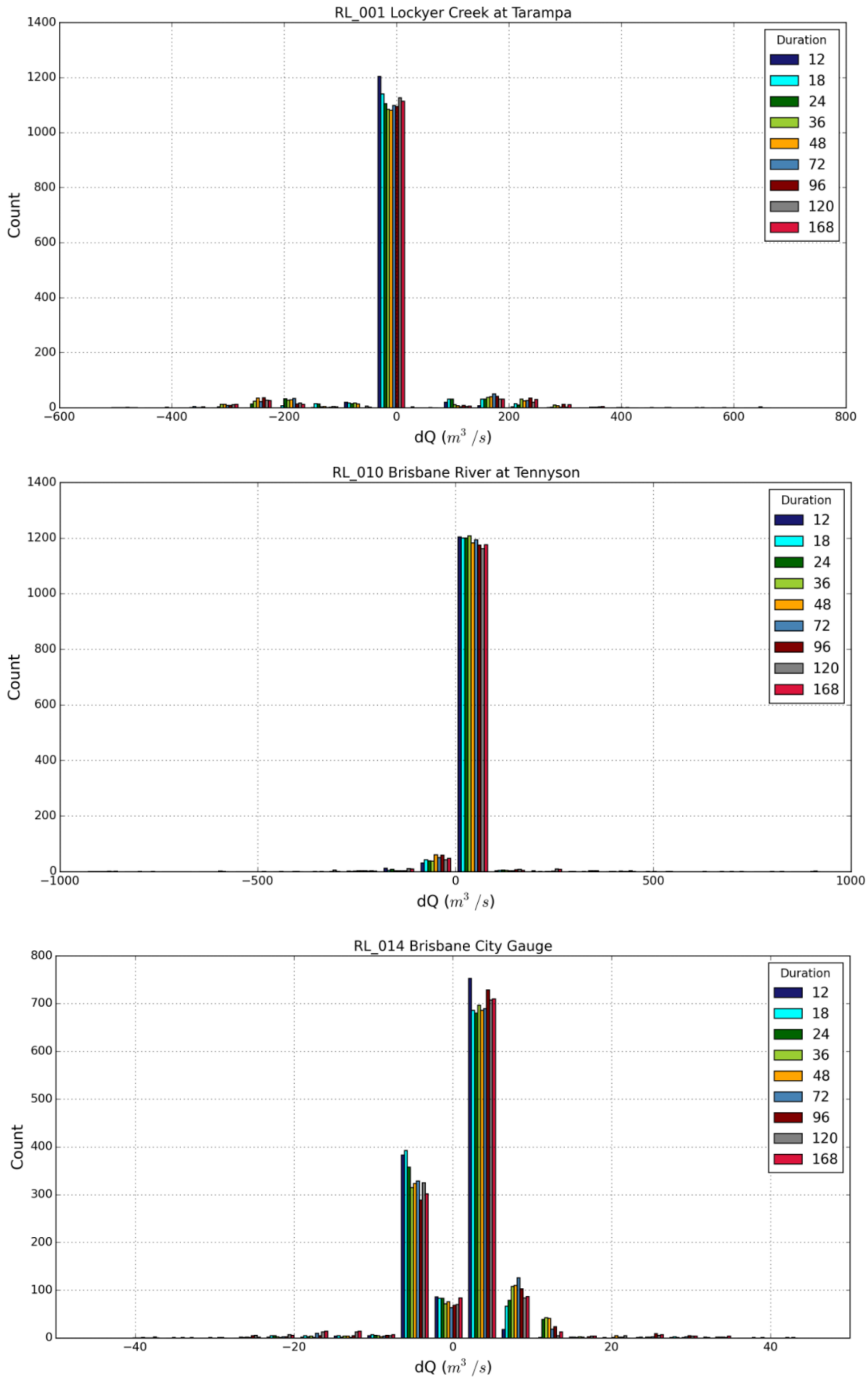


Figure 3-8 Examples of Maximum Change in Flow over One Timestep Plots

3.3.6 Time of Peak Water Level

Plot 17 to Plot 19 show frequency charts of the time of peak water level. The bars are coloured according to the rainfall duration, therefore, the expectation is that the peak water level for the shorter duration events would tend to occur earlier than the longer durations. Note, longer duration events can potentially have shorter duration bursts near the start of the event, therefore it is possible that some long duration events may experience an early peak.

Figure 3-9 presents an example of one of the plots at Moggill.

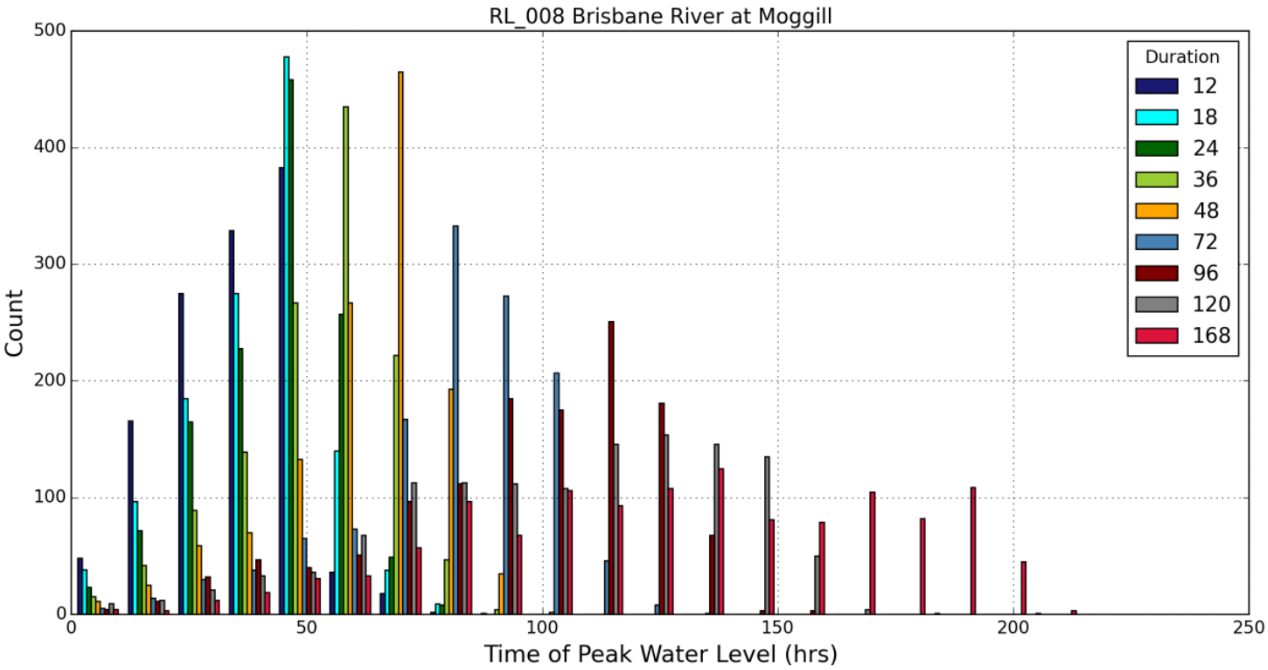


Figure 3-9 Example of Time of Peak Water Level Plots

3.3.7 Time of Peak Flow

Similar to the plots of time of peak water level, Plot 20 to Plot 22 show charts of time of peak flow. The bars are coloured according to the rainfall duration, therefore, the expectation is that the peak flow for the shorter duration events would tend to occur earlier than longer durations. Note, longer duration events can have potentially having shorter duration bursts near the start of the event, therefore it is possible that some long duration events may experience an early peak.

Figure 3-10 presents an example of one of the plots at Moggill.

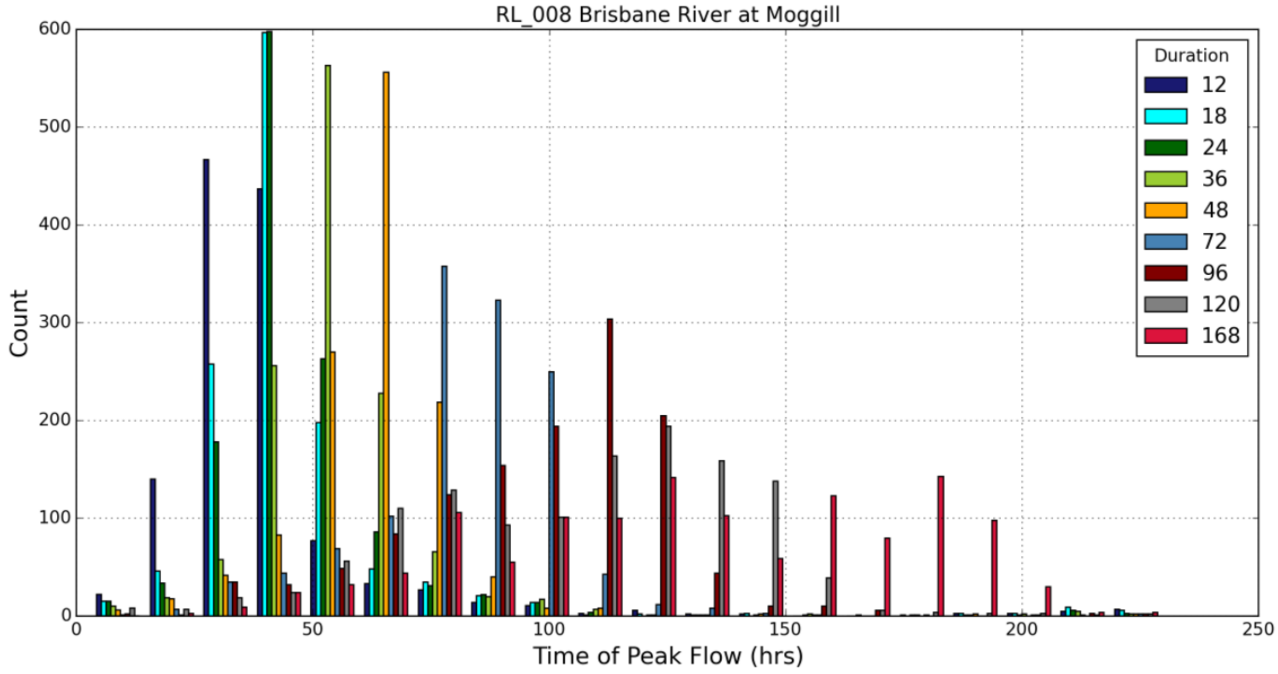


Figure 3-10 Example of Time of Peak Flow Plots

3.4 Isolating or Correcting Invalid Peak Water Levels and Flows

Review of the outputs described in Section 3.3 highlighted that the vast majority of Fast Model simulations showed no signs of numerical instabilities. However, based on the review of the maximum changes in water level and flow over one timestep (Section 3.3.4 and Section 3.3.5), several Reporting Locations potentially have a small percentage of events may have experienced a numerical instability. These events were identifiable by having an unusually large change in water level and/or flow over one computational timestep. The locations of Tarampa and Tennyson are good examples.

Initially, some of these events were manually identified and the time histories of water level and flow were plotted at the problematic location(s), along with the peak water level and flow.

An example of one of these plots is shown in Figure 3-11 for Tennyson. The water level hydrograph (based on model outputs at one hourly intervals) is shown as a black line and the peak water level (based on tracking the peak level across each computational timestep) as a dark purple circle/value. Close inspection shows the tracked peak water level sits above the peak water level of the hydrograph. More easily identifiable is the instability in the flow. The peak flow is shown as a red circle/value and the flow hydrograph as the blue line. The maximum change in flow over one timestep is the black value (984). The maximum value from the flow hydrograph (blue line) is shown as the green circle/value. In this example, the instability in the flows has caused a higher peak water level.

Options to rectify or handle these instabilities were:

- Remove the results for these events from the database of peak water levels and flows used for the AEP level frequency analysis. As the number of events was only a small percentage at only several of the Reporting Locations, this was considered a viable option.
- Make minor enhancements to the Fast Model to remove/reduce the number of instabilities.
- For these events, replace peak water levels and peak flows with the maximum values from the time-series hydrographs.

The approach adopted was firstly to check the Fast Model at problematic locations, and if possible, improve the stability of the model for these events. This was carried out, the Fast Model calibration cross-checked for no change to results, and the 11,340 runs re-simulated. Of note is that in many cases the problematic events were of a rare AEP, ie. extreme events. The changes to the Fast Model were very minor, and had no demonstrable effect on the Fast Model's results elsewhere or on the model's calibration to historical events.

A second review still highlighted the presence of problematic events. These events were filtered out by the process described in the following section, and the approach of replacing the invalid peak water level and/or flow with the hydrograph maximum was adopted so as to retain a complete set of 11,340 events for the AEP level frequency analysis.

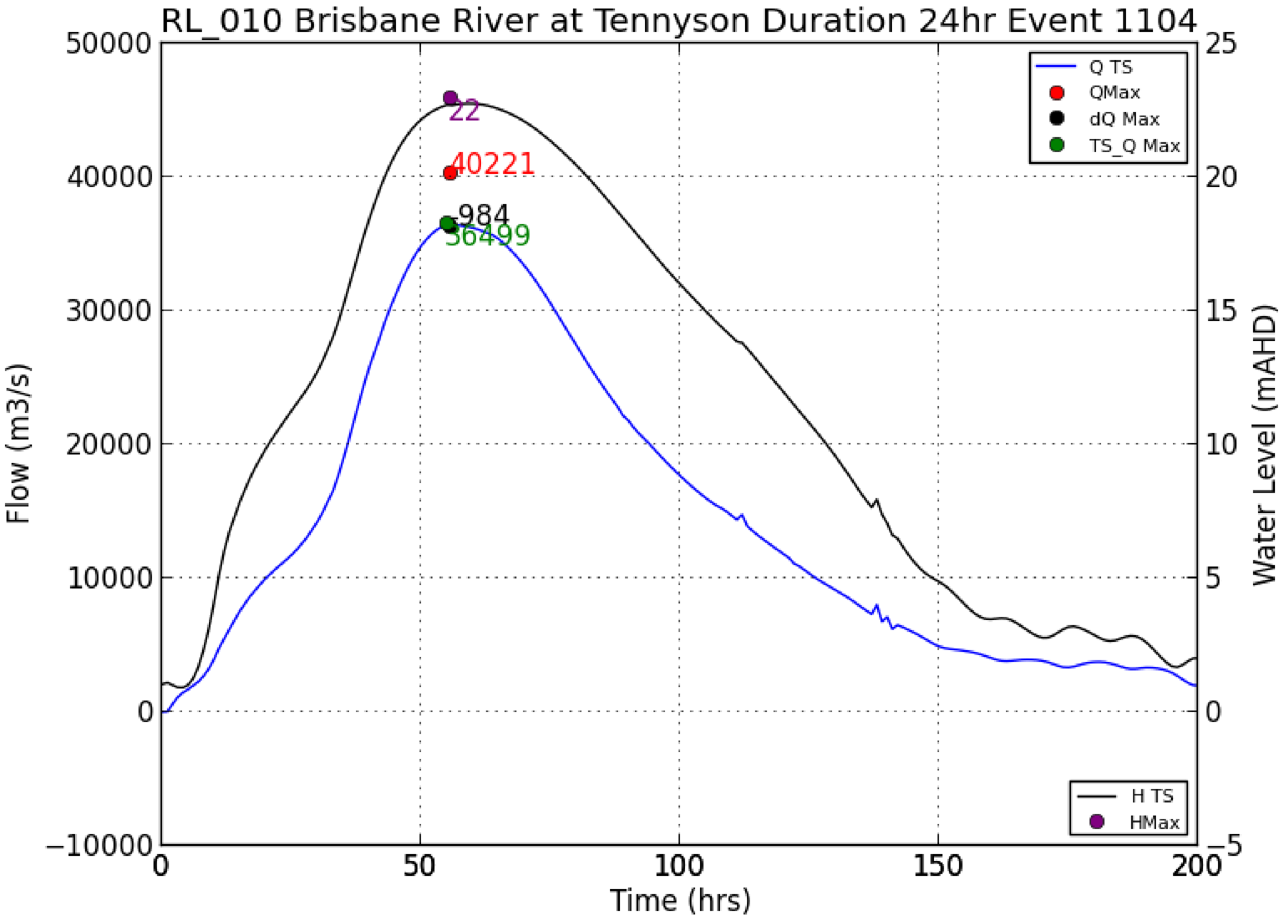


Figure 3-11 Example of Plots used to Identify Numerical Instabilities

3.4.1 Approach to Correcting Invalid Peak Water Level and Flows

Potentially invalid peak water levels were identified through a filtering process that compared the peak water level with the maximum water level from the time series water level hydrograph at all Reporting Locations for all 11,340 events (ie. 317,520 hydrographs). A tidal zone filter also needed to be applied as discussed below.

The primary filter applied was that the peak water level exceeded the hydrograph maximum by more than 0.15m. Where this occurred, the Reporting Location and Event ID were logged, and the peak water level was replaced by the level hydrograph maximum. The value of 0.15m was chosen, partly through trial and error, and to be preferably equal to or less than the smallest ITO desired flood accuracy value (±0.15m). Correcting an excessive number of numerically stable hydrographs would start to distort the peak water level database. Therefore, if too small a filtering tolerance was adopted, numerous sites/events would be selected that show no signs of instabilities, as it is possible for the peak level within the one hour time-series hydrograph output interval to vary by up to around 0.1m.

It was also necessary to apply a tidal zone filter based on the maximum of the water level hydrograph needed to exceed 2.0 mAHD because the water level within the time-series hydrograph one hour interval could readily exceed the 0.15m filter tolerance in tidally dominated areas with little or no flood flows (ie. for frequent AEP events).

Of the 317,520 hydrographs (11,340 events times 28 Reporting Locations), 6 cases were filtered out. Three were at Wivenhoe Dam Tailwater, two at Tennyson and one at Tarampa, with differences between the peak water level and the hydrograph maximum varying from 0.16m to 0.30m. They were all for events in excess of 20,000m^3/s.

Similarly, potentially invalid peak flows were identified and the peak flow values set to the flow hydrograph maximum through a similar process to that described for peak levels in the previous section. Whilst flows are not the focus of the Monte Carlo AEP frequency analysis presented in Section 4, correcting any peak flows was considered worthwhile to minimise any data noise in the peak flow database.

The filters applied were:

- The peak flow must exceed the flow hydrograph maximum by +5%.
- The maximum change in flow over one timestep needed to be greater than ±5% of the flow hydrograph maximum. This filter was needed to not select stable locations/events that experienced a rapid change in flow (for example, when the flood wave first travels through), yet demonstrated numerical stability.
- A minimum flow rate roughly estimated between the 50% and 20% AEP values available from a preliminary AEP frequency analysis. This filter was particularly required at locations that peaked due solely to backwater flooding (for example, at Wivenhoe Dam Tailwater when there was no flow out of Wivenhoe Dam).
- The water level tidal filter of 2.0 mAHD to isolate sites that experienced a peak flow nearly entirely due to tidal propagation.

Of the 317,520 hydrographs, 156 locations (0.05%) were filtered out from 152 events as potentially having an unreliable peak flow. The breakdown at locations was 9 at Tarampa, 6 at Lyons Bridge, 2 at Wivenhoe Dam Tailwater, 6 at Lowood, 8 at Mt Crosby, 54 at Woogaroo Creek, 3 at Tennyson and 68 at Rocklea on Oxley Creek. Not all of the 156 cases were considered numerically unstable, however, given the inconsequential effect on the AEP level frequency analysis that changing the peak flow to the flow hydrograph maximum for these 0.05% of cases has, there was no manual intervention.

Figure 3-12 provides an example of a case correctly *not* selected. As shown, a numerical instability did occur (as evidenced by the high maximum change in flow over one timestep value shown by the black circle/value), but results were stable at the occurrence of the peak flow and therefore did not require adjustment. Figure 3-13 shows a case that *was* selected, where the peak flow (red dot/value) is clearly invalid and therefore required adjustment to reflect the flow hydrograph maximum (green value).

3.4.2 Logic Applied to Correcting Invalid Peak Water Level and Flows

The general logic applied to carry out the above filtering is as follows where:

- Q Max = Reporting Location peak flow rate – (All timesteps)
- dQ Max = Reporting Location peak change in flow over one timestep – (All timesteps)
- TS_Q Max = Reporting Location peak flow rate – (From hourly timeseries output)
- Hmax = Reporting Location peak level – (All timesteps).

To identify runs that experienced oscillations, results for each run at each Reporting Location were subjected to a series of tests. These tests were based either on flow rate or water level results.

The amendment of results was a two-step process, comprising:

(1) Screening of results for erroneous behaviour; and

(2) Amendment of peak recorded flows or levels based on hourly timeseries results.

This screening and amendment process is detailed further as follows for peak flows and levels respectively:

Global Screens (irrespectively of flow or water level checks)

- Peak water levels needed to exceed 2m at any time during the simulation.
- Flow rates needed to exceed the 5% AEP flow rate, based on preliminary AEP frequency analysis, at each respective location, at any time during the simulation.

Screening for Peak Flow Issues

- The Reporting Location peak change in flowrate over one timestep (dQ Max) needed to exceed ±5 % of the Reporting Location peak flowrate (Q Max). This exceedance could occur at any time during the simulation; or

- The difference between the Reporting Location peak flow rate (Q Max) and the peak flow rate from the one hourly timeseries output (TS_Q_Max) needed to be greater than ±5% of the hourly timeseries peak flow (TS_Q_Max).

Amendment of Peak Flow Issues

- If a location was selected by the above, then TS_Q_Max was used to replace the Q Max value. These events were marked with a '1' indicating they had been amended.

Screening for Peak Level Issues

- The difference between the Reporting Location peak level (H Max) and the peak level from the one hourly timeseries output needed to be greater than ±0.15m of the hourly timeseries peak flow.

Amendment of Peak Level Issues

- If a location was selected by the above, then the time series maximum water level was used to replace the H Max value. These events were marked with a '1' indicating they had been amended.

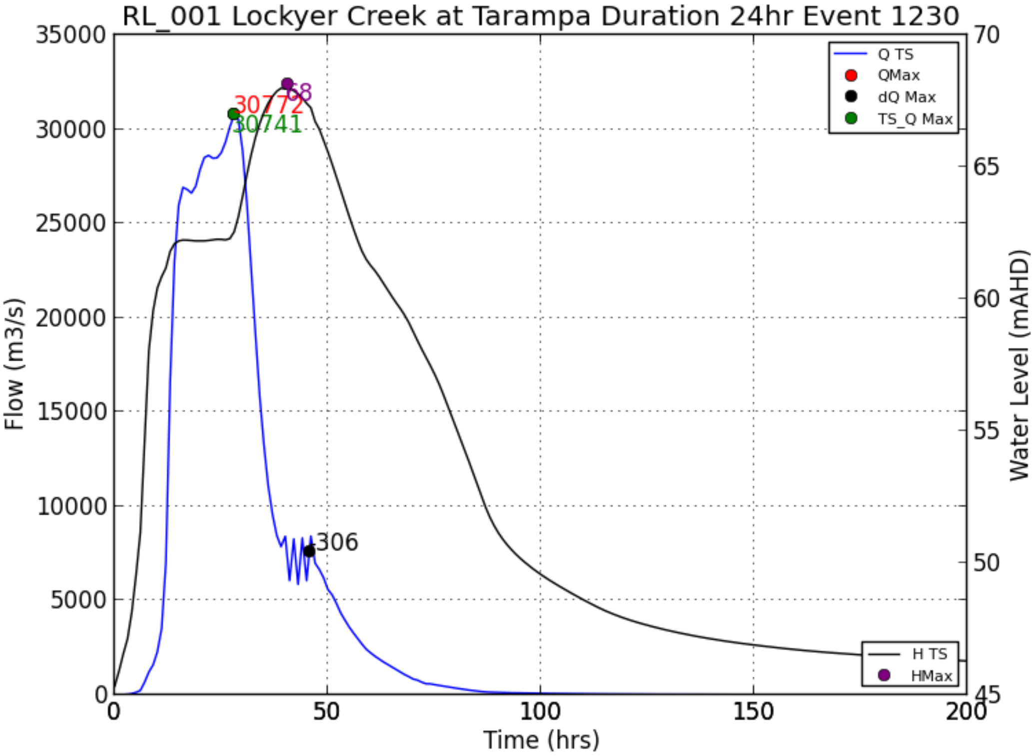


Figure 3-12 Example of a Numerical Instability Not Needing Correction

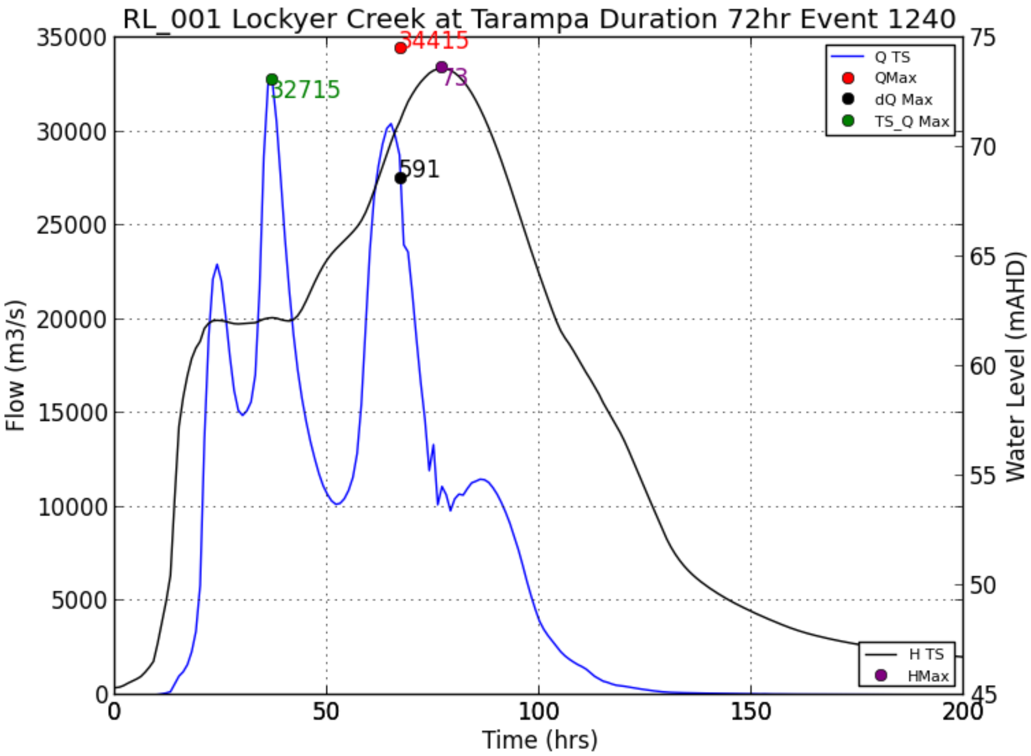


Figure 3-13 Example of a Numerical Instability Needing Correction

4 Monte Carlo AEP Analysis

4.1 Introduction

This section summarises the analyses undertaken to derive level frequency relationships (ie. the relationships between maximum flood level and Annual Exceedance Probability) for all Reporting Locations (identified in Table 2-3). All analysis is undertaken with Wivenhoe and Somerset Dams in place.

4.2 Data Provision

The analysis utilised the database of peak water levels and flows generated by the Fast Model for the 11,340 events. The database consists of 1,260 runs for 28 reporting sites for 9 durations (12, 18, 24, 36, 48, 72, 96, 120, 168 hours), which represents the peak levels at 28 Reporting Locations from a total of 11,340 separate simulations.

For each Reporting Location the following was provided by the Hydrologic Assessment (Deltares, 2015) combined with the Fast Model results for the 11,340 events:

- Location identifier
- Storm duration
- Event identifier
- Peak flow (m^3/s)
- Peak level (mAHD)
- Annual exceedance probability for the rainfall depth over the whole of the Brisbane River catchment (dimensionless)
- Annual exceedance probability for the rainfall depth over the subcatchment upstream of the site (dimensionless)
- Rainfall depth over the whole Brisbane River catchment and the sub-catchment upstream of the site (mm)
- Peak flow rate at Brisbane City gauge (m^3/s)
- Peak flow (m^3/s) at peak level (m AHD), and vice versa.

It is to be noted that the rainfall depths were provided by Deltares (2015) (and reported upon by Aurecon *et al* (2015a)), and that the estimates of AEPs corresponding to the local and whole-of-catchment rainfall depths were obtained by log-Normal interpolation (and extrapolation) of the IFD design data provided by Aurecon *et al* (2015b).

4.3 Flood Level Frequency Analysis

The general approach adopted to estimate annual exceedance probabilities (AEPs) of the maximum river levels is based on use of the Total Probability Theorem. The adopted solution was first developed for this type of Monte Carlo scheme by Nathan and Weinmann (2002), and is described in more detail in Nathan and Weinmann (2013).

For this implementation, the probability domain was divided into 24 intervals (with evenly spaced standardised normal variate bounds) between AEPs of 1 in 2 to 1 in 10^6. The number of simulation results that fell within each interval varied generally between 30 and 50. Within each probability interval, conditional probability estimates were derived for a total of 50 threshold levels, where the levels were selected to vary uniformly between the minimum and maximum values obtained from the set of 1,260 simulation results.

The expected probability that a flood level (*H*) exceeds a particular threshold value *h* was calculated from:

$$p(H > h) = \sum_i p[H > h \mid R_i]\, p[R_i]$$

where the term $p[R_i]$ represents the probability that rainfall occurs within the interval *i*, and the term $p[H>h|R_i]$ denotes the conditional probability that the flood level *H* generated using a rainfall depth from within this interval R_i exceeds *h*.

An example illustration of the information used to calculate the expected probabilities of the maximum levels at each site is shown in Figure 4-1. The plot shows the peak levels at Savages Crossing obtained from 1,260 simulations of flows resulting from 72 hour rainfall bursts (small circle symbols). These levels are plotted at AEPs corresponding to rainfalls over the whole Brisbane River catchment, as determined from the design rainfall information.

It is seen that there is considerably more scatter at frequent events than there is evident for rarer events; this merely reflects the fact that the flows rarer than $1{:}10^4$ AEP were derived using fixed patterns of rainfall and those more frequent reflect the variability present in the spatially-varied temporal patterns, and for some sites, the more influential effect of Wivenhoe Dam on frequent events compared with extreme events. The blue curve represents the expected probability quantiles derived using the Total Probability Theorem, and (as expected) it is seen that this curve sits centrally within the scatter of points. There are a small number of maxima for events more frequent than the left hand limit of the plot (around 1 in 1.7 AEP), and while these points do contribute to exceedances of the lowest threshold considered, their influence is negligible.

Also shown in Figure 4-1 is the 1% AEP flood level derived using the Total Probability Theorem. It is of interest to note that the rainfall AEPs contributing to this estimate range between 1 in 20 and 1 in 2,000. That is, there are occasions in which a 1 in 20 AEP rainfall falls on a very wet catchment and produces a flood level with an AEP of 1 in 100; at the other end of the extreme, it is seen that there are 1 in 2,000 AEP rainfalls that occur on a very dry catchment that yield the same flood level. Of course, it is not merely antecedent catchment conditions that influence this flood response, as the temporal and spatial patterns of rainfall also influence the nature and timing of flood response. A worked example of how the expected probabilities are computed using the Total Probability Theorem is provided in Section 7.4 of Nathan and Weinmann (2013).

Once the expected probability quantiles were derived for each duration, the final relationship between maximum level and annual exceedance probability was derived as the envelope of all durations. An example family of such curves and the resulting envelope curve is shown in Figure 4-2.

The application of this scheme to the Fast Model simulation results is conceptually straightforward, though a bespoke framework was developed to suit the large number of sites and the nature of the data sets involved. The premise of the above scheme is that rainfalls have a dominant role in the production of peak river levels, but that the maxima will vary due to the joint occurrence of other factors. This is a defensible assumption for riverine flooding, but special attention needed to be given to sites located on tributaries of the main channel of the Brisbane River (eg. the Bremer River). This situation is given further attention in Appendix C.

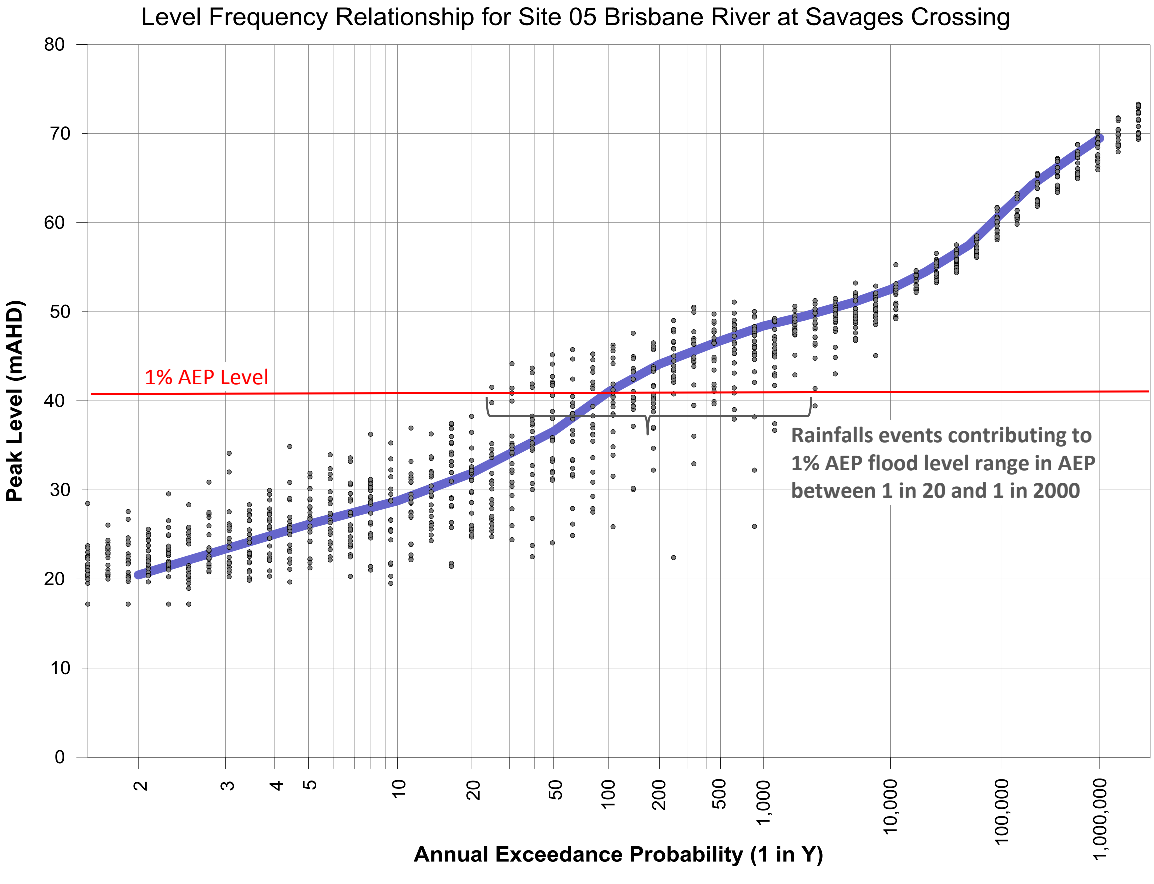


Figure 4-1 Example Level Maxima and Derived Level Frequency Relationship for 72 hour Event at Savages Crossing

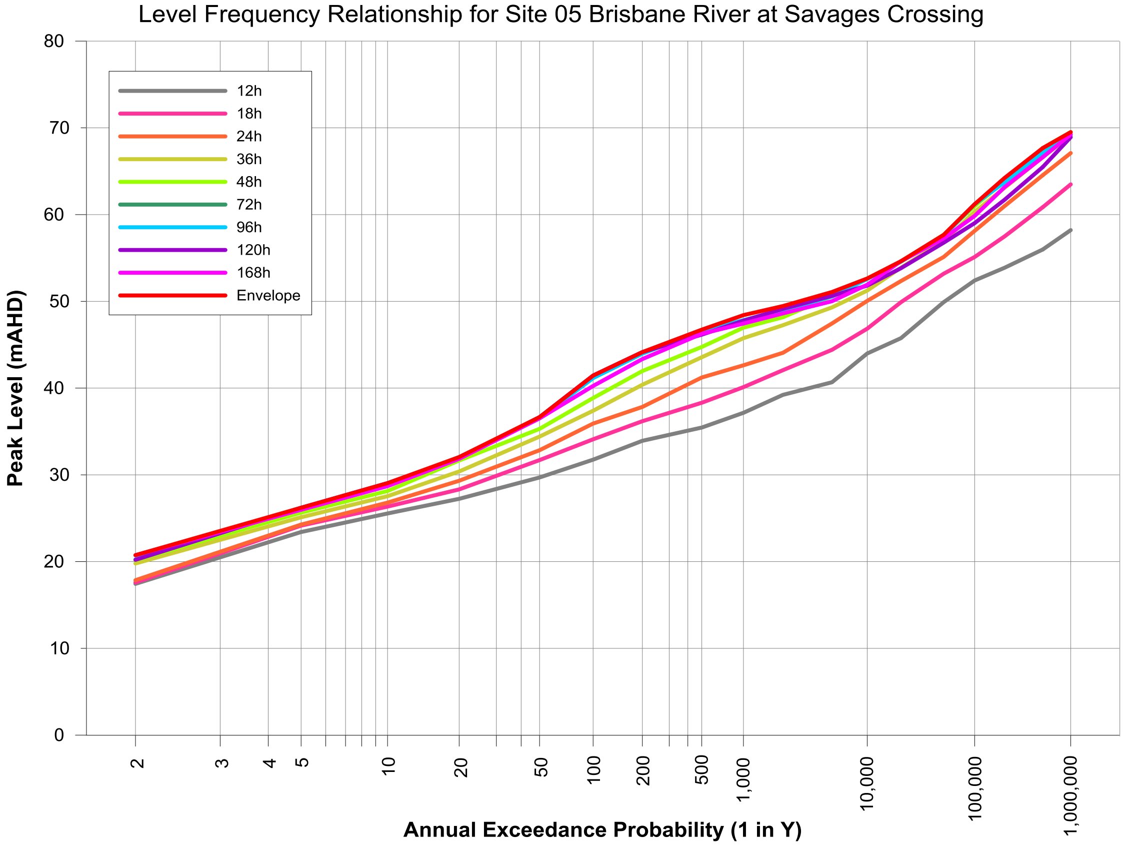


Figure 4-2 Example Frequency Relationships for All Durations at Savages Crossing, and the Envelope of Level Maxima with AEP

4.4 Results for Mainstream Brisbane River Sites

Results for Reporting Locations along the Brisbane River are shown in Figure 4-3 and Figure 4-4 respectively. Detailed results for all locations showing the information contained in Figure 4-1 and Figure 4-2 are provided in tabulated form in Appendix D and graphically in Plot 23 to Plot 36. Key numerical results for all reporting sites are shown in Table 4-1 (noting that the results for Site 14, Brisbane City Gauge, are identical to those provided for Brisbane Port Office).

It is a little difficult to compare these results to historic maxima as they only relate to conditions since construction of Wivenhoe Dam. However, on the basis of the records available, the estimated AEP of selected historic floods are summarised in Table 4-2. The results indicate that the annual exceedance probability of the 2011 event varied by location between around 1 in 100 AEP to 1 in 140 AEP. The slight variation in results either reflect the influence of sampling variability in the simulations, or else real differences in levels associated with localised conditions; either way, the consistency in these results is re-assuring.

Monte Carlo AEP Analysis

Table 4-1 Summary of Level Frequency Relationships for Reporting Sites (m AHD)

		Annual Exceedance Probability (1 in Y)														
Site	Name	2	5	10	20	50	100	200	500	1000	2000	5000	10000	20000	50000	100000
1	Lockyer Creek at Tarampa	45.75	57.01	59.35	60.52	61.00	61.28	61.40	61.61	61.70	61.77	61.86	61.93	62.03	62.19	62.45
2	Wivenhoe Dam Tailwater	23.76	32.08	35.09	38.66	43.21	47.16	48.83	49.84	50.38	51.11	52.45	53.82	55.69	58.70	62.07
3	Lockyer Creek at Lyons Bridge	48.01	60.22	62.49	64.28	64.94	65.29	65.64	65.91	66.10	66.28	66.48	66.60	66.84	67.01	67.11
4	Brisbane River at Lowood Pump Station	22.82	30.22	33.02	36.11	40.72	45.31	47.39	48.50	49.38	50.31	51.88	53.35	55.38	58.39	61.80
5	Brisbane River at Savages Crossing	20.74	26.20	29.05	32.05	36.65	41.46	44.15	46.74	48.41	49.46	51.08	52.64	54.63	57.67	61.20
6	Brisbane River Upstream Mt Crosby Weir	7.46	10.45	12.41	15.29	20.10	25.35	28.43	31.54	33.55	35.04	36.88	38.44	40.38	42.70	45.22
7	Brisbane River downstream Mt Crosby Weir	4.44	9.13	11.69	14.93	19.68	24.86	27.90	30.98	32.99	34.55	36.41	38.00	39.86	42.23	44.76
8	Brisbane River at Moggill	1.76	4.41	7.04	9.98	14.33	17.92	20.14	22.61	24.11	25.70	27.17	28.77	30.85	33.53	35.85
9	Brisbane River at Jindalee	1.57	2.55	3.96	6.08	9.39	12.13	13.82	15.71	16.94	18.72	20.53	22.31	24.54	26.76	28.67
10	Brisbane River at Tennyson	1.53	2.08	2.91	4.42	7.12	9.23	10.69	12.52	13.75	15.46	17.42	19.74	22.51	25.11	27.19
11	Brisbane River at Fairfield	1.51	2.02	2.64	3.85	6.29	8.13	9.55	11.43	12.60	14.26	16.37	19.14	21.67	24.22	26.39
12	Brisbane River at Toowong	1.52	1.92	2.32	3.25	5.07	6.69	8.01	9.82	11.04	12.67	15.00	17.59	20.08	22.27	24.27
13	Port Office Gauge/City Gauge	1.56	1.84	1.98	2.34	3.45	4.52	5.40	6.77	7.67	8.93	10.87	12.73	15.51	18.33	20.59
15	Brisbane River at Hawthorne	1.57	1.73	1.82	1.89	2.40	2.94	3.50	4.14	4.79	5.58	6.82	8.33	10.29	12.38	14.11
16	Brisbane River at Gateway Bridge	1.55	1.64	1.69	1.76	1.86	2.07	2.38	2.78	3.08	3.37	3.93	4.82	5.94	6.95	7.73
17	Warrill Creek at Amberley	20.84	25.79	27.01	27.71	28.14	28.43	28.65	28.98	29.36	29.82	31.06	32.02	32.86	34.25	36.56
18	Purga Creek at Loamside	22.26	26.55	27.06	27.51	27.85	28.13	28.34	28.71	29.35	29.78	31.05	32.06	32.77	34.44	36.49
19	Bremer River at Walloon	19.78	25.18	26.25	27.07	27.74	28.43	28.81	29.25	29.51	30.14	31.32	32.08	32.75	34.55	36.50
20	Bremer River at Three Mile Bridge	12.46	19.56	21.81	23.09	24.81	25.86	27.07	28.09	29.08	29.60	31.13	31.95	32.80	34.36	36.50
21	Bremer River at One Mille Bridge	7.71	16.60	19.47	21.07	23.24	24.65	26.26	27.44	28.53	29.13	30.64	31.75	32.38	34.34	36.41
22	Bremer River at David Trumpy Bridge	2.06	10.05	13.19	15.23	18.14	20.26	21.91	23.51	24.83	26.11	27.58	29.01	31.10	33.65	35.97
23	Bremer River at Hancock Bridge	2.31	11.66	15.22	17.30	20.17	21.98	23.61	24.94	25.92	26.85	27.90	29.09	31.18	33.75	36.06
24	Bremer River at Bundamba Confluence	1.83	7.38	10.19	12.48	16.02	18.66	20.92	23.38	24.72	26.04	27.60	29.01	31.07	33.63	35.95
25	Bremer River at Warrego Highway	1.80	6.13	8.72	11.53	15.53	18.61	20.92	23.32	24.70	26.03	27.59	28.99	31.06	33.63	35.94
26	Bundamba Creek at Hanlon St Alert	0.78	5.62	10.09	12.53	16.01	18.69	20.70	23.23	24.61	26.13	27.58	29.05	31.22	33.75	35.85
27	Woogaroo Creek at Brisbane Road Alert	1.35	3.50	5.69	8.34	12.55	15.92	17.94	20.38	21.90	23.55	25.50	27.41	30.08	32.77	35.13
28	Oxley Creek at Rocklea	1.50	2.44	3.56	4.80	7.34	9.37	10.93	12.73	13.84	15.53	17.54	20.21	22.58	25.16	27.24

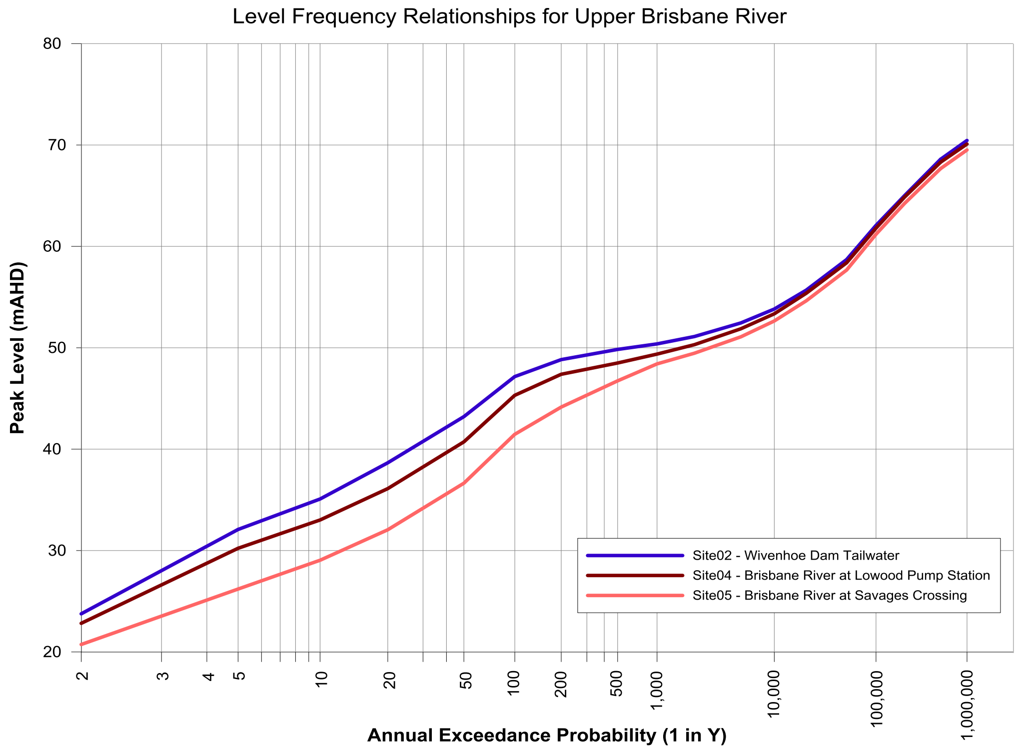


Figure 4-3 Derived Level Frequency Relationships for Sites along the Upper Reaches of the Brisbane River

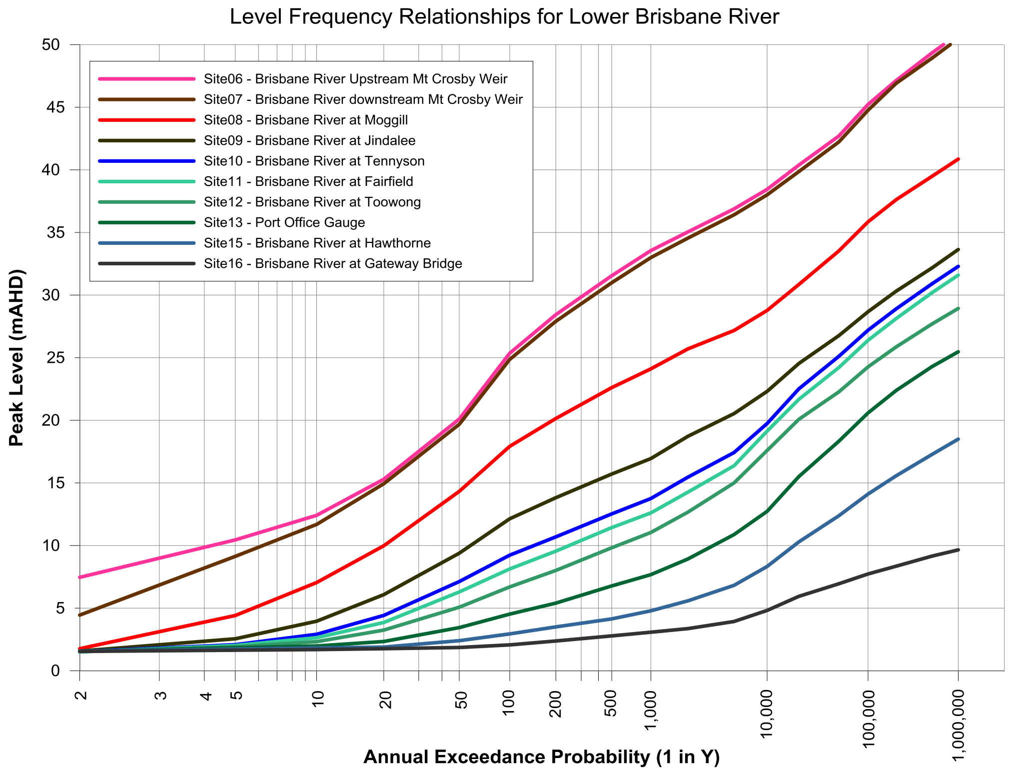


Figure 4-4 Derived Level Frequency Relationships for Sites along the Lower Reaches of the Brisbane River

Table 4-2 Estimated AEP of the 2011 Historic Event along the Brisbane River

Site	Name	Year	Level (mAHD)	AEP (1 in Y)
4	Brisbane River at Lowood Pump Station	2011	46.29	140
5	Brisbane River at Savages Crossing	2011	42.58	130
6	Brisbane River Upstream Mt Crosby Weir	2011	26.18	120
8	Brisbane River at Moggill	2011	18.17	110
9	Brisbane River at Jindalee	2011	12.07	100
13	Port Office Gauge	2011	4.46	100

It is also worth comparing these results to those obtained by Aurecon *et al* (2015a,b) in the Hydrologic Assessment. To this end, the peak flows extracted from the Fast Model were analysed using the same approach as described above for levels. The site selected for this comparison is Savages Crossing (Reporting Location 05), as this location would be expected to be reasonably free of backwater effects due to conditions in the lower Brisbane River. The comparison between the two sets of results is shown in Figure 4-5, from which it is seen that there is a satisfactory level of agreement between the results. The difference in levels associated with the 1 in 2 AEP event may reflect differences in the treatment of the probability calculations of the first interval considered (this study adopts a geometric mean rather than arithmetic mean for computation of the conditional probabilities in the first and last intervals, as recommended in Nathan and Weinmann, 2013).

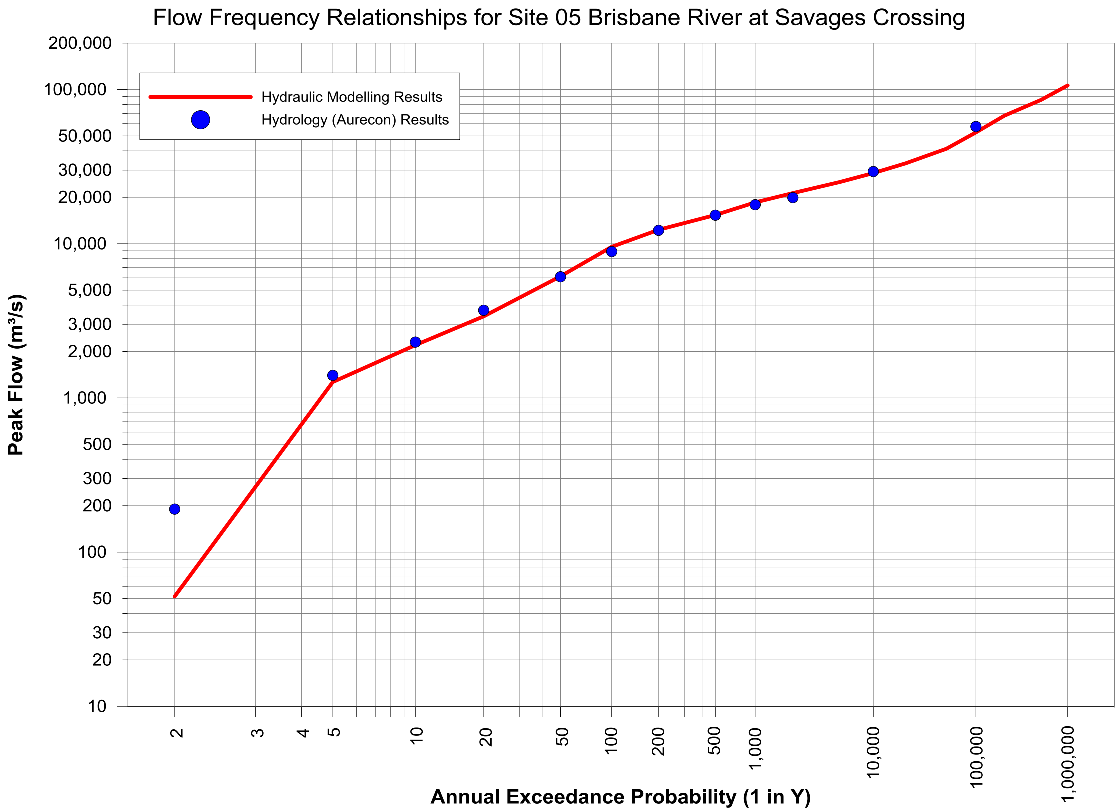


Figure 4-5 Comparison of Flood Frequency Relationships based on Results Obtained from the Hydrologic and Hydraulic Assessments

4.5 Results for Bremer River

Results for reporting sites along the Bremer River are shown in Figure 4-6. Detailed results for all sites showing the information contained in Figure 4-1 and Figure 4-2 are provided in tabulated form in Appendix D and graphically in Plot 23 to Plot 36. Numerical results for all reporting sites are shown in Table 4-1. It needs to be noted that these results are based on use of the whole-of-catchment rainfall AEPs as the conditioning variate in the computation of the Total Probability Theorem (i.e. “Option G” as discussed by the H&H working group and documented in Appendix A). A discussion on the rationale for this is given in Appendix C. The analysis presented in Appendix C highlights a number of issues in the input rainfall data, but overall it can be stated that:

(1) The difference in results obtained using AEPs from whole-of-catchment and local rainfalls (or upstream flows) is negligible for all but four sites in the vicinity of Ipswich.

(2) The four sites in the vicinity of Ipswich are subject to two major flood mechanisms, namely floods derived from local catchment rainfalls and those heavily influenced by flood levels in the Brisbane River; the latter mechanism dominates flows at these sites and thus it is considered that the best means of minimising bias is to use whole-of-catchment rainfalls as these most directly influence flood levels in the Brisbane River.

(3) Adoption of whole-of-catchment rainfalls yields results that are consistent with the frequency of historical floods and also with expected hydraulic behaviour, but this is not the case if local catchment rainfalls (or flow AEPs) are used.

(4) On the basis of the above, it was concluded that the whole-of-catchment rainfalls should be adopted as providing the best means of minimising bias in the derived expected probabilities.

It needs to be recognised that a longitudinal flood profile joining the AEP levels (i.e. a vertical section through the curves shown in Figure 4-6) does not represent the flood behaviour from any single event, and it cannot be expected that any single flood will conform to this profile. For example, the 1% AEP flood levels at each location represent the best estimate of flood risk based on the analysis of 11,340 events: it cannot be expected that any single hydraulic simulation will reproduce these levels at all reporting sites. While the AEP levels for the Reporting Locations in the vicinity of Ipswich are considered to provide the best available estimate of flood risk at those locations, the assumptions required to minimise bias in these estimates are perhaps less easily satisfied than those required for locations on the mainstream of the Brisbane River. Accordingly, while the nature of the hydrology and hydraulic simulation preclude a formal assessment of uncertainty, it is likely that the level AEP estimates in the tributary sites are more uncertain than those along the mainstream.

The information discussed in Appendix B also indicates that tributary hydrographs provided for the Hydraulics Assessment using whole-of-catchment rainfalls are somewhat higher than those adopted for the Hydrology Assessment based on local catchment rainfalls. It may be assumed that it is easier to derive a rainfall frequency distribution for smaller catchments, and thus it is likely that the level AEP estimates along the Bremer River are conservatively high. Without a detailed analysis of the different rainfall fields developed for the Hydrologic Assessment it is difficult to quantify the possible magnitude of this conservatism; however, given the uncertainties of other factors involved in transforming rainfall frequencies into flood levels, and the dependency on levels in the Brisbane River, this is not considered to be a material issue.

The estimated AEP of selected historic floods are summarised in Table 4-3. There are some interesting variations in these results that warrant further consideration, and these are included here for discussion purposes. It is seen that the results suggest that the AEP of the 2011 event at Ipswich is around 1 in 80, and that in general the AEP of the event becomes rarer with closer proximity to the Brisbane River. This reflects the observation that rainfalls in January 2011 were more extreme in the Brisbane catchment upstream of the Bremer confluence and therefore had a greater impact beyond the local catchment of Bremer River.

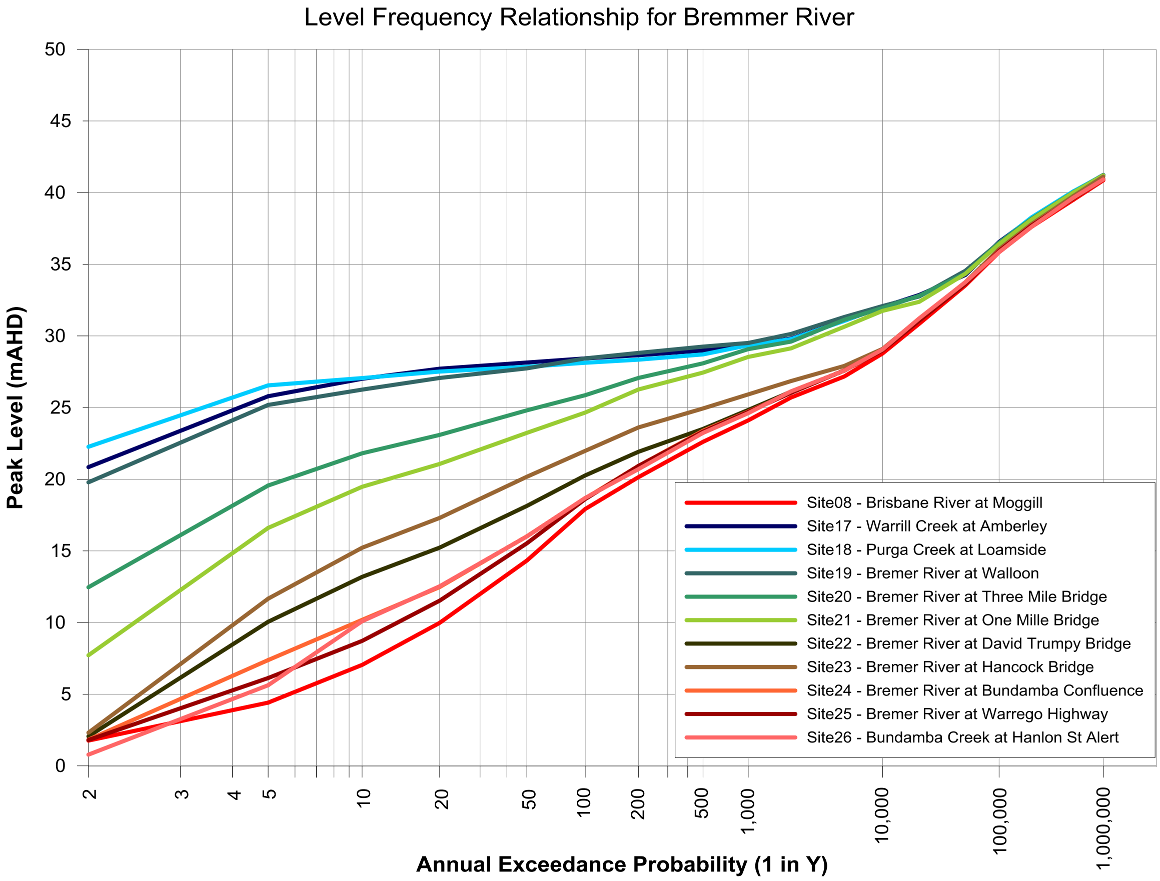


Figure 4-6 Derived Level Frequency Relationships for Sites along the Bremer River

Table 4-3 Estimated AEP of Selected Historic Events along the Bremer River

Site	Name	Year	Level (m AHD)	AEP (1 in Y)
17	Warrill Creek at Amberley	2013	27.79	25
18	Purga Creek at Loamside	2011	26.14	5
19	Bremer River at Walloon	2011	27.68	50
20	Bremer River at Three Mile Bridge	1999	17.26	5
21	Bremer River at One Mile Bridge	2011	21.98	30
22	Bremer River at David Trumpy Bridge	2011	19.30	80
26	Bundamba Creek at Hanlon St Alert	2011	19.40	130

As before, it is also worth comparing these results to those obtained by Aurecon *et al* (2015a,b) in the Hydrologic Assessment. Using the same approach as described above, peak flows for the Bremer River at Walloon (Reporting Location 19) were analysed and compared to the peak flows as derived by Aurecon. The comparison between the two sets of results is shown in Figure 4-7(a), from which it is seen that the flows derived from the Fast Model simulations (using whole-of-catchment rainfalls) sit counter-intuitively above that derived by Aurecon for the Hydrologic Assessment (using local catchment rainfalls). However, examination of Aurecon *et al* (2015) shows this effect stems from the differences between the local and whole-of-catchment inflows as shown in Figure 4-7(b), reproduced from Aurecon *et al* (2015). That is, the flow quantiles derived using results extracted from the Fast Model simulations are consistent with those provided by Aurecon *et al* (2015).

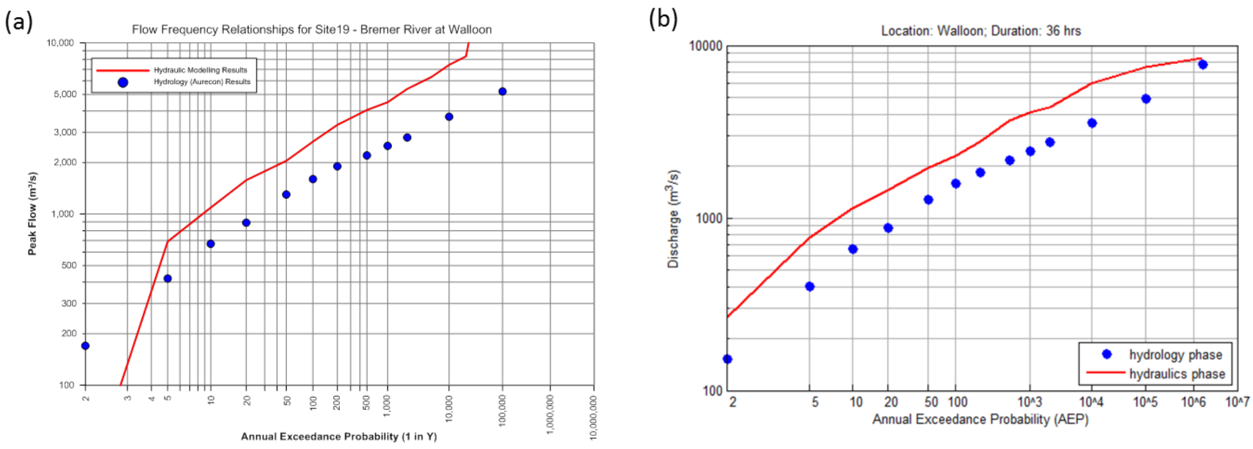


Figure 4-7 Comparison of flood frequency relationships at Walloon

(Based on results obtained from (a) the Hydrologic Assessment and analysis of flows from the Fast Model and (b) the Hydrologic Assessment using local catchment rainfalls (blue symbols) and whole-of-catchment rainfalls (red line), as provided in Aurecon *et al* (2015))

4.6 Results for Other Locations

Results for the remaining reporting sites along Lockyer Creek and Oxley Creek are shown in Figure 4-8. Again, detailed results for these sites showing the information contained in Figure 4-1 and Figure 4-2 are provided in tabulated form in Appendix D and graphically in Plot 23 to Plot 36. Numerical results for all reporting sites are shown in Table 4-1. These results are based on use of the whole-of-catchment rainfall AEPs as the conditioning variate in the computation of the Total Probability Theorem.

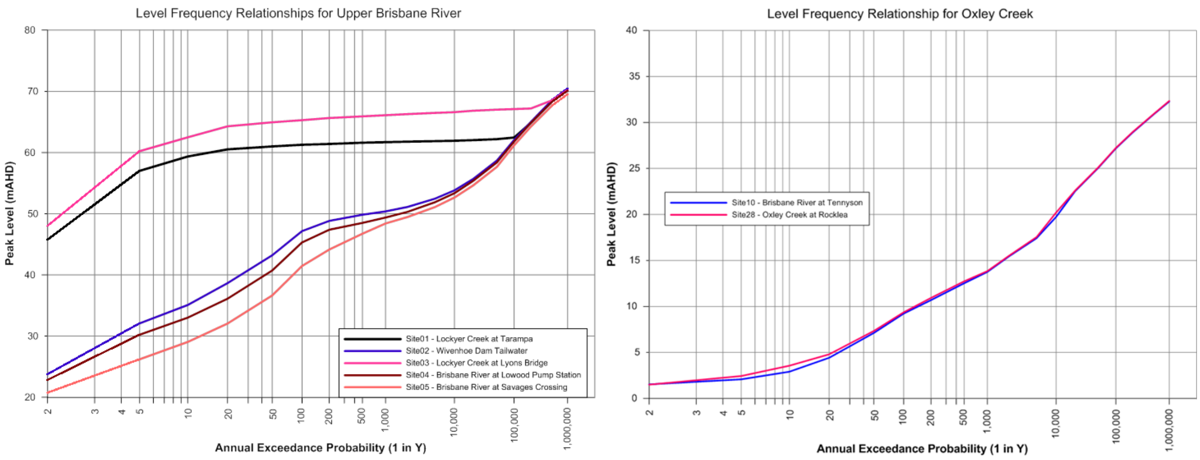


Figure 4-8 Flood level frequency relationships for sites along the Lockyer and Oxley Creeks

4.7 Sensitivity Analysis

An analysis was undertaken that varies parameters affecting the statistical analysis to help quantify the uncertainty associated with statistical noise or error generated by the analysis. Such uncertainty is best quantified by increasing the size of the sample, in this case by repeating the Hydrologic Assessment's Monte Carlo analysis to generate alternative sets of Monte Carlo events (ie. use different random number seeding). However, as this cannot be undertaken for practical reasons, the effect of varying parameters, such as reducing the sample size, was carried out. Details of this analysis are presented and discussed in Appendix E.

In general it is concluded that sample size ("sampling uncertainty") means that results are sensitive to the adopted discretisation (ie. the number and width of selected thresholds & interpolation). The sensitivity tests indicate the analysis has an uncertainty typically less than 1% of flow depth; this sensitivity can only be reduced by increasing the sample size as mentioned above. It is noted that the notional 1% uncertainty identified by these sensitivity tests on this aspect of the study is minor compared to the uncertainty in the estimation of the design rainfalls, their conversion to flood hydrographs, and the uncertainty inherent in the sample of events contained in a historic record that is very much shorter than the extrapolated extremes of interest. However, given that there is some sensitivity demonstrated to differing sampling approaches; it is recommended that the same threshold and bin discretisation sampling strategies used in this assessment are also used in potential future assessments to provide consistency. Should there be a justifiable reason to change the future sampling strategy, any issues associated with possible inconsistencies in results need to be considered and addressed as appropriate.

4.8 Conclusions and Observations

The analyses undertaken provide estimates of the annual probability that flood levels will be equalled or exceeded at each of the Reporting Locations based on the Fast Model simulation of 11,340 Monte Carlo events. The level frequencies were derived using a statistical approach was developed to minimise the bias in the associated expected probabilities. The approach used the exceedance probabilities of total catchment rainfalls as the conditioning variate. Some investigations were undertaken to determine whether use of an alternative variate would be more appropriate, and it was found that the results at all but four sites (in the vicinity of Ipswich) were insensitive to the adopted choice. These four sites are heavily influenced by levels in the Brisbane River; these levels are most dependent on rainfalls over the whole catchment, and it was thus considered appropriate to retain the results based on total catchment rainfalls.

The results are consistent with the flow quantiles derived during the Hydrologic Assessment. They are also consistent with expectations based on historical evidence and with expected hydraulic behaviour.

It should be noted that a longitudinal flood profile joining the AEP levels does not represent the flood behaviour from any single event, and it is unlikely that any single flood will conform to this profile. For example, the 1% AEP flood levels at each location represent the best estimate of flood risk based on the analysis of 11,340 events: it cannot be expected that any single hydraulic simulation will reproduce these levels at all Reporting Locations. This is of particular importance for locations (such as near Ipswich) exhibit a significant spread in peak flood levels for a given peak flow. This variation reflects the influence of different rainfall patterns over the upstream catchment and also the influence of backwater from the Brisbane River. While the AEP levels for these locations are considered to provide the best available estimate of flood risk, the assumptions required to minimise bias in these estimates are perhaps less easily satisfied than those required for locations on the mainstream of the Brisbane River. Accordingly, while the nature of the hydrology and hydraulic simulation preclude a formal assessment of uncertainty, it is likely that the level AEP estimates in the tributary sites are more uncertain than those along the mainstream. The tributary hydrographs provided for the Hydraulics Assessment using whole-of-catchment rainfalls are somewhat higher than those adopted for the Hydrology Assessment based on local catchment rainfalls, and thus it is likely that the level AEP estimates along the Bremer River are conservatively high.

5 Selection of Fast Model AEP Ensemble Events

5.1 Overview

On completion of the 11,340 Monte Carlo Fast Model simulations (Section 3) and peak level frequency analysis at the Reporting Locations (Section 4), initial representative event ensembles were selected for each AEP (referred to as AEP Ensembles). On the basis that no single Monte Carlo event would be representative of the AEP levels at all Reporting Locations, therefore, an ensemble of events would be required. This is analogous to the use of several durations to derive the AEP levels throughout a catchment because the critical duration varies within the catchment with short, more intense rainfall durations typically dominating the upper catchment, and longer duration, larger volume events prevailing in the lower areas.

The ITO (DILGP, 2014) states that the estimated number of events for all 11 AEPs would be around 50. Selection of the estimated 50 events forms part of the H&H Interface #3 ITO requirement:

"A subset will be drawn from the fast hydraulic model Monte Carlo simulation results of approximately 500 scenarios, for use in the detailed 2D hydraulic model as boundary conditions, including downstream ocean levels. This subset will consist of approximately 50 'events', covering a range of design probabilities, for different river reaches and for pre- and post-dam scenarios, and will be the final output of the Monte-Carlo analysis. Selection of the subset will form part of the Monte Carlo analysis and, as such, should be undertaken in line with the objectives of the previously completed analysis. Again, the selection of approximately 50 'events' would be made based on the interaction process (involving the IPE, TWG, the hydrology consultant and the hydraulics consultant) to be facilitated by the client. Approval from the client is required prior to the use of these 50 events in the detailed hydraulic modelling."

5.2 Background

For the purposes of selecting the AEP Ensemble events it is usual practice to select events based on peak water levels. Other hydraulic outputs such as peak flows and hazard (VxD) are typically not used as their peak may occur at a different time, and therefore the design flood level will be below the peak level. For the other hydraulic outputs, for example hazard, the peak VxD value can still be tracked independently of the peak water level so that the peak VxD mapping is based on the peak VxD, not the VxD that occurred at the peak water level.

Also of note is that the Fast Model, due to its 1D only construction, produces estimates of the flood levels and flows along the main creeks and rivers. The representation of the floodplains and overland flowpaths is very simplistic compared to the much higher resolution 2D solution of the Detailed Model. The Fast Model is not suited to producing flood hazard mapping and other hydraulic outputs over the floodplain, therefore, using other hydraulic outputs such hazard to select the events was not possible using the Fast Model.

The only practical option for an ensemble of events to be functional is for the AEP flood level surface to be calculated as the maximum of the ensemble's flood peaks, sometimes referred to as the maximum of the maximums. That is, the peak flood level at any given point is the highest peak water level of all the AEP Ensemble's events. This ensures that there is a smooth transition in peak AEP water level throughout the Hydraulic Assessment study area.

In selecting the events that best approximate the AEP flood levels from the Monte Carlo level frequency analysis presented in Section 4, the following criteria for each AEP are required:

- The critical event at a Reporting Location is the ensemble event that produces the highest water level.
- The critical event at a Reporting Location must peak at or within an acceptable tolerance of the AEP level, referred to as the Critical Event Tolerance (CET).
- The CET at each Reporting Location should be the same or less than the desired design flood accuracy tolerances specified in the ITO (DILGP, 2014) as follows:
  - Brisbane River and tributaries upstream of Goodna (for non-urban areas), including Bremer River and Lockyer Creek ± 0.50 m
  - Brisbane River downstream of Oxley Creek ± 0.15 m
  - Brisbane River between Goodna and Oxley Creek ± 0.30 m
  - Ipswich urban area ± 0.30 m.
- The critical event cannot exceed the AEP level at another Reporting Location (within the CET), otherwise the principle of taking the maximum of the maximums fails.

Also of note:

- When selecting events, the starting list of events is not confined to just those that have a rainfall AEP equal to the AEP of the ensemble. All 11,340 events can be considered for every AEP and every Reporting Location.
- In selecting the final ensemble events, a greater accuracy in terms of matching the AEP levels at Reporting Locations could be assigned to AEPs of greater importance (eg. 1% AEP). That is, for the 1% AEP Ensemble, smaller CETs may be adopted if justified, or conversely for a lower importance AEP greater CETs could be adopted to reduce the overall number of selected events to within a manageable number. Councils' priority ranking of AEP events is provided in Section 2.2.
- Whilst an estimated 50 events is the target, should an acceptable selection be achieved using less than 50 events, this would have benefits in terms of simulating and managing the design events. Conversely, should more than 50 events be selected, there will be an increase in time to simulate the events and greater data management requirements.
- Different Reporting Locations can be given different weightings in terms of importance, and/or different target CETs.
- There is a risk that there are not enough events from the 11,340 to achieve the target tolerances at all Reporting Locations. Therefore, either a greater tolerance needs to be accepted, more events synthesised, and/or existing events modified by factoring.
- The minimum requirement is that the CET is the same as the ITO tolerances (these are listed above). In a few locations and/or different AEPs it was beneficial to reduce the tolerance so as to select events closer to the AEP target level. For example, for larger events in the Lockyer, there is much less change in peak levels once the floods become out-

of-bank due to the large floodplain. Therefore, using the ITO tolerance of 0.5m would cause many events to be selected, with sometimes the result being, for example, the 1 in 500 being higher than the 1 in 2,000. It was therefore necessary to reduce the CET in the Lockyer for the larger floods to prevent this from occurring.

- As presented in Section 4.7, there is estimated to be around a 1% of depth statistical error associated with the AEP analysis. The ITO tolerances used to guide the CET are of similar magnitude and in general agreement with the uncertainty identified in Section 4.7.

5.3 Methodology for Selecting Events

The approach to selecting the estimated 50 events is summarised in Figure 5-1 and described in detail in the text following.

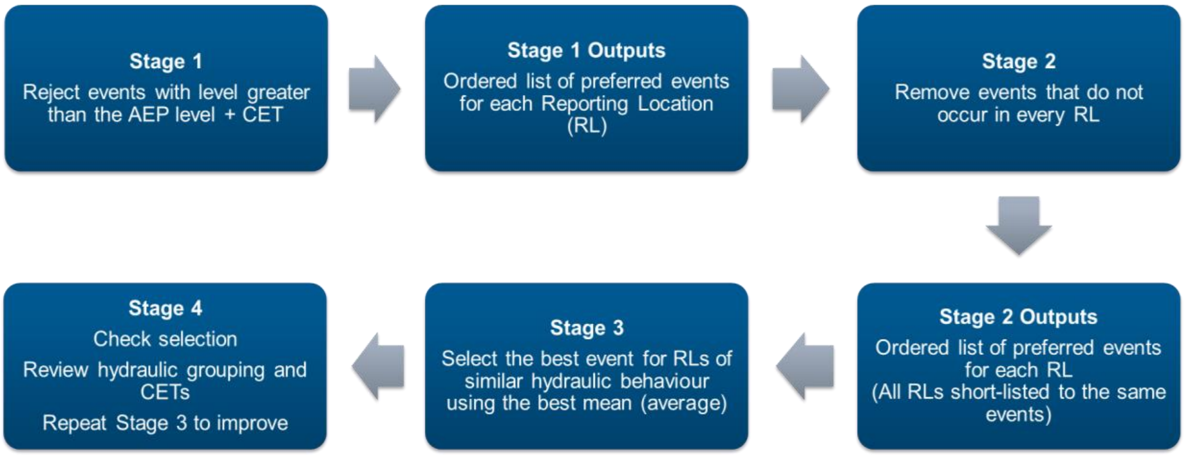


Figure 5-1 Flow Chart of Event Selection Methodology

(1) **Stage 1:** For each Reporting Location, independently of the other Reporting Locations, produce a list of preferred events at each location for each AEP as follows:

(a) Reject all events that produce a higher level than the Reporting Location's AEP level plus the CET.

(b) List the un-rejected events in order of those closest to the Reporting Location's AEP level. This list is referred to as the "Stage 1 List". Each Reporting Location will have its own Stage 1 List such as the example in Table 5-1. The duration of the event is the first three digits within the Event ID.

Table 5-1 Example of a Stage 1 List for an AEP

	Reporting Location A		Reporting Location B	
#	Event	Difference with AEP Level (m)	Event	Difference with AEP Level (m)
	AEP Level	*61.12*	*AEP Level*	*46.06*
1	048_0228	0.05	096_0265	-0.01
2	048_0890	-0.06	072_0346	0.05
3	072_0346	0.09	072_0132	0.09
4	096_0265	-0.20	036_0561	-0.10
5	072_0132	-0.28	048_0890	-0.21

(2) **Stage 2:** For each Reporting Location for each AEP carry out the following:

(a) For each event in the Reporting Location's Stage 1 List do the following:

(i) If the event does not occur in the Stage 1 Lists of any other Reporting Location, remove the event. This removes events that have peaked above the AEP level at one or more other Reporting Locations, and therefore cannot be considered as the maximum AEP Ensemble level at the other Reporting Locations will produce a level outside the CETs at those Reporting Locations.

(ii) The resulting list is referred to as the "Stage 2 List" and for all Reporting Locations the events will be the same, noting that if ordered based on the closest to the Reporting Location's AEP level, the order will be different at different locations.

Table 5-2 Example of Stage 2 List for an AEP

	Reporting Location A		Reporting Location B	
#	Event	Difference with AEP Level (m)	Event	Difference with AEP Level (m)
	AEP Level	*61.12*	*AEP Level*	*46.06*
1	048_0890	-0.06	096_0265	-0.01
2	072_0346	0.09	072_0346	0.05
3	096_0265	-0.20	072_0132	0.09
4	072_0132	-0.28	048_0890	0.11

(3) **Stage 3:** For the AEP, identify potential ensembles as follows:

(a) Initially, using the Stage 2 List select the event that gives the best statistical match to the AEP levels at all Reporting Locations.

(b) This initial selection proved to be effective for the selection of events along the Brisbane River due to the high number of Reporting Locations and numerous events that produce a match. However, the dominance of the Brisbane River

Reporting Locations meant that other Reporting Locations often were outside the CET. The selection approach consequently added in the following steps.

(c) For hydraulically similar Reporting Locations that produced a good match, these locations were grouped and removed from the analysis. The steps above were repeated, each time producing a new group. The groupings were based on hydraulically similar behaviour clarified by manual review. Of note is that the groups vary depending on the AEP to reflect the different behaviour of some locations for different size events. Section 5.4 discusses and presents the adopted groupings.

(d) For the AEP Ensemble, produce a table (see example in Table 5-3) showing for each Reporting Location the critical event, the difference between the critical event and the AEP Level, and the AEP Ensemble level. As discussed previously, the critical event is the event that produces the highest level of all the AEP Ensemble events. As shown in Table 5-3 by colour matching with Table 5-2, it is possible that the critical (highest) event may not be the event that is closest as it is possible that an event that is critical at another location is higher (but within the CET). The example in the tables shows for Reporting Location B that the closest event is 096_0265, but the critical event is 048_0890 as this event, which was selected for Reporting Location A, is higher than 096_0265. This effect can result in redundant events, which were manually removed – see Stage 5 below.

Table 5-3 Example of Critical Events Table for an AEP

Reporting Location	Critical Event ID	Difference (m)	Critical Event Level (mAHD)
Rep Loc A	048_0890	-0.06	61.06
Rep Loc B	048_0890	0.11	46.17

(4) Stage 4: Once the Stage 3 table was produced for each AEP, the following quality control checks were carried out often resulting in repeating Stage 3.

(a) The Difference values were within the ITO desired design flood accuracies for all Reporting Locations and AEPs. If not, further iterations of Stage 3, primarily through adjustment of the Reporting Location groupings were made to improve the comparison. The AEPs that have one or more Reporting Locations with a difference not within the ITO accuracies is the 1 in 2 AEP (see Section 7.6 for further discussion and decision on the 1 in 2 AEP), and at one location (Fairfield) for the 1 in 10,000 AEP (which was considered to be acceptable after discussions with the TWG and IPE – the difference of 0.24m is well within 1% of the flood depth).

(b) The Critical Event Levels were monotonically increasing (with reducing %AEP). During initial passes, this was found to not always occur for the Lockyer Valley locations due to their levels "flat-lining" for large events. For these locations the CET was reduced for larger event AEPs from the ITO desired design flood accuracy of ±0.5m to a CET of ±0.15m, and Stage 3 repeated. This adjustment was also carried out at some other Reporting Locations.

(c) Selection of more events for AEP Ensembles by adding the 2nd then 3rd best group events was trialled. However, while this would very slightly improve (reduce) the *mean* difference between the average AEP Ensemble event levels and AEP levels, there was invariably a greater worsening between the Ensemble's maximum levels and the AEP Levels at some Reporting Locations. A more effective approach to improve the match with AEP Levels was to vary the distribution of the groupings as previously discussed.

The above methodology was applied with numerous iterations of Stage 3 and Stage 4.

(5) **Stage 5:** As discussed above in Stage 3 a final manual review is required as it is possible for some selected events to become redundant. This was carried out for each AEP.

5.4 Reporting Location Hydraulic Groupings

Table 5-4 presents the final groupings applied to the Reporting Locations. As discussed in Stage 3 of the methodology in Section 5.3, the groupings were based on a similarity in hydraulic behaviour along with manual trial and error of adjusting groupings to produce an improved event selection when a Reporting Location's hydraulic behaviour was somewhat indeterminate (eg. between flood and storm tide dominated, or backwater and conveyance dominated).

Initially the selection process treated each Reporting Location independently, ie. each location was given the same weighting. However, this approach can be flawed where groups of locations that would typically select the same critical event, for example, locations along the Brisbane River, would dominate the selection process. For example, if five locations in the Brisbane River all have the same critical event, while Loamside only has one, the Brisbane sites would bias the overall correlation five times more than the Loamside site. This automated approach whilst resulting in an acceptable match at the Brisbane sites, but a poor, unacceptable match at Loamside, would still produce an acceptable overall mean of the differences (for all locations) due to the statistical dominance of the Brisbane sites.

To remove this bias, approaches to adjusting the weighting of different locations to the overall statistical mean of the differences were investigated. Initially different weightings at different locations was trialled with some success. As a result of this approach, it became evident that locations that would typically select the same critical event also generally exhibited similar hydraulic characteristics, noting that these groups of locations could vary depending on the magnitude of the flood event.

The concept of grouping locations of similar hydraulic behaviour and/or event selection was adopted, with each group having an equal statistical weighting, ie. each group would contribute one event to an ensemble. This approach largely resolved the bias originally demonstrated, resulting in locations such as Loamside achieving an improved match with no or little adverse effects on locations where a good match previously occurred. For each group the selected event for the AEP Ensemble was the one that produced the smallest average of the absolute mean differences between Reporting Location Fast Model levels and Monte Carlo AEP levels.

Of note is that the number of groups for an AEP can exceed the number of events selected for the ensemble, due to the same event being selected for two or more groups.

Table 5-4 Reporting Location Groups*

Reporting Location	AEP		
	50%	20%, 10%, 5%	2%, 1%, 0.5%, 0.2%, 0.05%, 0.01%, 0.001%, 0.0001%
RL_001 Lockyer Creek at Tarampa	8	8	9
RL_002 Wivenhoe Dam Tailwater	3	3	7
RL_003 Lockyer Creek at Lyons Bridge	8	8	9
RL_004 Brisbane River at Lowood Pump Station	3	3	7
RL_005 Brisbane River at Savages Crossing	3	3	7
RL_006 Brisbane River Upstream Mt Crosby Weir	3	3	7
RL_007 Brisbane River downstream Mt Crosby Weir	3	3	7
RL_008 Brisbane River at Moggill	3	3	7
RL_009 Brisbane River at Jindalee	3	3	7
RL_010 Brisbane River at Tennyson	3	3	7
RL_011 Brisbane River at Fairfield	3	3	7
RL_012 Brisbane River at Toowong	3	3	7
RL_013 Brisbane River at Port Office	3	3	7
RL_014 Brisbane City Gauge	3	3	7
RL_015 Brisbane River at Hawthorne	9	9	10
RL_016 Brisbane River at Gateway Bridge	9	9	10
RL_017 Warrill Creek at Amberley	6	6	6
RL_018 Purga Creek at Loamside	5	5	5
RL_019 Bremer River at Walloon	4	4	4
RL_020 Bremer River at Three Mile Bridge	2	2	3
RL_021 Bremer River at One Mile Bridge	2	2	3
RL_022 Bremer River at David Trumpy Bridge	1	1	1
RL_023 Bremer River at Hancock Bridge	1	1	2
RL_024 Bremer River at Bundamba Confluence	2	2	8
RL_025 Bremer River at Warrego Highway	2	2	8
RL_026 Bundamba Creek at Hanlon St Alert	2	2	8
RL_027 Woogaroo Creek at Brisbane Road Alert	N/A	2	7
RL_028 Oxley Creek at Rocklea	7	7	7

* Numbers in the table indicate to which hydraulic group the Reporting Location has been assigned.

N/A = Not Applicable. This is the case for Woogaroo as inundation of this Reporting Location is not predicted to occur in the 50% AEP event and thus assigning Woogaroo to a hydraulic group is meaningless for this event.

5.5 Selected Events Based on Fast Model Results

Based on the Fast Model results from the 11,340 events and the AEP frequency analysis of these events at the Reporting Locations, 61 events were selected for the 11 AEPs using the criteria outlined in Section 5.3. These events are distributed amongst the AEPs as follows in Table 5-5.

Following selection of these events, minor refinements were made to the selection by cross-checking the design event levels, particularly in areas not well represented by the Reporting Locations, by simulating the events using the calibrated Detailed Model (refer Section 6), resulting in the final set of selected events to be used for the design event modelling and mapping (to be presented in Milestone Report 5).

Table 5-5 Number of Events in each AEP Ensemble Based on Fast Model Results

AEP	% AEP	Number of Events in Ensemble
1 in 2	50%	8
1 in 5	20%	5
1 in 10	10%	6
1 in 20	5%	6
1 in 50	2%	6
1 in 100	1%	5
1 in 200	0.5%	7
1 in 500	0.2%	6
1 in 2,000	0.05%	4
1 in 10,000	0.01%	4
1 in 100,000	0.001%	4
	Total	61

6 Fine-tuning Selection of Events using Detailed Model

6.1 Background

The Monte Carlo events selected based on the Fast Model results and AEP frequency analysis (as documented in the preceding sections) were cross-checked for consistency by simulating the events through the calibrated Detailed Model (as documented in Milestone Report 3).

Whilst the Fast Model and AEP frequency analysis focus on the Reporting Locations, the Detailed Model, which is to be used for the final design event modelling and mapping, produces 3D surfaces of peak flood levels across the study area at a much higher resolution and accuracy than the Fast Model. Simulating the selected events through the Detailed Model allows the checking for consistency of peak design levels in areas not well represented by the Reporting Location AEP analysis, for example, clarification of increasing flood levels with reducing AEP probability. These areas are typically located upstream and downstream of the Reporting Locations' coverage, or potentially on the floodplains where the hydraulic behaviour is not controlled by the main waterways, on which the Reporting Locations are located.

6.2 Non-Ascending Peak Flood Levels

The 61 Monte Carlo events were simulated through the calibrated Detailed Model and the 11 AEP design flood surfaces generated using the maximum of the maximums approach. Comparison of the changes in design flood levels with change in AEP highlighted that peak flood levels did not always ascend with AEP rarity in some areas distant from the Reporting Locations. This is referred to as "non-ascending peak flood levels". Generally, the peak levels were in good agreement with the Fast Model at the Reporting Locations and between Reporting Locations along the main waterway. However, there were several general areas where non-ascending levels were occurring. These were investigated and identified as occurring for the following reasons:

- In the upper modelled reaches of small tributaries that flow into the main waterway.
- In parts of the Lockyer floodplain, particular upstream of the first Reporting Location at Lyons Bridge.
- In the tidal section downstream of the Gateway Motorway, which is the most downstream Reporting Location.

All three causes are artefacts of the Monte Carlo process, and are due to the spatial resolution of the Reporting Locations. As distance from Reporting Locations increases, there is greater potential for the peak modelled flood levels to deviate from the targeted AEP levels. This issue is compounded when the hydraulic behaviour is complex and/or the influence of the main river riverine flows on peak levels diminishes. For each of the general areas identified above, a summary is provided in the following sections on the causation and the resolutions adopted after discussion and agreement with the TWG and IPE.

6.2.1 Local Tributaries Inflows

Non-ascending peak flood levels were noted within the upper modelled reaches of some local tributaries, particularly Buaraba Creek, and some of the local creeks within the Brisbane City Council LGA. Of note is that an objective of the Hydraulic Assessment is to produce riverine (backwater) flood levels. That is, while local inflows from all tributaries within the study area are included in this assessment, tributary flooding caused by a localised event with event duration critical to that tributary, is not considered.

For the larger side tributaries, the peak flood levels in the upper sections can be caused by the local catchment inflows that were being applied to the model in these areas removed from the main waterway. Investigation of the Detailed Model's design flood results indicated that these local catchment inflows, which are subject to the Monte Carlo process of applying probabilistic variations in rainfall and other parameters, could experience a greater or lesser rainfall than the whole of the Brisbane River catchment rainfall.

For example, an event that produces a flood level representative of the 1 in 100 AEP in the main river, may have a 1 in 500 AEP rainfall over a short duration on the local tributary. Conversely, an event representative of the 1 in 500 AEP on the main river may only include a 1 in 50 AEP local rainfall event on a particular tributary. Under these circumstances, where backwater effects from the main waterway have not dominated, the tributary may show, for example, higher flood levels for the 1 in 100 AEP event than the 1 in 500 AEP.

Whilst this issue is an artefact of the Monte Carlo process, the non-ascending flood levels were apparent as the local tributary inflows for the larger tributaries were applied along the length of the tributary covered by the hydraulic modelling.

The majority of local tributary inflows applied to the Detailed Model are taken from the tributary's most downstream sub catchment, which is usually offset from the main river. After discussions with the TWG and IPE, the adopted solution was to move the offset tributary inflows to be applied directly to the main waterway at the tributary's confluence. The implication is that a minor proportion of that inflow is not being hydraulically routed, whereas previously it would have been. The expectation is that this is likely to have negligible influence on model results as local tributary inflows tend to occur well before, and are of much lower magnitude, than the main peak of the Brisbane and Bremer Rivers. In total, 22 tributary inflows were adjusted in this manner as listed in Table 6-1.

Table 6-1 Local Tributaries with Adjusted Inflows

Main River	Tributary
Brisbane	Bulimba Creek
Brisbane	Breakfast Creek
Brisbane	Norman Creek
Brisbane	Oxley Creek
Brisbane	Moggill Creek
Brisbane	Pullen Pullen Creek
Brisbane	Bullock Head Creek
Brisbane	Sandy Creek (Wacol)
Brisbane	Woogaroo Creek
Brisbane	Six Mile Creek
Brisbane	Kholo Creek
Brisbane	Cabbage Tree Creek
Brisbane	Sandy Creek/Watercress Creek
Brisbane	Black Snake Creek
Brisbane	Banks Creek
Brisbane	Ferny Gully
Brisbane	England Creek
Brisbane	Pryde Creek
Brisbane	Spring Creek
Bremer	Bundamba Creek
Bremer	Deebing Creek
Warrill	Ebenezer Creek

Using this method to change the inflow locations was considered an improvement as it removed the potential for peak flood levels to be caused by local flooding, regardless of the effects of the Monte Carlo approach. As a result of this change, the resulting Detailed Model flooding within local tributaries is solely a function of backwater propagation from the main river, which is in keeping with the Hydraulic Assessment objectives.

The exceptions to this approach were as follows:

- Bulimba Creek – Originally the hydrographs were applied as a total hydrograph inflow at the edge of the Detailed Model followed by the addition of two local hydrographs before Bulimba Creek met the Brisbane River. This arrangement was changed such that a single total inflow hydrograph from the tributary's most downstream sub catchment was applied directly into the confluence with the Brisbane River, thereby replacing the original total plus two local hydrographs.

- Oxley Creek – Originally, a total inflow hydrograph was applied at the Detailed Model's perimeter followed by the addition of a local hydrograph before the confluence with the Brisbane River. This schematisation was adjusted to apply the total hydrograph from the most downstream sub catchment to the Detailed Model, thereby replacing both the total and local hydrographs. Due to the expanse of the Oxley Creek floodplain, the total inflow for Oxley Creek was not applied directly into the Brisbane River, but across the area represented by the two most downstream sub catchments to ensure the revised inflows were well distributed onto the Detailed Model and there were no local inflow effects causing non-ascending levels.
- Buaraba Creek – the timing of inflows into Lockyer Creek was considered to be important and thus, in order to ensure this timing was well-represented, hydraulic routing of Buaraba Creek flows was preferred. Therefore, insertion of the total flow hydrograph of Buaraba Creek at the confluence of Lockyer Creek was not considered an option. The treatment of Buaraba Creek was therefore considered separately as discussed in Section 6.2.2.

6.2.2 Lockyer Floodplain

Substantial sections of the lower Lockyer Creek floodplains lie at a ground elevations well below the creek's natural and constructed levees. When flood waters overtop the creek's banks and flow down into the floodplain, the floodplains can effectively become hydraulically independent of the creek, combining with local runoff and relying on the floodplain terrain for conveyance. Consequently significantly different flood levels can occur on the floodplain compared with that in the adjoining creek. Targeted AEP flood levels from the frequency analysis at the Reporting Locations located within Lockyer Creek may therefore not be representative of the flood levels on the floodplains.

Furthermore, the Fast and Detailed Models extend for more than 25km upstream from the most upstream Reporting Location at Lyons Bridge, therefore, design flood levels upstream of Lyons Bridge should be treated with a greater degree of uncertainty, with uncertainty increasing with increasing distance upstream from Lyons Bridge. Importantly, the Hydraulic Assessment study area, to meet the objective of covering all areas that are affected by Brisbane River flooding, extends to around the Lyons Bridge location. The hydraulic modelling was extended further upstream to reach acceptable locations at which to apply boundary inflows and to better account for the hydraulic routing and storage effects of the Lockyer floodplain upstream of Lyons Bridge. However, the derivation of AEP design flood levels and selection of events for the AEP ensembles focuses on the areas from Lyons Bridge downstream.

Whilst the modelled flood results upstream from Lyons Bridge are to be treated with caution, it was the view of Lockyer Valley Regional Council[10] that the results still provide valuable insight into flood behaviour and the flood dynamics of the complex floodplain. Results have therefore been treated as follows:

- Where it is deemed that results deviate sufficiently from expected values to warrant caution, these areas need to be highlighted in the flood mapping to be carried out for Milestone

[10] Discussions with Quentin Underwood, LVRC

Report 5. In this way, the results are still presented to aid with understanding of floodplain dynamics, but a caveat is applied to their use.

- As discussed in Section 6.2.1, the local tributary of Buaraba Creek requires special treatment due to the influence of local inflows, plus the influence on Atkinsons Dam on flood levels. In consultation with Somerset Regional Council[11] it was decided that this area, whilst not removed from the modelling, should be excluded from the Milestone Report 5 mapping where the levels in Buaraba Creek are due to local flooding rather than backwater effects from Lockyer Creek. The limit of exclusion may vary depending on the extent of the backwater effects, ie. for larger flood events, the extent of mapping may progress further upstream.

6.2.3 Upper Bremer River

A review of the 1 in 500 AEP and 1 in 2000 AEP events in the Upper Bremer near Walloon indicated that the 1 in 500 AEP event provided peak flood levels that were above the 1 in 2000 AEP event. This was solved by substituting for the original 1 in 500 AEP event. The substitution of this event was undertaken such that the envelope of the events for each AEP ensemble still met the specified tolerances and targets.

6.2.4 Tidal Section (Downstream of Gateway Motorway)

The most downstream Reporting Location is at the Gateway Motorway (Sir Leo Hielscher Bridges), however, the Brisbane River continues downstream for a further 10km to its outlet at Moreton Bay. Examination of the design flood levels below the Gateway Motorway showed that the peak ensemble levels would not necessarily ascend with increasing AEP rarity as would be expected.

Investigation of the tidal boundaries for the Monte Carlo events, which were generated by the Hydrologic Assessment's Monte Carlo analysis, showed that the boundaries were based on applying variable storm and tide conditions with peak storm tide levels derived from the Coastal Plan Implementation Study (Draft) carried out for Brisbane City Council by GHD (GHD, 2014). Due to the variability in the storm tide levels derived during the Hydrologic Assessment's Monte Carlo process, the storm tide peak could consequently fall above or below the GHD (2014) levels downstream of the Gateway Bridge Reporting Location, for particular AEPs.

After discussion and agreement with the TWG and IPE, this issue was resolved through the adjustment of the storm tide levels at the hydraulic models' Moreton Bay boundary. This adjustment was influenced by two scenarios:

- If one or more events in an AEP ensemble over-predicted the equivalent GHD AEP level, the storm tide boundaries for these events were adjusted or replaced by storm tide boundaries of similar timing but more representative levels.
- If an ensemble had no event/s that produced a sufficiently high storm tide level downstream of the Gateway Bridge Reporting Location, the storm tide boundary of one of the ensemble events was replaced with a boundary representative of the GHD level for that AEP. The ensemble event selected was one that was not providing the peak levels at the tidally

[11] Discussion with Tony Jacobs, SRC

influenced Brisbane River Reporting Locations (such as for an event that may have been selected to provide peak levels in the Lockyer Valley). This ensured that peak flood levels at the tidally influenced Reporting Locations were not altered by the change in the storm tide level at the downstream model boundary. The change in storm tide boundary was undertaken such that the envelope of the events for each AEP ensemble still met the specified tolerances and targets at all Reporting Locations.

The above approach ensured consistency between the Hydraulic Assessment and the GHD storm tide study, and ensures the non-ascending flood level issue does not occur due to the Monte Carlo variability in the storm tide boundaries downstream of the Gateway Motorway.

Details of the adopted peak tidal levels of each of the selected event’s storm tide boundary are provided in Table 6-2. The table shows the original peak level and the modified peak level. Events shaded with a light blue are events that were modified, while the yellow shaded cells are the event that causes the peak level and therefore the design level at Moreton Bay due to the maximum of the maximums approach.

6.2.5 Cross-Check of Fast Model Tolerances

The revised selection of events was also cross-checked by re-simulating the events with storm tide boundary changes through the Fast Model. The events were cross-checked to ensure that the ensemble peak flood levels at the Reporting Locations remained within the tolerances and criteria as documented in Chapter 5. Section 7.2 presents the difference charts that graphically demonstrate that the design flood levels are within the target tolerances at the Reporting Locations.

Table 6-2 Moreton Bay Storm Tide Boundary Modified Monte Carlo Events

AEP	Event	GHD Storm Tide AEP Level (mAHD)	Original Fast Model Peak Level Moreton Bay (mAHD)	Original Difference (BMT WBM less GHD) (m)	Modified Fast Model Peak Level Moreton Bay (mAHD)	Modified Difference (BMT WBM less GHD) (m)	Change (Modified less Original) (m)
2	024_0008	1.55	1.50	-0.05	1.50	-0.05	No change
	048_0227	1.55	1.50	-0.05	1.50	-0.05	No change
	072_0054	1.55	1.61	0.06	1.55	**0.00**	**-0.06**
	120_0010	1.55	1.50	-0.05	1.50	-0.05	No change
	012_0381	1.55	1.64	**0.09**	1.55	**0.00**	**-0.09**
	018_0102	1.55	1.50	-0.05	1.50	-0.05	No change
	012_0058	1.55	1.53	-0.02	1.53	-0.02	No change
	012_0232	1.55	1.51	-0.04	1.51	-0.04	No change
5	120_0264	1.59	1.50	-0.09	1.50	-0.09	No change
	012_0693	1.59	1.43	-0.16	1.43	-0.16	No change
	036_0346	1.59	1.50	-0.09	1.50	-0.09	No change
	096_0261	1.59	1.63	**0.04**	1.59	**0.00**	**-0.04**
	168_0183	1.59	1.50	-0.09	1.50	-0.09	No change
10	024_0518	1.64	1.53	-0.11	1.53	-0.11	No change
	120_0404	1.64	1.50	-0.13	1.50	-0.13	No change
	036_0400	1.64	1.50	-0.13	1.50	-0.13	No change
	168_0086	1.64	1.50	-0.13	1.64	**0.01**	**0.14**
	168_0481	1.64	1.56	**-0.08**	1.56	-0.08	No change
20	018_0299	1.68	1.53	-0.15	1.53	-0.15	No change
	048_0611	1.68	1.50	-0.18	1.50	-0.18	No change
	024_0670	1.68	1.50	-0.18	1.50	-0.18	No change
	018_0462	1.68	1.71	**0.03**	1.71	**0.03**	No change
	096_0328	1.68	1.52	-0.16	1.52	-0.16	No change
	120_0479	1.68	1.60	-0.08	1.60	-0.08	No change
50	048_0620	1.78	1.50	-0.28	1.50	-0.28	No change
	048_0678	1.78	1.50	-0.28	1.50	-0.28	No change
	048_0663	1.78	1.50	-0.28	1.50	-0.28	No change
	072_0653	1.78	1.50	-0.28	1.50	-0.28	No change
	120_0625	1.78	1.50	-0.28	1.79	**0.01**	**0.29**
	120_0558	1.78	1.52	**-0.26**	1.52	-0.26	No change
100	012_0902	1.86	1.52	-0.34	1.52	-0.34	No change
	120_0776	1.86	1.61	-0.25	1.61	-0.25	No change
	048_0770	1.86	1.72	**-0.14**	1.72	-0.14	No change
	096_0742	1.86	1.52	-0.34	1.52	-0.34	No change
	018_0789	1.86	1.51	-0.35	1.86	**0.00**	**0.35**

AEP	Event	GHD Storm Tide AEP Level (mAHD)	Original Fast Model Peak Level Moreton Bay (mAHD)	Original Difference (BMT WBM less GHD) (m)	Modified Fast Model Peak Level Moreton Bay (mAHD)	Modified Difference (BMT WBM less GHD) (m)	Change (Modified less Original) (m)
200	024_0859	2.05	1.52	-0.53	1.52	-0.53	No change
	096_0803	2.05	2.05	0.00	2.05	0.00	No change
	120_0762	2.05	1.50	-0.55	1.50	-0.55	No change
	096_0774	2.05	2.44	**0.39**	2.05	**0.00**	**-0.39**
	096_0786	2.05	2.09	0.04	2.09	0.04	No change
	048_0808	2.05	1.66	-0.39	1.66	-0.39	No change
	048_0657	2.05	1.67	-0.38	1.67	-0.38	No change
500	024_0774	2.30	2.31	**0.01**	2.31	**0.01**	No change
	072_0867	2.30	1.51	-0.79	1.51	-0.79	No change
	072_0783	2.30	2.18	-0.12	2.18	-0.12	No change
	168_0887	2.30	2.17	-0.13	2.17	-0.13	No change
	168_0725	2.30	1.50	-0.80	1.50	-0.80	No change
2000	018_0991	2.76	1.52	-1.24	1.52	-1.24	No change
	096_0889	2.76	2.94	**0.18**	2.76	**0.00**	**-0.18**
	168_0952	2.76	1.84	-0.92	1.84	-0.92	No change
	036_0991	2.76	1.52	-1.24	1.52	-1.24	No change
	072_0914	2.76	1.52	-1.24	1.52	-1.24	No change
10000	072_0899	3.25	1.53	-1.72	1.53	-1.72	No change
	072_0994	3.25	1.61	-1.64	1.61	-1.64	No change
	120_0988	3.25	2.79	-0.46	2.79	-0.46	No change
	036_1026	3.25	3.27	**0.02**	3.27	**0.02**	No change
100000	012_1236	3.25	3.28	**0.03**	3.28	**0.03**	No change
	096_1142	3.25	2.58	-0.67	2.58	-0.67	No change
	072_1114	3.25	1.85	-1.40	1.85	-1.40	No change
	072_1130	3.25	3.22	-0.03	3.22	-0.03	No change

6.3 Final Event Selection after Fine-Tuning using Detailed Model

As described in Section 6.2, a number of events and inconsistencies were identified that caused design levels to not ascend with increasing AEP rarity within small parts of the overall modelled area outside the area covered by the Reporting Locations. After adjusting the local creek inflow locations and substituting storm tide boundaries, a final manual cross-check selection process was undertaken. The manual cross-check resulted in the substitution of a few events and the removal of one event, to remove non-ascending level issues in the Lockyer floodplains upstream of Lyons Bridge, and one instance of a minor non-ascending issue at the model boundary in the Bremer River. Thus, the 61 events initially selected (refer to Chapter 5) were finalised as a set of 60 events as presented in Table 6-3.

Table 6-3 Events in each AEP Ensemble after Fine-Tuning Selection using Detailed Model

AEP	% AEP	Number of Events in Ensemble
1 in 2	50%	7
1 in 5	20%	6
1 in 10	10%	5
1 in 20	5%	6
1 in 50	2%	6
1 in 100	1%	5
1 in 200	0.5%	7
1 in 500	0.2%	5
1 in 2,000	0.05%	5
1 in 10,000	0.01%	4
1 in 100,000	0.001%	4
	Total	60

6.4 Cross-Check of Detailed Model Calibration

To ensure that the change in inflow locations had not adversely affected the model's performance, the five calibration events were re-simulated in the Detailed Model after adjustment of the local inflow boundary locations.

The updated results have been presented in the form of histograms of calibration points and a summary of the performance at the gauges as discussed in the following sections. The largest differences are very minor and isolated (typically less than a few centimetres) and do not compromise the performance of the Detailed Model's calibration.

6.4.1 Changes to Peak Flood Levels

The changes to the 1974 and 2011 peak flood levels was observed to be:

- Zero in areas upstream of the revised local creek inflows.

- Elsewhere typically lower by less than 2cm, with some localised changes of up to 8cm for the 2011 event that were identified through sensitivity testing as being caused by a slight change in timing with the ocean tide.
- These changes to peak levels represent a 0.0 to -0.3% shift.

6.4.2 Calibration Points Check

Prior to comparing with calibration flood marks, the marks were reviewed to ensure that they were representative of Bremer and Brisbane River backwater levels, rather than local creek flood levels. The review concluded:

- For the 2011 event, one flood mark was removed from the upstream end of the Oxley basin as this was a local flood level over 1m higher than Brisbane River backwater flood levels. An amendment was also made to two flood levels around the Lowood bend reflecting updated information provided by SRC post Milestone Report 3 “Detailed Model Calibration” (BMT WBM, 2015b).
- For the 1974 event, 12 flood marks were removed from the Bulimba Creek floodplain as these marks were identified as local flood marks with levels well above the Brisbane River backwater flood levels.

Figure 6-1 and Figure 6-3 present updated Milestone Report 3 histograms of the calibration points for the 2011 and 1974 events respectively. There has been a negligible change in the Detailed Model calibration to the calibration points from that presented in Milestone Report 3.

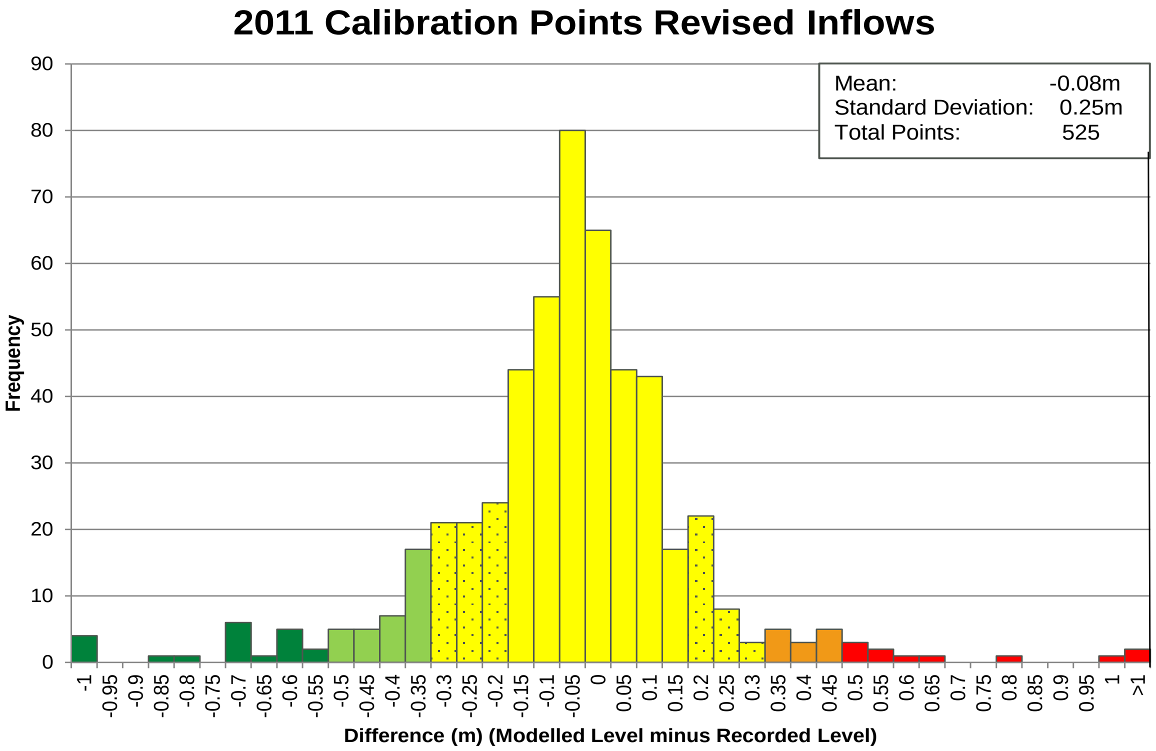


Figure 6-1 2011 Detailed Model Verification Check - Statistical Assessment of Differences between Observed & Modelled Peak Flood Levels

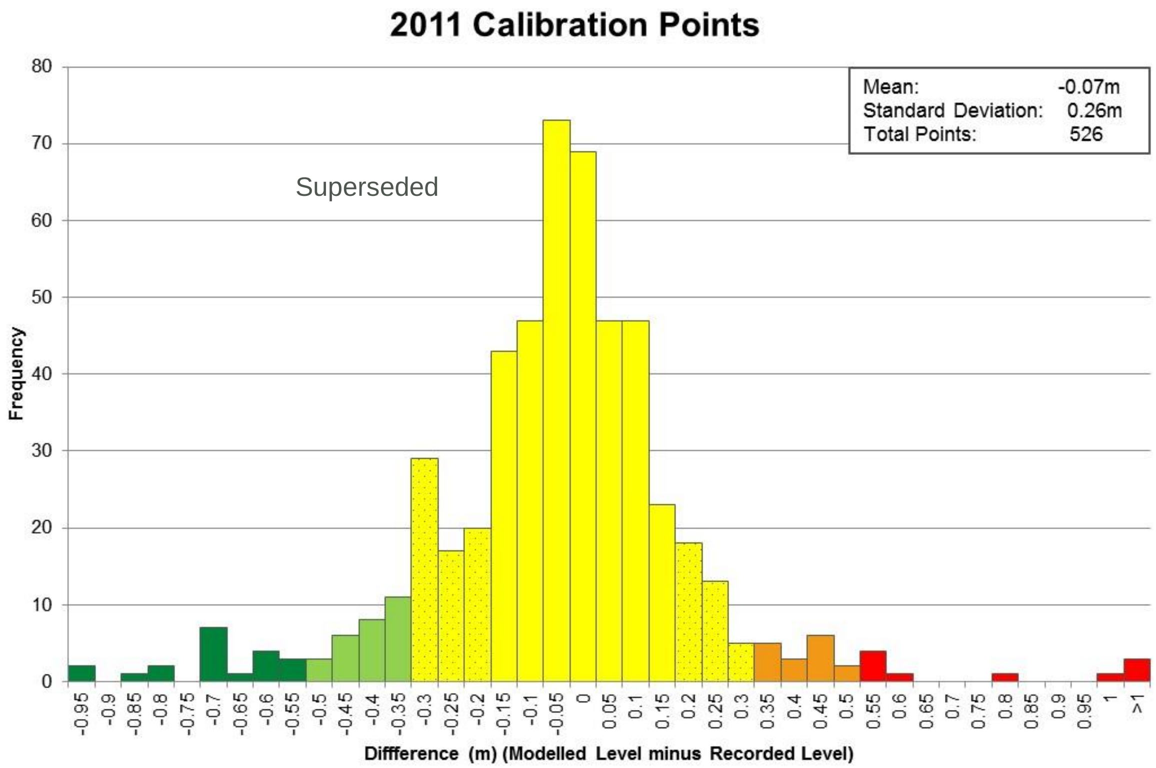


Figure 6-2 Superseded 2011 Detailed Model Calibration Statistics from MR3 (copy of Figure 3-2 from BMT WBM, 2015b) for the Purpose of Comparison with Updated Model Results Above

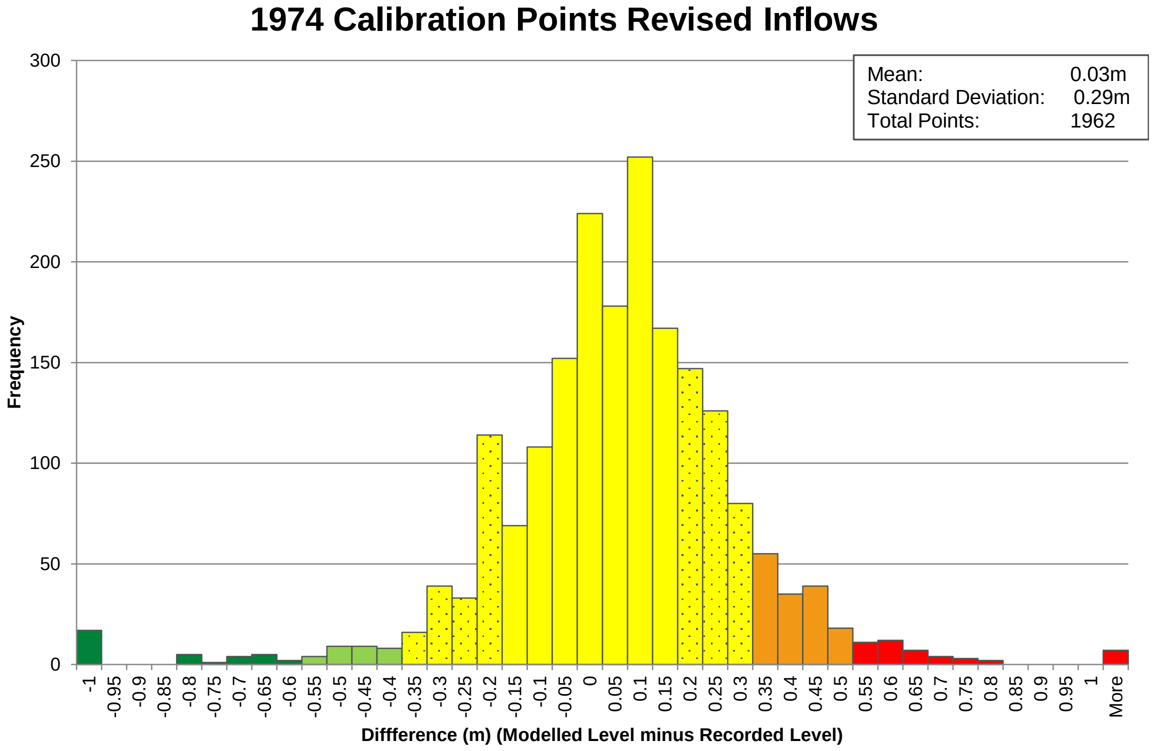


Figure 6-3 1974 Detailed Model Verification Check - Statistical Assessment of Differences between Observed & Modelled Peak Flood Levels

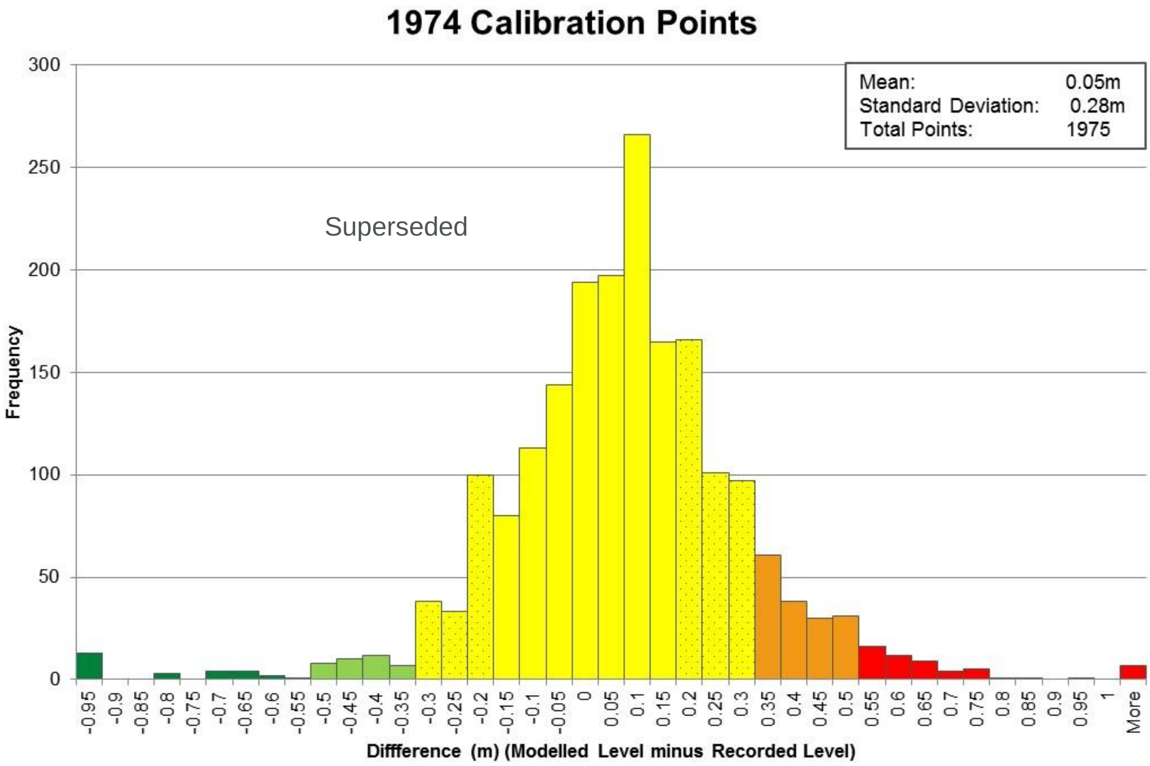


Figure 6-4 Superseded 1974 Detailed Model Calibration Statistics from MR3 (copy of Figure 3-3 from BMT WBM, 2015b) for the Purpose of Comparison with Updated Model Results Above

6.4.3 Peak Levels at Gauges

Table 6-4 presents an updated version of Table 3-4 presented in Milestone Report 3. This table provides the Detailed Model calibration and verification peak level comparison at gauges.

There is no or negligible change in peak levels from the original table presented in Milestone Report 3. Calibration at some locations has improved while other locations have not. Typically the difference is a few millimetres when compared to results presented in Milestone Report 3.

6.4.4 Conclusions on Calibration Cross-Check

The revised inflow locations result in negligible changes to peak flood levels, and the quality of the Detailed Model calibration remains unchanged from that presented in Milestone Report 3. This result is in line with expectations.

The revised inflow locations are expected to:

- Remedy the issue of design flood levels within local creeks being higher for more frequent AEP events.
- Ensure that design flood levels within the local creeks are solely representative of the backwater level from the Brisbane and Bremer Rivers.

Table 6-4 Cross-Check of Detailed Model Calibration and Verification Peak Level Comparison at Gauges (Updated Version of MR3 Table 3-4)

Location	Accuracy Tolerance	BoM Gauge No.	AWRC Gauge No.	Gauge Name	System	PO ID / Node ID	Domain	Recorded and Modelled Peak Water Surface Levels														
								1974*			1996			1999			2011			2013		
								Recorded	Modelled	Difference	Recorded	Modelled	Difference	Recorded	Modelled	Difference	Recorded	Modelled	Difference	Recorded	Modelled	Difference
Brisbane River D/S of Oxley Creek	±0.15m	540495	143891	Whyte Island Tide AL	Moreton Bay	1	2D	x	1.51	x	x	1.32	x	x	1.32	x	1.63	1.66	0.03	1.79	1.87	0.08
		540286	143877	Breakfast Creek Mouth Al	Lower Brisbane	5	2D	x	3.09	x	x	1.63	x	x	1.40	x	2.50	2.61	0.11	2.12	2.07	-0.05
		540198	143838	Port Office / City Gauge	Lower Brisbane	7	2D	5.45	5.60	0.15	2.10	1.92	-0.18	1.44	1.46	0.02	4.46	4.38	-0.08	2.32	2.25	-0.07
		-	-	Highgate Hill - Paradise St	Lower Brisbane	43	2D	8.36	8.80	0.44	x	2.57	x	x	1.60	x	x	7.33	x	x	2.69	x
		-	-	St Lucia Ferry	Lower Brisbane	46	2D	?	9.04	?	x	2.59	x	x	1.61	x	x	7.47	x	x	2.69	x
				Dutton Park Cemetery	Lower Brisbane	42	2D	9.57	9.33	-0.24	x	2.69	x	x	1.64	x	x	7.77	x	x	2.77	x
		-	-	Sandy Creek	Lower Brisbane	45	2D	?	9.97	?	x	2.83	x	x	1.68	x	x	8.33	x	x	2.85	x
				Yeronga St	Lower Brisbane	48	2D	10.83	10.78	-0.05	x	3.02	x	x	1.72	x	x	9.05	x	x	2.97	x
		-	-	Tennyson Powerhouse	Lower Brisbane	44	2D	10.81	10.84	0.03	x	3.08	x	x	2.00	x	x	9.14	x	x	3.01	x
				Tennyson	Lower Brisbane	49	2D	11.04	10.92	-0.12	x	7.45	x	x	7.45	x	x	9.17	x	x	7.45	x
Brisbane River D/S of Goodna, U/S of Oxley Creek	±0.30m	540274	143872	Oxley Ck Mouth AL	Lower Brisbane	9	2D	x	11.06	x	x	3.20	x	x	1.76	x	9.20	9.36	0.16	3.36	3.10	-0.26
				OxleyCkCorinda	Lower Brisbane	47	2D	11.00	11.06	0.06	x	4.41	x	x	1.70	x	x	9.37	x	x	4.17	x
		-	-	Clarence Rd	Lower Brisbane	41	2D	11.20	11.33	0.13	x	3.41	x	x	3.15	x	x	9.64	x	x	3.23	x
		41472	-	Centenary Bridge	Lower Brisbane	12	2D	14.10	14.00	-0.10	x	4.51	x	x	2.26	x	12.07	12.23	0.16	x	4.30	x
		540192	143832	Jindalee Alert	Lower Brisbane	11	2D	?	14.74	?	x	4.89	x	?	2.47	?	12.90	12.95	0.05	4.98	4.67	-0.32
Brisbane River U/S of Goodna	±0.50m	540200	143840	Moggill Alert	Lower Brisbane	14	2D	19.91	20.05	0.14	7.10	8.46	1.36	?	4.91	?	18.17	18.35	0.18	7.97	8.08	0.11
		540063	143868	Colleges Crossing Alert	Mid Brisbane	28	2D	x	24.70	x	x	12.29	x	x	10.04	x	?	23.58	?	?	11.31	?
		540199	143839	Mt Crosby AL	Mid Brisbane	29	2D	26.70	26.69	-0.01	14.10	14.67	0.57	11.97	12.99	1.02	26.18	25.89	-0.29	13.41	13.74	0.33
		540256	143864	Kholo Bridge AL	Mid Brisbane	30	2D	x	29.51	x	x	17.22	x	x	15.66	x	?	28.82	?	16.62	16.20	-0.42
		540257	143856	Burtons Bridge	Mid Brisbane	32	2D	x	36.25	x	x	25.29	x	x	23.87	x	?	36.16	?	24.69	24.46	-0.23
		540066	143001C	Savages Crossing TM	Mid Brisbane	33	2D	42.13	42.47	0.34	31.03	30.82	-0.21	29.83	29.44	-0.39	42.58	42.65	0.07	30.53	30.03	-0.50
		540182	143001A	Lowood Alert-B	Mid Brisbane	34	2D	?	45.87	?	34.99	35.16	0.17	33.61	33.62	0.01	46.29	46.11	-0.18	35.28	34.57	-0.71
		540178	143823	Wivenhoe Dam TW Alert-P	Mid Brisbane	40	2D	x	48.63	x	x	37.47	x	?	36.35	?	?	48.88	?	37.26	36.88	-0.38
Ipswich Urban Area	±0.30m	40831	143954	Ipswich Alert	Bremer River	17	2D	20.72	20.89	0.17	11.31	13.82	2.51	6.58	7.83	1.25	19.30	19.15	-0.15	13.90	14.10	0.20
		540250	143852	Brassall (Hancocks Bridge)	Bremer River	18	2D	x	22.77	x	x	15.67	x	x	10.03	x	?	19.78	?	?	15.92	?
		40836	14953	One Mile Bridge Alert	Bremer River	19	2D	x	25.16	x	x	18.46	x	12.93	13.93	1.00	21.98	21.63	-0.35	19.05	18.66	-0.39
Bremer River, Non-Urban Area	±0.50m	540550	143114	Berry's Lagoon Alert	Bremer River	WA15_09155.2	1D	x	26.18	x	x	20.15	x	x	15.61	x	?	23.05	?	20.07	20.38	0.31
		40838	143956	Three Mile Bridge AL	Bremer River	BM20_00000.1	1D	x	26.59	x	x	21.45	x	17.26	17.51	0.25	?	23.98	?	?	21.61	?
		540504	143896	Walloon AL	Bremer River	BM10_05036.2	1D	27.96	27.94	-0.02	26.65	26.31	-0.34	?	24.16	?	27.68	27.73	0.05	26.25	26.53	0.28
		540062	143983	Loamside Alert	Purga Creek	PU10_00000.2	1D	x	28.12	x	x	27.00	x	24.71	25.32	0.61	26.14	26.46	0.32	25.33	26.03	0.70
		540210	143113	Loamside TM	Purga Creek	PU10_00000.2	1D	27.68	28.12	0.44	26.47	27.00	0.53	x	25.32	x	x	26.46	x	x	26.03	x
		40816	143108	Amberley (DNRM) TM	Warrill Creek	WA10_04293.2	1D	28.69	28.36	-0.33	25.18	25.23	0.05	23.83	23.62	-0.21	?	26.80	?	27.79	27.47	-0.32
		540180	143825	Amberley-P (Greens Road)	Warrill Creek	WA10_03014.2	1D	x	29.84	x	26.62	27.18	0.56	25.21	25.65	0.44	27.99	28.55	0.56	?	29.21	?
Lockyer Creek	±0.50m	540051	143207	O'Reilly's Weir AL	Lockyer Creek	LO60_03917.2	1D	?	48.31	?	39.47	40.13	0.65	36.29	36.05	-0.24	?	48.63	?	?	39.71	?
		540544	143700	Rifle Range Rd Alert -P	Lockyer Creek	LO30_02619.2	1D	x	60.43	x	61.09	60.30	-0.80	56.69	54.68	-2.01	60.92	60.47	-0.45	61.14	60.36	-0.78
		540174	143819	Lyons Bridge Alert-P	Lockyer Creek	LO20_02940.2	1D	64.95	64.29	-0.66	x	63.98	x	60.08	58.58	-1.50	?	64.41	?	63.93	64.10	0.17
		540149	143808	Glenore Grove Alert	Lockyer Creek	LO10_17895.2	1D	82.05	82.02	-0.03	81.41	81.48	0.07	77.79	76.51	-1.28	82.45	82.05	-0.40	82.21	81.78	-0.43

B:\B20702 BRCFS Hydraulics\50_Hydraulic_Models\000_General\090_Gauges\[WSLGauge_CalibrationComparison_DM_600_rev_inflows.xlsx]Calibration Comparison

x	Gauge data not available
?	Gauge data questionable (e.g. gauge failure before peak)
0.12	Difference between recorded and measured within tolerance
0.34	Difference between recorded and measured outside tolerance
18.17	Moggill Gauge Peak Level in 2011 manually adjusted to 18.17m AHD (Seqwater, 2013c)

7 Presentation of Selected Events

7.1 Introduction

As discussed in Sections 3 to 6, 60 events were selected for the 11 AEPs based on the criteria outlined in Section 5.3 and fine-tuning of the selection using the Detailed Model as presented in Chapter 6.3.

To summarise the outcomes of the selection of events, plots, charts and tables are provided. All plots/charts are presented in the Plot Addendum. Discussion to assist in interpreting these tabular and graphical illustrations are provided in the following sections. The media includes:

- Difference Charts (Plot 37 to Plot 39)
- Longitudinal Profiles
  - Brisbane River (Plot 40 to Plot 51)
  - Bremer River and Lockyer Creek (Plot 52 to Plot 63)
- Water Level and Flow Hydrographs (Plot 64 to Plot 96)
- Tabulated Output (Table 7-1).

7.2 Difference Charts

Plot 37 to Plot 39 present a chart for each AEP (ie. 11 charts) that schematically show the difference in metres between the maximum AEP Ensemble level and the Monte Carlo AEP Level for all Reporting Locations. The charts provide a summary of the match between the peak of the AEP Ensemble events and the Monte Carlo AEP Levels at all Reporting Locations for each AEP. An example of one of the charts is shown in Figure 7-1.

The charts illustrate:

- CET (Critical Event Tolerance) adopted at each Reporting Location (red dashed line).
- ITO desired design flood accuracy (grey shaded area).
- AEP Level Difference for each event in the AEP Ensemble (thin coloured lines). The difference is calculated as the Event Level minus the Monte Carlo AEP Level. A positive value indicates that the Event Level is higher than the AEP Level. The events are labelled "DDD_XXXX" where DDD is the duration in hours and XXXX is the unique ID of the event for that duration. The lines are coloured according to the event duration, therefore, it is possible for two or more of the events to have the same coloured line.
- AEP Level Difference of the maximum AEP Ensemble level (thick solid black line). The difference is calculated as the maximum of the maximums of the AEP Ensemble events minus the Monte Carlo AEP Level. This is labelled "Max" and is a thick black line.

The objective of the selection process is to have the solid black line (the maximum of the maximums) as close to zero as possible, below the CET red dashed line and within the ITO desired flood accuracy grey zone. The critical event at different locations is the coloured line that lies on top of or joins the solid black line.

As an example, in Figure 7-1 the objective is that the maximum of the maximums (black/thickest line) all lie within the ITO tolerances (grey shaded area). This is ensured on the high side of the zero change line through the application of the CET (red dashed line), and on the low side by having sufficient events that meet the selection process. The maximum of the maximums represents the highest flood level at each Reporting Location based on the five events making up the 1 in 100 AEP ensemble (in this example). Also of note is that while an event may have been selected as being the closest to a zero difference, it may not be the event that controls the maximum of the maximums level. For example, Event 018_0789 shown in light blue was the closest event at the Three Mile and One Mile Bremer River gauges, but other events produce a higher level, and therefore set the maximum of the maximums level.

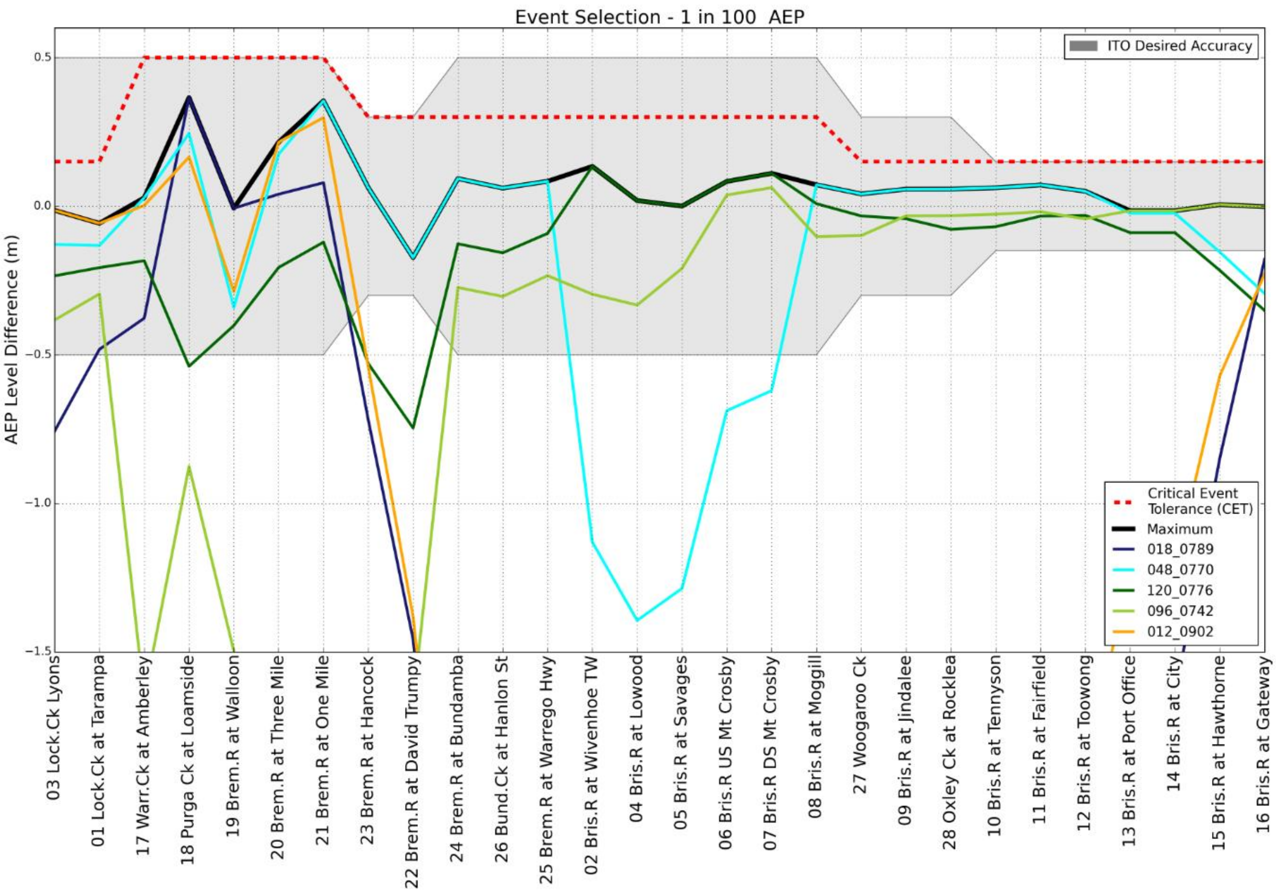


Figure 7-1 Example of an AEP Level Difference between Ensemble and Monte Carlo Analysis Chart

7.3 Longitudinal Profiles

Longitudinal profiles are provided to view the peak levels of each event in an AEP Ensemble and to provide comparisons with historical events. The plots are based on the same format agreed upon for the Fast and Detailed Model calibration milestone reports (BMT WBM, 2015a, 2015b). The same vertical scale has been used for all profiles showing the 50% to 0.5% AEPs and another, coarser, vertical scale for the 0.1% to 0.001% AEPs and All AEP profiles. The profiles are:

- Plot 40 to Plot 51: Mid and Lower Brisbane River longitudinal profiles for each of the 11 AEPs from the 50% AEP to the 0.001% AEP, followed by a profile plot of all AEPs.
- Plot 52 to Plot 63: Bremer River and Lockyer Creek longitudinal profiles for each of the 11 AEPs from the 50% AEP to the 0.001% AEP, followed by a profile plot of all AEPs.

An example of one of the charts is shown in Figure 7-2. The profiles for each individual AEP include:

- Profiles for each of the selected events in the AEP Ensemble.
- These events are labelled "DDD_XXXX" where DDD is the duration in hours and XXXX is the unique ID of the event for that duration. These profile lines are coloured according to the event duration, therefore, it is possible for two or more of the events shown to have the same colour.
- Profile of the maximum of the maximums of the AEP Ensemble shown as a thick dashed black line and is labelled in the legend as "Maximum".
- The AEP Level at each Reporting Location (shown as a reddish purple circle) from the Monte Carlo AEP Analysis discussed in Section 4.
- The Fast Model (FM) Calibration Event Profiles for the five calibration events. These are provided for relativity and are shown as thin dashed lines.

The two plots displaying all the AEP profiles (Plot 51 and Plot 63) show:

- Profiles of the maximum of the maximums for every AEP event. This is labelled in the legend as "MC_Max_Y" where Y is the 1 in Y AEP.
- The Fast Model (FM) calibration profiles for the five calibration events. These are provided for relativity and are shown as thin dashed lines.
- Note that the bed levels shown in the longitudinal profile are extracted from the DEM using an approximate thalweg line and do not necessarily represent the lowest bed elevations. Hence, the 1 in 2 AEP event, which can be a zero flow event, may appear below the approximate bed level line.

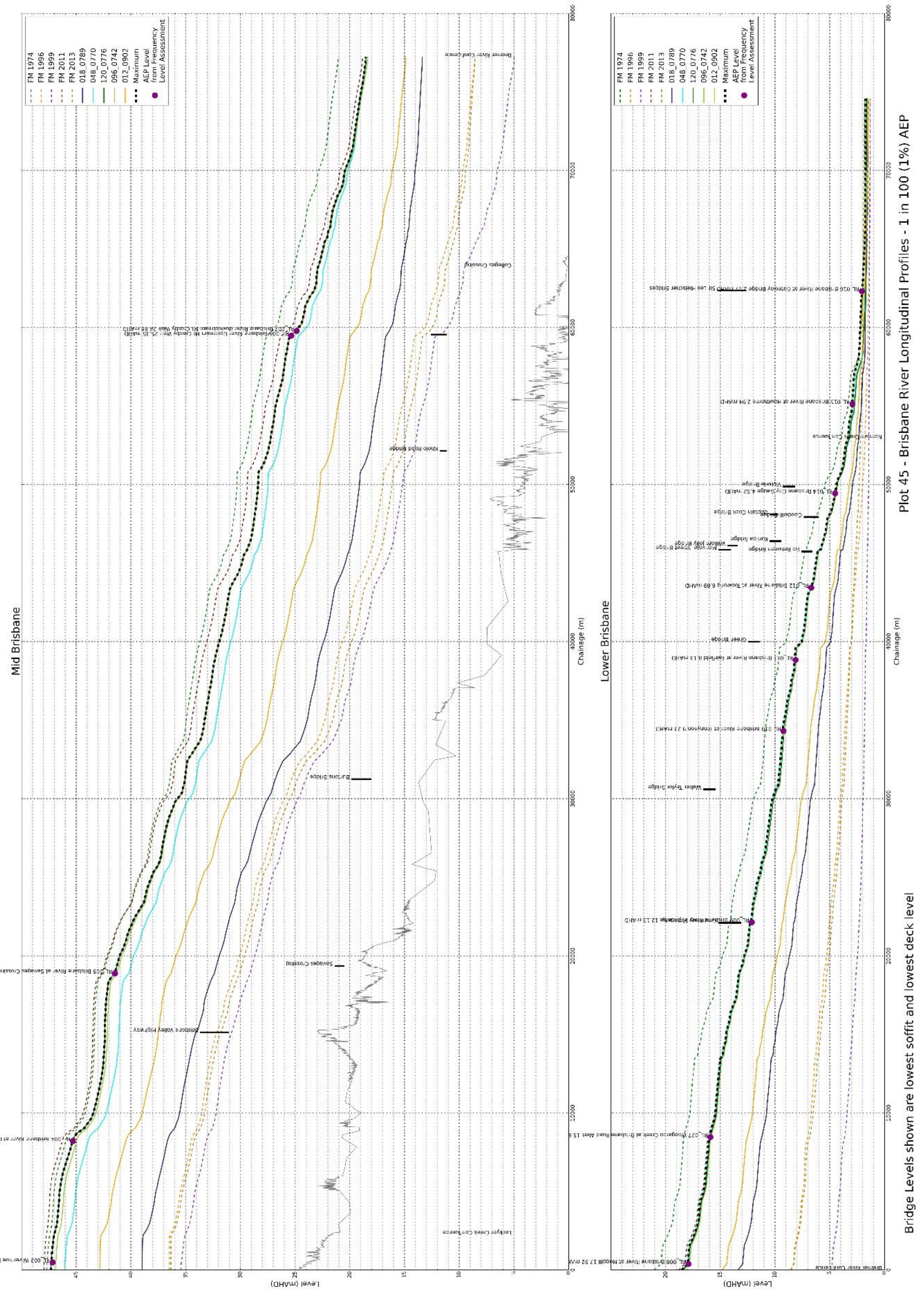


Figure 7-2 Example of a Longitudinal Profile Plot

7.4 Ensemble Water Level and Flow Hydrographs

Plot 64 to Plot 96 present hydrographs of water level (solid lines) and flow (dashed lines) to allow appreciation of the timing and shape of the selected events for each AEP Ensemble at each Reporting Location. An example of the hydrographs from the 1% AEP plots at Walloon, David Trumpy Bridge (Ipswich) and Brisbane City Gauge are presented in Figure 7-3.

The hydrograph charts display the following at each Reporting Location:

- Monte Carlo AEP level at the Reporting Location (dashed black line).
- Water level time series for each event in the AEP Ensemble. These are labelled "DDD_XXXX" where DDD is the duration in hours and XXXX is the unique ID of the event for that duration. These events are coloured according to their duration, therefore, it is possible for two or more of the events to have the same colour line.
- The event that produces the maximum water level at the Reporting Location (ie. the critical event) is highlighted by a thicker line style. For example, in Figure 7-3, the critical event at Walloon is 018_0789 (dark-blue), David Trumpy Bridge is 048_0770 (light-blue) and for Brisbane City is 096_0742 (green).
- Flows for each of the events have been plotted on the secondary axis using a dashed transparent line style.

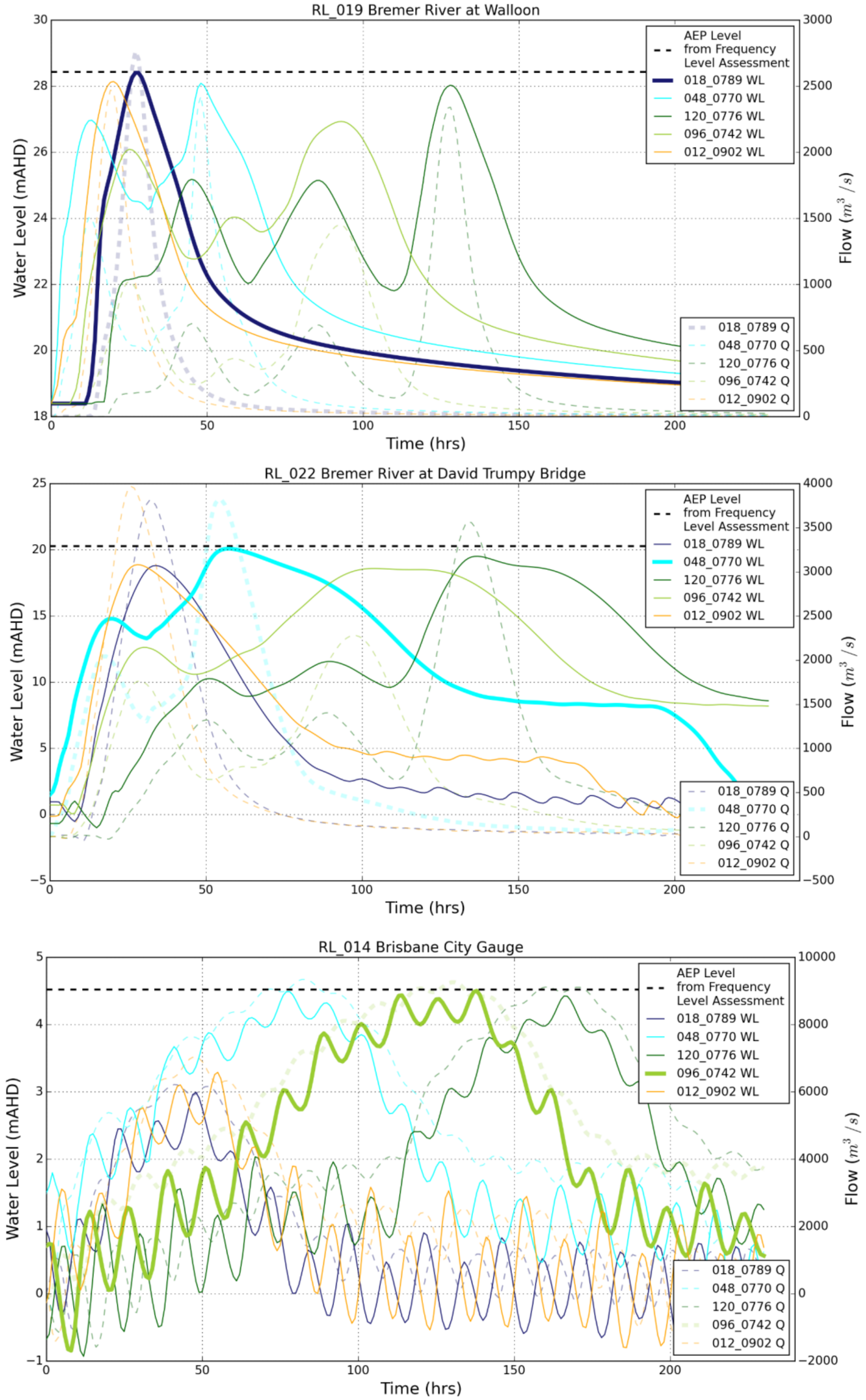


Figure 7-3 Example of Ensemble Water Level and Flow Hydrographs from the 1% AEP Plot

7.5 Tabulated Output

Table 7-2 at the end of this section (as an A3 fold-out) presents a summary of the critical events for each AEP at each Reporting Location. The table contains the following columns:

- **Reporting Location Names:** Names of each of the 28 Reporting Locations.

And for each of the 11 AEPs:

- The overarching column title contains the total number of events in the ensemble for that AEP.
- **Critical Event ID:** The ID of the selected event from the AEP Ensemble that provides the maximum level at that Reporting Location with a naming convention of "DDD_XXXX" where DDD is the duration in hours and XXXX is the unique ID of the event for that duration.
- **Difference (m):** The Critical Event Level minus the Monte Carlo AEP Level. The table cells are shaded green if the difference is within the ITO desired design flood accuracy band, and red if it is not.
- **Critical Event Level (mAHD):** The peak water level of the AEP Ensemble's critical event at that Reporting Location.

A summary table, provided as Table 7-1, lists the events that are critical in terms of peak flood level for each AEP within each LGA. It is important to note that these LGA critical events may not necessarily be critical in terms of other hydraulic outputs (such as hazard or velocity) and if individual LGAs are interested in outputs other than peak water level, it may be beneficial to consider other events in addition.

Table 7-1 Summary of Selected Events for each LGA

AEP (1 in ...)	2	5	10	20	50	100	200	500	2,000	10,000	100,000
LGA	**Critical Event ID**										
SRC	024_0008	024_0534	024_0518	018_0299	048_0620	012_0902	024_0859	024_0774	018_0991	072_0899	012_1236
	048_0227	120_0264	120_0404	048_0611	048_0678	120_0776	096_0803	072_0867	096_0889	072_0994	096_1142
	072_0054						120_0762				
ICC	012_0058	012_0693	024_0518	018_0462	048_0620	012_0902	048_0657	024_0774	036_0991	036_1026	072_1114
	012_0232	024_0534	036_0400	024_0670	048_0663	018_0789	048_0808	072_0783	072_0914	072_0994	072_1130
	018_0102	036_0346	168_0086	096_0328	120_0558	048_0770	096_0774	168_0725	096_0889		096_1142
	072_0054				120_0625			168_0887			
	120_0010										
BCC/ICC (Moggill)	120_0010	012_0693	120_0404	048_0611	048_0663	048_0770	096_0803	072_0783	096_0889	072_0994	072_1114
BCC/ICC (Woogaroo)	120_0010	012_0693	120_0404	048_0611	048_0663	048_0770	096_0803	072_0783	168_0952	072_0994	072_1114
BCC	012_0058	012_0693	036_0400	018_0462	048_0678	048_0770	096_0774	072_0783	096_0889	072_0994	072_1114
	072_0054	024_0534	120_0404	024_0670	072_0653	096_0742	096_0786	072_0867	168_0952	120_0988	072_1130
	120_0010	096_0261	168_0086	048_0611	120_0558	120_0776	120_0762	168_0887			096_1142
		168_0183	168_0481	120_0479							

7.6 Observations and Conclusions

The selection of the AEP Ensemble events for each of the 11 AEPs produced maximum ensemble levels at each Reporting Location within the desired tolerances specified in the ITO (DILGP, 2014). The exception is for the 50% AEP event as discussed below.

Key observations and conclusions were:

- The grouping of Reporting Locations to reflect the different hydraulic behaviour of different creek/river reaches was a critical part of the process. Also important was varying the grouping on an AEP by AEP basis as a Reporting Location may be conveyance dominated for minor events, but backwater dominated for larger events. A good example of this occurring is at locations within the Bremer River catchment.
- A total of 60 events have been selected to achieve the desired accuracy tolerances outlined in the ITO (DILGP, 2014). The number of events per ensemble varies as follows:

AEP	% AEP	Number of Events in Ensemble
1 in 2	50%	7
1 in 5	20%	6
1 in 10	10%	5
1 in 20	5%	6
1 in 50	2%	6
1 in 100	1%	5
1 in 200	0.5%	7
1 in 500	0.2%	5
1 in 2,000	0.05%	5
1 in 10,000	0.01%	4
1 in 100,000	0.001%	4
	Total	60

- The ITO (DILGP, 2014) estimated the number of events as “approximately 50” so as to provide some guidance to tenderers. The final number of 60 events was found to adequately represent the design events (11 AEPs) for the catchment. As such the current methodology of the study is therefore compliant with the ITO.
- The AEP Ensembles typically include a wide range of durations, reflecting the differing hydraulic responses of different Reporting Locations. The 1% AEP Ensemble of six events has five different durations: 12, 18, 48, 96 and 120, with some correlation between local catchment size and duration (ie. the smaller the local catchment area the shorter the duration).

- Adding more events to an ensemble may slightly improve (reduce) the mean difference between Event Levels and Monte Carlo AEP Levels at some Reporting Locations, however, there was invariably a greater worsening between the Ensemble's maximum levels and the AEP Levels at other Reporting Locations. Taking the maximum of the maximums for an AEP Ensemble is a key part of the design flood mapping process, therefore, adding more events to an ensemble was consistently found to not be beneficial once a set of events was selected that were within tolerance. A more effective approach to improve the match with AEP Levels was to vary the distribution of the groupings (see Table 7-1).
- Simulation of potential events using the calibrated Detailed Model allowed consistency between events to be checked. Flood levels are required to increase as event magnitude increases. Use of the Detailed Model allowed this requirement to be checked and fine tuning of event selection undertaken as required. This provided additional guidance on the final selection of events in areas not represented by the Reporting Locations. Such areas include:
    - Locations further upstream from the most upstream reporting locations on major tributaries (e.g. upstream of the Lyons Bridge Reporting Location on Lockyer Creek);
    - Locations further downstream from the most downstream Reporting Location on the Brisbane River (Gateway Bridge); and
    - Floodplains where the hydraulic behaviour is not controlled by the main waterways on which the Reporting Locations are located.
- At the TWG/IPE meeting on 13 August 2015, it was recommended that stakeholders consider whether the 1 in 2 AEP be removed from the assessment. This consideration was particularly relevant for Lockyer Creek and upper Bremer River as the Monte Carlo AEP levels effectively reflect a dry bed at Reporting Locations along these tributaries that is further exacerbated by the use of LiDAR for in-bank topography. However, following discussion at meeting and afterwards, stakeholders decided to continue with the assessment of the 1 in 2 AEP event as per the ITO (Invitation to Offer).
- Besides the 1 in 2 AEP, only one location at Fairfield for the 1 in 10,000 AEP was outside the desired tolerances with a difference of -0.24m in a 0.15m tolerance zone. Repeated attempts were made to identify an event that reduced this difference, without adversely affecting other locations. Given the magnitude of this event and that -0.24m is less than 1% of the flood depth, it was resolved that this outcome was the best achievable.

Table 7-2 Event Selection Table for All AEPs

AEP (Number Events in Ensemble)		1 in 2 AEP 8 Events			1 in 5 AEP 5 Events			1 in 10 AEP 6 Events			1 in 20 AEP 6 Events			1 in 50 AEP 6 Events			1 in 100 AEP 5 Events			1 in 200 AEP 7 Events			1 in 500 AEP 6 Events			1 in 2,000 AEP 4 Events			1 in 10,000 AEP 4 Events			1 in 100,000 AEP 4 Events		
Reporting Location	ITO Desired Design Flood Accuracy (m)	Critical Event ID	Difference (m)**	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD	Critical Event ID	Difference (m)	Critical Event Level mAHD
RL_001 Lockyer Creek at Tarampa	0.5	024_0008	-0.41	45.34	120_0264	-0.01	57.00	024_0518	0.18	59.53	018_0299	0.13	60.65	048_0620	0.06	61.06	012_0902	-0.06	61.22	024_0859	0.06	61.46	024_0774	0.08	61.69	018_0991	-0.03	61.74	072_0899	-0.02	61.91	012_1236	-0.18	62.27
RL_002 Wivenhoe Dam Tailwater	0.5	048_0227	0.01	23.77	024_0534	0.19	32.27	120_0404	0.21	35.30	048_0611	-0.41	38.25	048_0678	-0.08	43.13	120_0776	0.13	47.29	096_0803	0.12	48.95	072_0867	-0.02	49.82	096_0889	-0.31	50.80	072_0994	0.16	53.98	096_1142	0.11	62.18
RL_003 Lockyer Creek at Lyons Bridge	0.5	024_0008	-0.39	47.62	120_0264	-0.01	60.21	024_0518	0.19	62.68	018_0299	-0.14	64.14	048_0620	0.10	65.04	012_0902	-0.01	65.28	024_0859	-0.06	65.58	024_0774	0.06	65.97	018_0991	0.04	66.32	072_0899	0.05	66.65	012_1236	0.14	67.25
RL_004 Brisbane River at Lowood Pump Station	0.5	048_0227	-1.01	21.81	024_0534	0.19	30.41	120_0404	0.20	33.22	048_0611	-0.11	36.00	048_0678	-0.25	40.47	120_0776	0.02	45.33	120_0762	0.12	47.51	072_0867	-0.17	48.33	096_0889	-0.22	50.09	072_0994	0.15	53.50	096_1142	0.10	61.90
RL_005 Brisbane River at Savages Crossing	0.5	072_0054	0.01	20.75	024_0534	0.22	26.42	120_0404	0.14	29.19	048_0611	-0.12	31.93	048_0678	-0.12	36.53	120_0776	0.00	41.46	120_0762	0.14	44.29	072_0867	-0.27	46.47	096_0889	-0.19	49.27	072_0994	0.18	52.82	096_1142	0.08	61.28
RL_006 Brisbane River Upstream Mt Crosby Weir	0.5	072_0054	0.00	7.46	024_0534	0.00	10.45	120_0404	0.04	12.45	048_0611	0.14	15.43	048_0678	0.12	20.22	120_0776	0.08	25.43	120_0762	0.18	28.61	072_0867	0.04	31.58	096_0889	0.15	35.19	072_0994	0.18	38.62	096_1142	-0.02	45.20
RL_007 Brisbane River downstream Mt Crosby Weir	0.5	072_0054	-0.20	4.24	024_0534	-0.09	9.04	120_0404	0.11	11.80	048_0611	0.07	15.00	048_0678	0.15	19.83	120_0776	0.11	24.97	120_0762	0.17	28.07	072_0867	0.03	31.01	096_0889	0.12	34.67	072_0994	0.16	38.16	096_1142	0.08	44.84
RL_008 Brisbane River at Moggill	0.5	120_0010	0.12	1.88	012_0693	0.04	4.45	120_0404	-0.14	6.90	048_0611	0.11	10.09	048_0663	0.05	14.38	048_0770	0.07	17.99	096_0803	0.07	20.21	072_0783	0.13	22.74	096_0889	-0.05	25.65	072_0994	0.09	28.86	072_1114	-0.06	35.79
RL_009 Brisbane River at Jindalee	0.3	120_0010	0.08	1.65	012_0693	-0.21	2.34	120_0404	-0.14	3.82	048_0611	0.02	6.10	048_0678	0.00	9.39	048_0770	0.06	12.19	096_0774	0.10	13.92	072_0867	0.07	15.78	168_0952	-0.10	18.62	072_0994	0.00	22.31	072_1114	0.04	28.71
RL_010 Brisbane River at Tennyson	0.15	072_0054	0.05	1.58	024_0534	-0.09	1.99	120_0404	-0.12	2.79	048_0611	0.04	4.46	048_0678	-0.10	7.02	048_0770	0.06	9.29	096_0774	0.15	10.84	072_0867	0.10	12.62	168_0952	-0.10	15.36	120_0988	0.12	19.86	072_1114	0.00	27.19
RL_011 Brisbane River at Fairfield	0.15	072_0054	0.07	1.58	024_0534	-0.10	1.92	120_0404	-0.10	2.54	048_0611	0.13	3.98	048_0678	-0.10	6.19	048_0770	0.07	8.20	096_0774	0.12	9.67	072_0867	0.01	11.44	168_0952	-0.10	14.16	120_0988	-0.24	18.90	072_1114	0.02	26.41
RL_012 Brisbane River at Toowong	0.15	072_0054	0.07	1.59	024_0534	-0.08	1.84	036_0400	-0.06	2.26	048_0611	0.08	3.33	048_0678	0.02	5.09	048_0770	0.05	6.74	096_0774	0.08	8.09	072_0867	0.01	9.83	168_0952	-0.06	12.61	120_0988	-0.14	17.45	072_1114	0.01	24.28
RL_013 Brisbane River at Port Office	0.15	072_0054	0.06	1.62	024_0534	-0.12	1.72	036_0400	-0.09	1.89	024_0670	0.06	2.40	048_0678	0.02	3.47	096_0742	-0.02	4.50	096_0774	0.14	5.54	072_0867	0.06	6.83	168_0952	0.01	8.94	120_0988	0.09	12.82	072_1114	0.06	20.65
RL_014 Brisbane City Gauge	0.15	072_0054	0.06	1.62	024_0534	-0.12	1.72	036_0400	-0.09	1.89	024_0670	0.06	2.40	048_0678	0.02	3.47	096_0742	-0.02	4.50	096_0774	0.14	5.54	072_0867	0.06	6.83	168_0952	0.01	8.94	120_0988	0.09	12.82	072_1114	0.06	20.65
RL_015 Brisbane River at Hawthorne	0.15	072_0054	0.05	1.62	096_0261	-0.07	1.66	168_0086	-0.11	1.71	018_0462	0.07	1.96	072_0653	0.00	2.40	096_0742	0.01	2.95	096_0774	-0.06	3.44	072_0783	0.12	4.26	168_0952	0.06	5.64	120_0988	0.01	8.34	072_1114	-0.03	14.08
RL_016 Brisbane River at Gateway Bridge	0.15	072_0054	0.05	1.60	096_0261	0.00	1.64	168_0086	0.00	1.69	018_0462	0.00	1.76	072_0653	0.00	1.86	096_0742	0.00	2.07	096_0786	0.08	2.46	168_0887	0.06	2.84	168_0952	-0.07	3.30	120_0988	0.03	4.85	072_1130	-0.02	7.71
RL_017 Warrill Creek at Amberley	0.5	018_0102	-0.05	20.79	012_0693	0.42	26.21	036_0400	0.45	27.46	024_0670	-0.03	27.68	048_0620	0.19	28.33	048_0770	0.03	28.46	048_0808	0.00	28.65	168_0725	-0.14	28.84	036_0991	0.12	29.94	036_1026	0.03	32.05	096_1142	0.24	36.80
RL_018 Purga Creek at Loamside	0.5	012_0058	0.00	22.26	012_0693	0.49	27.04	036_0400	0.47	27.53	024_0670	0.17	27.68	120_0625	0.00	27.85	018_0789	0.37	28.50	048_0808	0.27	28.61	168_0725	0.00	28.71	036_0991	0.11	29.89	036_1026	0.00	32.06	096_1142	0.32	36.81
RL_019 Bremer River at Walloon	0.5	012_0232	0.48	20.26	036_0346	0.00	25.18	168_0086	0.00	26.25	096_0328	0.00	27.07	048_0620	0.00	27.74	018_0789	-0.01	28.42	048_0657	0.00	28.81	024_0774	0.06	29.31	036_0991	-0.13	30.01	036_1026	0.23	32.31	096_1142	0.31	36.81
RL_020 Bremer River at Three Mile Bridge	0.5	012_0232	0.07	12.53	024_0534	0.25	19.81	036_0400	0.23	22.04	018_0462	0.11	23.20	120_0558	0.21	25.02	012_0902	0.22	26.08	048_0808	0.21	27.29	024_0774	-0.01	28.08	036_0991	0.17	29.77	036_1026	0.08	32.03	096_1142	0.29	36.79
RL_021 Bremer River at One Mile Bridge	0.5	012_0232	-0.69	7.02	024_0534	0.39	16.99	036_0400	0.26	19.73	018_0462	0.13	21.20	120_0558	0.47	23.71	048_0770	0.35	25.00	048_0808	0.30	26.56	024_0774	0.00	27.44	036_0991	0.24	29.37	036_1026	0.01	31.76	096_1142	0.33	36.74
RL_022 Bremer River at David Trumpy Bridge	0.3	120_0010	-0.10	1.96	024_0534	0.08	10.13	024_0518	0.13	13.32	024_0670	0.07	15.30	120_0558	0.04	18.18	048_0770	-0.17	20.09	096_0774	-0.16	21.75	072_0783	0.00	23.51	072_0914	0.01	26.12	072_0994	0.11	29.12	072_1114	-0.02	35.95
RL_023 Bremer River at Hancock Bridge	0.3	120_0010	-0.30	2.01	024_0534	0.24	11.90	024_0518	0.20	15.42	018_0462	-0.06	17.24	120_0558	0.12	20.29	048_0770	0.06	22.04	048_0808	0.21	23.82	168_0887	-0.02	24.92	036_0991	-0.24	26.61	036_1026	0.19	29.28	072_1130	0.05	36.11
RL_024 Bremer River at Bundamba Confluence	0.5	120_0010	0.07	1.90	012_0693	-0.12	7.26	024_0518	-0.05	10.14	024_0670	0.25	12.73	048_0663	-0.05	15.97	048_0770	0.09	18.75	096_0774	0.04	20.96	072_0783	0.00	23.38	096_0889	0.05	26.09	072_0994	0.10	29.11	072_1114	-0.02	35.93
RL_025 Bremer River at Warrego Highway	0.5	120_0010	0.08	1.88	012_0693	-0.08	6.05	024_0518	-0.21	8.51	024_0670	0.13	11.66	048_0663	0.00	15.53	048_0770	0.08	18.69	096_0774	0.01	20.93	072_0783	0.06	23.38	096_0889	0.06	26.09	072_0994	0.12	29.11	072_1114	-0.01	35.93
RL_026 Bundamba Creek at Hanlon St Alert	0.5	072_0054	0.31	1.09	012_0693	-0.19	5.43	024_0518	0.05	10.14	024_0670	0.19	12.72	048_0663	-0.05	15.96	048_0770	0.06	18.75	096_0774	0.26	20.96	072_0783	0.15	23.38	096_0889	-0.04	26.09	072_0994	0.06	29.11	072_1114	0.08	35.93
RL_027 Woogaroo Creek at Brisbane Road Alert	0.3	120_0010	0.45	1.80	012_0693	-0.02	3.48	120_0404	-0.09	5.6	048_0611	0.08	8.42	048_0663	0.00	12.55	048_0770	0.04	15.96	096_0803	0.13	18.07	072_0783	0.05	20.43	168_0952	-0.16	23.39	072_0994	0.14	27.55	072_1114	0.10	35.23
RL_028 Oxley Creek at Rocklea	0.3	012_0058	0.11	1.61	168_0183	0.00	2.44	168_0481	0.01	3.57	120_0479	0	4.8	120_0558	-0.16	7.18	048_0770	0.06	9.43	096_0774	0.06	10.99	072_0867	0.03	12.76	168_0952	-0.06	15.47	120_0988	-0.28	19.93	072_1114	0.01	27.25

**The difference is calculated as the Critical Event Level minus the Frequency Analysis AEP Level for that location and AEP.

Blue shaded cells are for events that the Moreton Bay storm tide boundary was changed – refer Section 6.2.4.

8 Conclusion

The derivation of AEP levels at 28 Reporting Locations throughout the Hydraulic Assessment study area, and selection of groups of Monte Carlo events (AEP Ensembles) that form the basis for the Detailed Model design floods was carried out in three stages as follows.

(1) Simulation and checking of 11,340 Monte Carlo events provided by the Hydrologic Assessment through the Fast Model.

(2) Undertaking of a level frequency analysis at 28 Reporting Locations to estimate the flood levels for a range of Annual Exceedance Probabilities (AEP) varying from the 1 in 2 (50%) to 1 in 100,000 AEP (0.001%).

(3) Selection of groups of Monte Carlo events for each AEP (AEP ensembles) that when combined are representative of the AEP levels at the Reporting Locations. These AEP Ensembles are to be used in the Detailed Model for simulating the AEP design floods and producing flood maps.

Key observations and conclusions are:

- The Fast Model simulated all 11,340 events producing peak water levels and flows, and water level and flow hydrographs at the 28 Reporting Locations. The results were checked and in a very small percentage of cases, corrected to remove numerical instabilities. Of the 317,520 sets of outputs (11,340 events times 28 Reporting Locations), 6 peak water levels and 152 peak flows (0.05% of peak flows) were corrected.

- The peak level and flow frequency analyses used a statistical approach that minimised the bias in the associated expected probabilities. The approach used the exceedance probabilities of total catchment rainfalls as the conditioning variate. Investigations were undertaken to determine whether use of an alternative variate would be more appropriate, and it was found that the results at all but four sites (in the vicinity of Ipswich) were insensitive to the adopted choice. These four sites are heavily influenced by levels in the Brisbane River; these levels are most dependent on rainfalls over the whole catchment, and it was thus considered appropriate to retain the results based on total catchment rainfalls. Estimated AEP levels from the Fast Model simulation of the 11,340 events were produced.

- The frequency analysis results are consistent with the flow quantiles derived during the Hydrologic Assessment. They are also consistent with expectations based on historical evidence and with expected hydraulic behaviour.

- Event ensembles for each of the 11 AEPs have been compiled that produce peak levels at each Reporting Location within the desired design flood tolerances specified in the ITO (DILGP, 2014). The only AEP where the desired accuracies are not met at all Reporting Locations is the 1 in 2 (50%) AEP, which is discussed further below.

- A total of 60 events have been selected to achieve the desired accuracy tolerances outlined in the ITO (DILGP, 2014). The number of events per ensemble varies as follows:

AEP	% AEP	Number of Events in Ensemble
1 in 2	50%	7
1 in 5	20%	6
1 in 10	10%	5
1 in 20	5%	6
1 in 50	2%	6
1 in 100	1%	5
1 in 200	0.5%	7
1 in 500	0.2%	5
1 in 2,000	0.05%	5
1 in 10,000	0.01%	4
1 in 100,000	0.001%	4
Total	**Total**	60

- The ITO (DILGP, 2014) estimated the number of events as “approximately 50” so as to provide some guidance to tenderers. The final number of 60 events was found to adequately represent the design events (11 AEPs) for the catchment. As such the current methodology of the study is therefore compliant with the ITO.
- The AEP Ensembles typically include a wide range of durations, reflecting the differing hydraulic responses of different Reporting Locations. The 1% AEP Ensemble of five events has five different durations: 12, 18, 48, 96 and 120 with some correlation between local catchment size and duration (ie. the smaller the local catchment area the shorter the duration).
- Simulation of potential events using the calibrated Detailed Model allowed consistency between events to be checked. Flood levels are required to increase as event magnitude increases. Use of the Detailed Model allowed this requirement to be checked and fine tuning of event selection undertaken as required. This provided additional guidance on the final selection of events in areas not represented by the Reporting Locations. Such areas include:
  - Locations further upstream from the most upstream reporting locations on major tributaries (e.g. upstream of the Lyons Bridge Reporting Location on Lockyer Creek);
  - Locations further downstream from the most downstream Reporting Location on the Brisbane River (Gateway Bridge); and
  - Floodplains where the hydraulic behaviour is not controlled by the main waterways on which the Reporting Locations are located.
- It is recommended that the 50% AEP not be considered (ie. removed), at least for Lockyer Creek and upper Bremer River as the Monte Carlo AEP levels effectively reflect a dry bed at Reporting Locations along these tributaries that is further exacerbated by the use of LiDAR for in-bank topography. 50% AEP levels along the main Brisbane River and lower Bremer are also

of questionable value but are considered useable, especially in the tidal reaches where accurate in-bank topography exists.

- Besides the 50% AEP, only one location at Fairfield for the 1 in 10,000 AEP was outside the desired tolerances with a difference of -0.24m in a 0.15m tolerance zone, demonstrating that there was sufficient number of events in the total of 11,340 to meet the tolerances specified in the ITO. Repeated attempts were made to identify an event that reduced this difference, without adversely affecting other locations. Given the magnitude of this event and that -0.24m is less than 1% of the flood depth, it was resolved that this outcome was the best achievable.

To summarise the outcomes of the selection of the AEP Ensemble events, a series of plots and tables are provided along with discussion for interpreting these media.

Of note is that the process of deriving AEP levels and selecting design event ensembles is a stepping stone to producing the final design levels using the Detailed Model. The AEP levels presented in this report are not the final AEP design levels, but levels statistically derived from the 11,340 Monte Carlo events simulated using the Fast Model. The final AEP design levels, as 3D flood surfaces, will be produced by simulating the design event ensembles through the Detailed Model and presented in Milestone Report 5.

9 References

Aurecon *et al* (2015a), BRCFS Hydrology: H&H Interface Quality Control Report Stage 3 – With Additional Comparisons, Memorandum to Pushpa Onta of DNRM from Rob Ayre and Ferdinand Diermanse, Aurecon & Deltares, dated 14 April 2015.

Aurecon *et al* (2015b), Monte Carlo Simulation Framework and Methodology – Final, Revision 4, Prepared for Department of State Development & Infrastructure by Aurecon, Royal Haskoning DHV, Hydrobiology, Deltares, Don Carroll PM as part of the Brisbane River Catchment Flood Study Comprehensive Hydrologic Assessment, 15 May 2015.

Aurecon *et al* (2015c), Draft Final Hydrology Report, Prepared for Department of State Development & Infrastructure by Aurecon, Royal Haskoning DHV, Hydrobiology, Deltares, Don Carroll PM as part of the Brisbane River Catchment Flood Study Comprehensive Hydrologic Assessment, 15 May 2015.

BCC (2014a), Brisbane River Catchment Disaster Management Tool Model Development and Calibration Outcomes Final Report, Prepared for Department of State Development Infrastructure and Planning by Flood Management Unit, City Projects Office, Brisbane Infrastructure Division, Brisbane City Council, 19 June 2014.

BMT WBM (2014), Milestone Report 1: Data Review and Modelling Methodology Draft Final, as part of the Comprehensive Hydraulic Assessment as part of the Brisbane River Catchment Flood Study, Prepared for State of Queensland by BMT WBM, 29 October 2014.

BMT WBM (2015a), Milestone Report 2: Fast Model Development and Calibration Draft Final, as part of the Comprehensive Hydraulic Assessment as part of the Brisbane River Catchment Flood Study, Prepared for State of Queensland by BMT WBM, April 2015.

BMT WBM (2015b), Milestone Report 3: Detailed Model Development and Calibration Draft Final, as part of the Comprehensive Hydraulic Assessment as part of the Brisbane River Catchment Flood Study, Prepared for State of Queensland by BMT WBM, August 2015.

Deltares (2015), Phase 3 Data provided to BMT WBM by Deltares, 24 March 2015.

DPI (1994), Brisbane River and Pine River Flood Study, Prepared for South East Queensland Water Board by Qld Department of Primary Industries (DPI), 1994.

DILGP (2014), Invitation to Offer No. DILGP-2327-14 - For the provision of a Comprehensive Hydraulic Assessment as part of the Brisbane River Catchment Flood Study, Version 005, State of Queensland, 14 February 2014.

GHD (2014), Coastal Plan Implementation Study, Draft Report, Prepared for Brisbane City Council by GHD, September 2014.

Nathan, R.J., Weinmann, P.E. and Hill, P.I. (2002), Use Of A Monte Carlo Framework To Characterise Hydrological Risk, *ANCOLD Bulletin* - Issue No. 122, 55-64 .

Nathan RJ and Weinmann, PE (2013), Monte Carlo Simulation Techniques. *Australian Rainfall and Runoff Discussion Paper*, *Report D2*. Engineers Australia, 41pp.

Appendix A Monte Carlo Option 5 Methodology and BMT WBM Work Specification to Deltares

Appendix A contains the methodology for Option 5 to run the MC events through the Fast Model, and the work specification for Aurecon/Deltares to provide the hydrologic inputs for the Fast Model. Option 5 incorporates the Option G/H methodology. The development of the Option 5 methodology was iterative, with Options 1 to 4 being progressively superseded as discussions progressed and Option 5 being the final and adopted methodology. Options 1 to 4 are therefore not relevant and are not presented in this report. Documentation of Option G/H is provided in Appendix B.

To prevent confusion, it is important to note that the Option 5 methodology documented below was developed prior to the decision to increase the number of durations considered in the Monte Carlo assessments from six to nine. The Hydrology Assessment simulated 1260 Monte Carlo events per duration and for six durations this equated to a total of 7,560 (6 x 1260) Monte Carlo events. This is the number of runs referred to in the Option 5 methodology below. However, the decision was made to include nine event durations (12, 18, 24, 36, 48, 72, 96, 120 & 168 hours) in the assessment, leading to a total of 11,340 (9 x 1260) Monte Carlo events. This is the number of events actually used and is referred to as such throughout the main body of the report. This is the source of the inconsistency in the number of Monte Carlo events to which various sections of the report refer.

Option 5 Methodology

(1) Monte-Carlo hydraulic model simulations will be undertaken using the Fast Model using the MC Events generated for the Brisbane City Gauge (ie. for the whole of the catchment) as identified for the H&H Interfacing Option G/H (refer to correspondence on Option G/H in Appendix B).

(2) The Monte-Carlo Event Set consists of 7,560 events to be simulated in the Fast Model. There is a chance that Option G will require and additional set of another 7,560 runs based on a different rainfall for the Lockyer Valley (refer to Option G/H documentation in Appendix B).

(3) Deltares is to provide the URBS MC events inflow hydrographs, plus the corresponding Wivenhoe Dam outflow and Moreton Bay Storm Tide hydrographs for each event, that are needed for the hydraulic modelling. A written work specification for Deltares is provided in this letter.

(4) Setup and trial a system of scripts that will ultimately simulate and process the 7,560 events.

(5) Initially, carry out a trial by running the 7,560 events. Derive peak level-frequency and peak flow-frequency relationships at one site at or downstream of Moggill. (Note: Due to the additional meta-data required for Option G/H at sites upstream of the Moggill to Brisbane City reach not being available for the trial, a site upstream of Moggill cannot be used for the trial statistical analysis). The peak-flow frequency relationship will be compared to that derived by the Hydrologic Assessment at the same site. A summary of the comparison will be provided in order to facilitate discussion with members of the IPE/TWG on the results.

(6) Hold discussions with members of the IPE/TWG as to whether the approach trialled above provides the necessary outputs and quality control checks. Fine-tune the approach / outputs / checks in agreement between stakeholders.

(7) Carry out final Fast Model runs using the finalised 7,560 simulations upon sign-off of the Hydrologic Assessment MCS.

Derive the peak level-frequency and peak flow-frequency relationship at the ~28 Reporting Locations using the Option G/H approach as the final frequency relationship. The peak-flow frequency relationships will be compared to those derived by the Hydrologic Assessment at locations common to both assessments.

Work Specification for Deltares to Generate and Transfer URBS Monte-Carlo Hydrographs for the Hydraulic Model

(1) Deltares to supply URBS local and total hydrographs for the hydraulic modelling from the MC Event Sets based on the Brisbane City location (ie. for the whole-of-catchment) representing around 7,560 events in total. There is a chance that an additional 7,560 events are required that focus on the Lockyer Valley, however, this will not be known till Option G has been applied.

(2) The hydraulic model has the following boundary sources:

(a) Catchment inflows from the URBS models as a mixture of local and total hydrographs.

(b) Wivenhoe Dam Outflow Discharge.

(c) Moreton Bay water levels (Brisbane Bar).

Deltares is to use the five (5) URBS .vec files previously provided by BMT WBM for the models downstream of Wivenhoe Dam (ie. a .vec file for each of the Lockyer, Bremer, Warrill, Purga and Lower Brisbane URBS models). The revised .vec files do not change the hydrologic routing, but produce around 100 hydrographs for input to the hydraulic models. Each output hydrograph location will be assigned a unique ID.

Deltares is to carry out the following tasks:

(d) Supply the URBS hydrographs for the ~100 locations in NetCDF format in a manner that allows the hydrograph to be readily associated with the meta-data described further below. BMT WBM will be responsible for accessing/post-processing the NetCDF files, however, Deltares will be responsible for documenting the NetCDF data structure, and for providing BMT WBM with scripts/assistance so that BMT WBM can access the file(s).

(e) In addition to the hydrographs, the Bremer, Warrill and Purga models each produce a base flow hydrograph in the URBS .bf file. The three base flow hydrographs (per event) need to be input into the hydraulic models, therefore, Deltares will need to add the base flow hydrographs to the NetCDF file containing the flow hydrographs or provide them in a separate NetCDF file.

(f) Deltares is to supply the Wivenhoe Dam outflow and Moreton Bay level hydrographs for each MC event, either as part of the NetCDF file(s) containing the hydrographs or in separate files in NetCDF format or as otherwise agreed between BMT WBM and Deltares.

(g) The gross and excess rainfall NetCDF file(s) used to generate the URBS .r files are to be provided by Deltares using a data structure that would allow regeneration of the URBS .r files for anyone of the 7,560 MC events.

(h) All hydrographs will be provided using a one hour time interval.

(i) Events will be run for a minimum period of 10 days from the commencement of the rainfall.

(j) Deltares will be responsible for ensuring that the hydrographs are translated correctly from the URBS .q and .bf files to the NetCDF file(s).

(3) Deltares is to provide in .csv, NetCDF or spreadsheet format a table that tags every event with the following meta-data fields.

Meta-Data Field	Description
1. MC Event Set	This will be Brisbane to conform to Option G/H.
2. Event ID	The MC Event's unique ID (for example 120_0001, 120_0002, …..) as already agreed.
3. Burst Duration	Storm burst duration in hours.
4. Rainfall Depth	Catchment rainfall depth based on the average depth of burst rainfall for the whole catchment.
5. Rainfall AEP	Catchment rainfall AEP based on the average depth of burst rainfall for the whole catchment.
6. Wivenhoe Rainfall	Rainfall depth over the combined Wivenhoe/Somerset dam catchment that produced the Wivenhoe Dam discharges.
7. IL-Stanley 8. IL-Upper 9. IL-Lockyer 10. IL-Bremer 11. IL-Warrill 12. IL-Purga 13. IL-Lower	Initial losses for each sub-catchment URBS model.
14. CL-Stanley 15. CL-Upper 16. CL-Lockyer 17. CL-Bremer 18. CL-Warrill 19. CL-Purga 20. CL-Lower	Continuing loss rates for each sub-catchment URBS model.
21. Vol-Cressbrook 22. Vol-Manchester 23. Vol-Moogerah 24. Vol-Perseverance 25. Vol-Somerset 26. Vol-Wivenhoe	Initial volumes in Wivenhoe, Somerset, Cressbrook, Perserverance, Moogerah and Lake Manchester Dams.
27. OReillys Rainfall AEP 28. OReillys Flow AEP 29. OReillys Volume AEP	If available or can be easily produced, OReillys Weir upstream catchment rainfall AEP, and OReillys Weir flow AEP and volume AEP.

30. Peak Flow <Rep_Loc> 31. Peak Flow AEP <Rep_Loc> 32. Rainfall Depth <Rep_Loc> 33. Rainfall AEP <Rep_Loc> 34. 24h Volume <Rep_Loc> 35. 24h Volume AEP <Rep_Loc> 36. 48h Volume <Rep_Loc> 37. 48h Volume AEP <Rep_Loc> 38. 72h Volume <Rep_Loc> 39. 72h Volume AEP <Rep_Loc>	Peak flow and flow AEP, upstream catchment rainfall and rainfall AEP, and 24, 48 and 72 hour volume and volume AEP for each hydrology Reporting Location as follows: • All locations on the Brisbane River downstream of and including Wivenhoe Dam • All locations downstream of and including Glenore Grove on Lockyer Creek • All locations downstream of and including Walloon on the Bremer River • All locations downstream of and including Amberley on Warrill Creek • All locations downstream of and including Loamside on Purga Creek
Field 40, 41, 42…	Repeat above fields 30 to 39 for each Reporting Location.

(4) Deltares is to carry out quality control checks showing that for each MC event the total volume of water and the peak flow at the outlet of the Lower Brisbane URBS model is the same as that previously calculated for the MC runs to ensure there is no change in the hydrologic calculations.

Deltares is to provide a table or spreadsheet showing the above quality control checks for each event.

Note: BMT WBM and Deltares have both completed quality control checks on the .vec files supplied by BMT WBM for a trial set of MC events, therefore it is expected there should be no issues with the supplied .vec files. However, should there be a significant mismatch between results, Deltares are to notify BMT WBM immediately and BMT WBM is to rectify the .vec files before proceeding further. The delivery timeframe will be extended due to any delays caused by BMT WBM having to correct the .vec files.

(5) Deltares to supply all files in a compressed form using a compression format agreed with BMT WBM (eg. zip or .7z). Delivery of the files is to be via digital media or through a web download as agreed with BMT WBM.

(6) Deltares is to carry out the above tasks in three stages as follows:

(a) **Stage 1:** Set up the FEWS configuration and produce trial outputs using a subset of events as is convenient for Deltares to produce. The outputs are to be sent to BMT WBM for review on an as-needed basis until agreement that the file formats and meta-data tagging meet the requirements above.

(b) **Stage 2:** Carry out the tasks using the Draft MC Event Set for Brisbane City as a trial to ensure all data are provided and appropriately tagged. BMT WBM will cross-check the data delivered and advise of any issues. This trial set of 7,560 events does not need to be identical to the final MC runs, as BMT WBM will solely be using these events for testing.

Note: The inclusion of the additional meta-data added to this Version 3 of the work spec is preferred, however is not essential for Stage 2.

(c) **Stage 3:** Once the Hydrologic Assessment's MC Analysis is signed off (ie. finalised), carry out the above tasks for the final MC Events for Brisbane City. This stage should not be started until written authorisation to proceed has been provided by the Qld Government.

Note: The additional meta-data added to this Version 3 of the work spec, whilst not essential for Stage 2, are to be provided with Stage 3.

(d) **Stage 4 (Optional):** Depending on the outcomes of applying Option G, a second set of 7,560 hydrographs may need to be generated using different rainfalls. If required, Stage 4 would be a repeat of Stage 3.

Appendix B Monte Carlo Option G/H Methodology – Resolving the Residual Catchment Rainfall Issue

The attached document included here as Appendix B (over page) was authored by the IPE is dated 3 February 2015 and was provided to BMT WBM on 6 February 2015.

The attached IPE document describes the Option G/H methodology that was developed to solve the issue of the residual catchment rainfall. This issue was noted during H-H Interfacing when it was realised that the Aurecon team had only applied rainfall to the URBS model catchments upstream of each hydrology Reporting Location of interest. That is, other “residual” catchments had no rainfall applied. This methodology was satisfactory in achieving the required outcomes of the Aurecon team’s Hydrology Assessment. However, for the purposes of hydraulic modelling, flows from the residual catchments were required. Hence, options for dealing with the residual catchment issue were investigated. The problem was considered by a group of experts including Rory Nathan from Jacobs, Michel Raymond from Seqwater (TWG Member), Ferdinand Diermanse from Deltares, Erwin Weinmann from the IPE in consultation with BMT WBM, Aurecon and the Client. Several options were considered and rejected prior to the acceptance of “Option G/H”. Option 5 (presented in Appendix A) incorporates Option G/H within its methodology and work specification to Deltares.

To prevent confusion, it is important to note that the Option G/H methodology documented here was developed prior to the decision to increase the number of durations considered in the Monte Carlo assessments from six to nine. The Hydrology Assessment simulated 1260 Monte Carlo events per duration and for six durations this equated to a total of 7,560 (6 x 1260) Monte Carlo events. This is the number of runs referred to in the Option G/H methodology. However, the decision was made to include nine event durations (12, 18, 24, 36, 48, 72, 96, 120 & 168 hours) in the assessment, leading to a total of 11,340 (9 x 1260) Monte Carlo events. This is the number of events actually used and is referred to as such throughout the main body of the report. This is the source of the inconsistency in the number of Monte Carlo events to which various sections of the report refer.

In addition, the methodology documented here was developed prior to the decision to define “whole-of-catchment” as the whole catchment to Brisbane Port Office gauge. Thus, any reference to “whole-of-catchment” in the attached document needs to be considered in this way.

Options G and H for H-H Interface (03/02/2015)

Background to suggested Options G and H

The main questions arising with the options proposed earlier and discussed at the teleconference of 20 January were:

1. How can the relative contributions to the flood level frequency curve at an upstream target location (e.g. Ipswich) of rainfall/flood events that are critical for peak flows at the target location and rainfall/flood events that produce critical backwater conditions downstream be adequately allowed for?
2. If the analysis of flood level frequencies uses simulations for the relatively short event durations that may be critical for flood peaks at the target locations, how can allowance be made for the longer lag times of Brisbane River peak flows, particularly for the with-dams case?
3. If the flood level frequency analysis (using the TPT approach) focuses on the sets of events for longer durations (say 72 to 120 hours) that are expected to produce critical backwater conditions, do these events include a sufficient sample of internal space-time patterns of rainfall which produce high peak flows in the target catchment (e.g. the Bremer River catchment at Ipswich)?
4. What is the most appropriate rainfall or flood characteristic to be used as conditioning variable in the TPT analysis?

The further exploration of these questions involved several email exchanges between Ferdinand Diermanse, Rory Nathan, Michel Raymond and Erwin Weinmann and was informed by a series of scatter plots prepared by Michel (based on Seqwater WSDOS simulations for complete storm events) and by Ferdinand (based on BRCFS FEWS simulations for rainfall burst events). Ferdinand also made available some spreadsheets with example computations to examine the impact of Option G on peak flow frequencies at downstream locations. What emerged from these discussions are the H-H Interface Options G and H described below.

Description of Option G

The following basic concepts and assumptions underlie Option G:

(i). Hydraulic modelling is only undertaken for a *'whole-of-catchment'*[1] *set of hydrograph inputs*

(ii). Simulations should be undertaken for *rainfall burst durations of 24, 48, 72, 96 and 120 hours*, possibly supplemented by an additional set of 168 hours duration) for hydraulic modelling. With 1250 simulations in each duration set this will amount to 6250 (7500) simulations at each of the two locations, a total of 12,500 (15,000) simulations.

(iii). Through the highly variable space-time patterns of rainfall used in the simulations for the AEP range of 0.5 to 0.0005, these longer duration simulation sets will also include events that produce large/rare peak flow outcomes at the target locations. However, as uniform spatial patterns have been used for the simulation of rainfall events with AEPs less than 0.0005, this assumption does not apply to these rarer events.

1 This note is an addition to the original document supplied by the IPE at the request of the IPE. In this document, "whole of catchment" should be taken to refer to the whole catchment to the Brisbane Port Office gauge, which was a decision made based on further assessments.

(iv). The simulations for the different durations are considered to be equally likely conditions which could produce critical flood levels at the target location and are thus combined for the TPT analysis.

(v). The TPT analysis for flood level frequencies at the target location will use *peak flows from the reconciled flood frequency curve at the 'whole-of-catchment' location as the conditioning variable.* As a check, an alternative calculation method using peak flows at the target location as conditioning variable will also be applied.

Discussion of Option G

Discussions of the merits of this option have covered the following points:

- In relation to (i) – the important influence of backwater conditions on upstream flood levels needs to be allowed for by extending the modelling domain sufficiently far downstream to capture any possible backwater effects. The space-time patterns generated for the total Brisbane River catchment have previously been shown to preserve the important correlations between Brisbane River and lower tributary catchments.
- In relation to (ii) – the potentially large differences in relative timings of the peaks at the target location and the Brisbane River location (demonstrated by the recently produced scatter plots) make it necessary to undertake simulations for a duration of 96 hours or longer (regardless of the shortness of the rainfall burst considered) for hydraulic modelling of the with-dams scenario.
- In relation to (iii) – the scatter plots of peak flows and volumes for the Ipswich and Moggill locations have confirmed that the longer duration events still produce a significant number of large events over the local catchment and even some extreme events. However, the peak flow frequency curve for the local catchment defined by this event set may not adequately match the reconciled peak flow frequency curve determined in the hydrology study. In that case some form of correction may need to be applied (see Option H below).
- The assumption made in (iv) is somewhat arbitrary but given that there is no information on the distribution of event durations, this is considered to be a pragmatic but reasonable assumption.
- The justification for (v) is based on the results of the exploratory spreadsheet calculations which have indicated that any mismatch of peak flow frequency curves is minimised by using the reconciled flood frequency curve at the downstream location as the conditioning variable. This will need to be re-visited once peak levels become available from the hydraulic modelling.

Option H

More detailed examination of the peak flow frequency curve for Moggill generated by Option G (in its originally proposed form, using the reconciled flood frequency curve at Ipswich as the conditioning variable) indicated that the downstream peak flow frequency curve would be substantially overestimated. The likely reason for this, when using the 'whole-of-catchment' event set, is the unequal representation (in terms of their AEP) of peak flow events at Ipswich and Moggill.

The use of the peak flow frequency curve at the downstream location as conditioning variable is expected to minimise any bias introduced in the implied peak flow frequencies at other locations.

However, if further analysis of simulation results still indicated significant bias, a modification of the TPT calculations in the form of Option H could be applied.

Option H aims to compensate for the unequal representation of 'whole-of-catchment' and 'local catchment' events in AEP bins by applying a set of weights in the calculation of conditional probabilities. These weights would be based on the application of an appropriate correlation model.

Conclusions

The main conclusions from the considerations that have led to Options G and H are:

1. The hydrographs produced by the corresponding 'whole-of-catchment' MC event sets will provide an appropriate basis for the fast hydraulic model simulations and calculation of flood level frequencies at the Lower Lockyer and Ipswich reporting locations.
2. For the with-dams scenario, the simulations should be conducted for rainfall bursts from 24 to 120 hours duration and, desirably, also for a duration of 168 hours; all simulations should cover a total period of at least 96 hours.
3. The metadata kept from these simulations should be comprehensive enough to allow various forms of post-processing to be applied and evaluated, – a detailed specification to be prepared by the consultants for the hydraulic modelling phase (with an appropriate degree of redundancy built in).
4. Option G, with possible extension to Option H, is expected to satisfy the requirements of the H-H interface, as stipulated at the teleconference of 20 January:
   - theoretically sound and defensible
   - pragmatic in terms of the feasibility of its implementation within the BRCFS
   - acceptable to the stakeholders

   However, as the TPT calculations to determine flood level frequencies are part of the post-processing phase, there is scope for further refinements of these options by the consultants for the hydraulic modelling phase over the next few weeks.

Appendix C Discussion on Bremer River Level Frequency Analysis

When applying the approach described in Section 4 to sites along the Bremer River, it is necessary to consider carefully how the Total Probability Theorem is constructed. As mentioned in Section 4.3, the approach is based on the assumption that upstream rainfalls are the dominant cause of flooding. While this assumption is easily accepted for the majority of sites, its defensibility when applied to sites affected by backwater was questioned during early discussions on the interfacing between the Hydrologic and Hydraulic Assessments. A number of alternatives were posed without being finalised, where one possible solution involved the use of weights in the calculation procedure that were based on the degree of correlation in rainfall maxima in the tributary and mainstream catchments (ie “Option H” as discussed by the H&H working group and documented in Appendix B).

In order to assess the nature of this issue, two sets of runs were undertaken. First, the level maxima were conditioned using rainfall AEPs local to the upstream catchment, and second, the level maxima were conditioned using the rainfall AEPs relevant to the whole-of-catchment rainfalls. The latter set of results correspond to Option G, and the difference between the two sets of results represent the bounds of results that would be obtained should Option H be implemented. (Note that Option G/H is documented in Appendix B).

The results of this analysis are summarised graphically in Figure C-1. The two sets of results reflect the differences in AEP of the rainfalls relevant to the portion of the local catchment upstream of the site (solid lines) and that for the whole of the Brisbane River catchment (dashed lines). For Savages Crossing, the AEPs for the two different catchment references are quite similar (see right hand panel, Figure C-2), and thus it is not surprising that the level frequency curves are also similar.

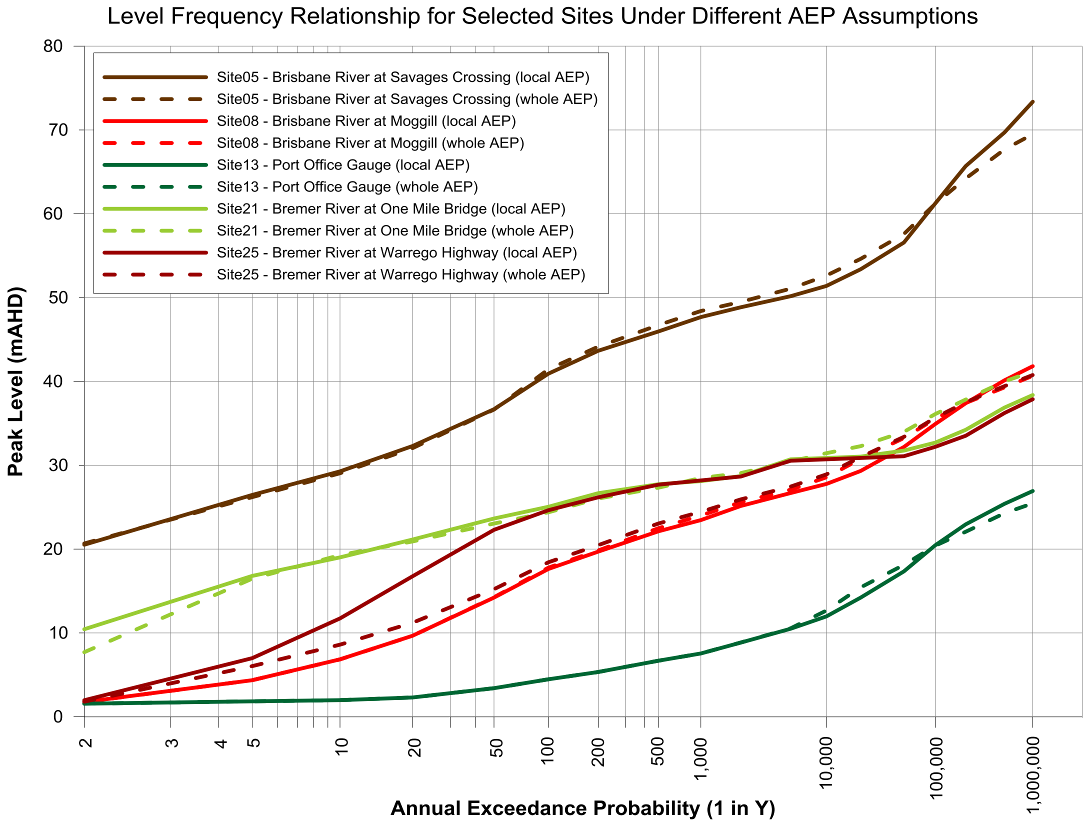


Figure C-1 Comparison of flood frequency relationships based on different conditioning AEP assumptions for selected sites

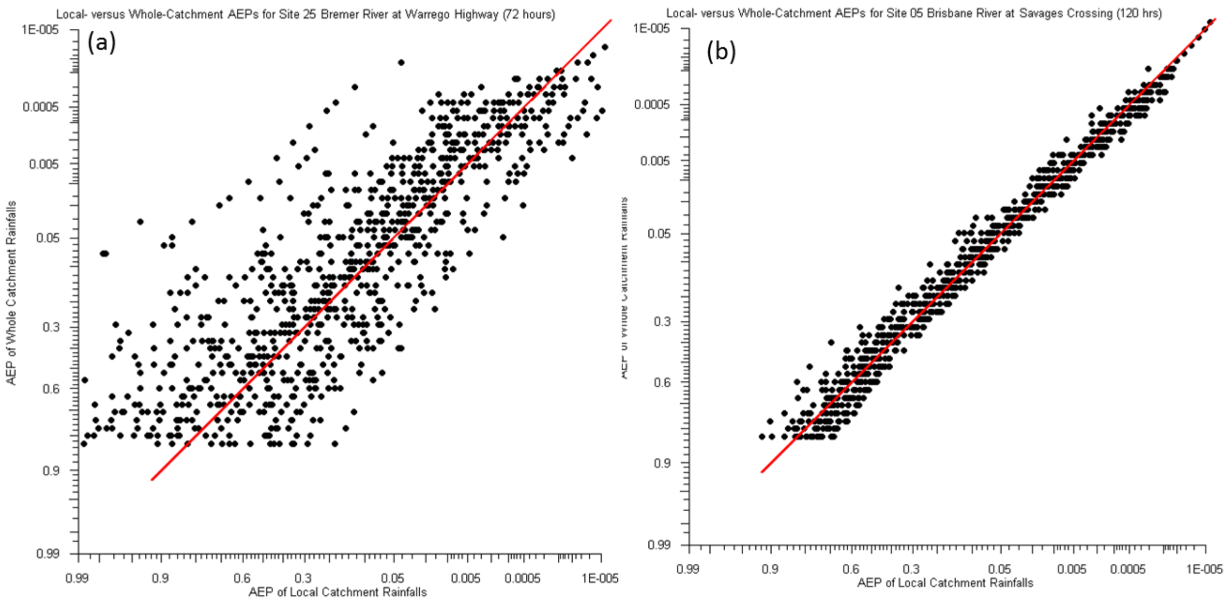


Figure C-2 Comparison of local and whole-of-catchment rainfall AEPs for (a) Bremer River at Warrego Highway and (b) the Brisbane River at Savages Crossing

The largest differences between using local and whole catchment AEPs for the selected locations shown in Figure C-1 are for Reporting Locations 21 and 25. These sites are located on the Bremer River and the difference in catchment areas, and hence differences in AEPs, is extreme (see left-hand panel of Figure C-2). Reporting Location 25 (Bremer River at Warrego Highway) is the most downstream site on the Bremer River and is thus subject to significant backwater influences from the Brisbane River, which is evident in the relationship between peak flows and levels derived from the Fast Model (see right hand panel of Figure C-3). Reporting Location 21 (Bremer River at One Mile Bridge) is above Ipswich and is still affected by backwater conditions, but this only tends to occur at higher levels starting around the 1 in 100 AEP event (Figure C-3a). This influence of backwater supports the need to use whole-of-catchment rainfalls as these conditions are associated with levels in the Brisbane River, and these levels are the result of rainfalls over the majority of the catchment and not the local upstream catchment.

It is seen in Figure C-1 that the level frequency curves derived using local catchment AEPs generally lie above the frequency curves derived from whole-of-catchment AEPs. It is also seen that the two sets of curves (derived using local and whole-of-catchment rainfalls) cross at an AEP of around 1 in 10^4. That is, the levels derived using the whole-of-catchment rainfalls are higher than that derived using the local catchment rainfalls beyond 1 in 10^4, which is the opposite of the case for more frequent events. Importantly, it is also seen that extreme flood levels at Reporting Location 8 in the Brisbane River at Moggill (corresponding to AEPs rarer than 1 in 10^4) lie above extreme levels derived using local catchment AEPs at both Reporting Location 21 and 25, but are similar to the results obtained using whole-of-catchment rainfalls.

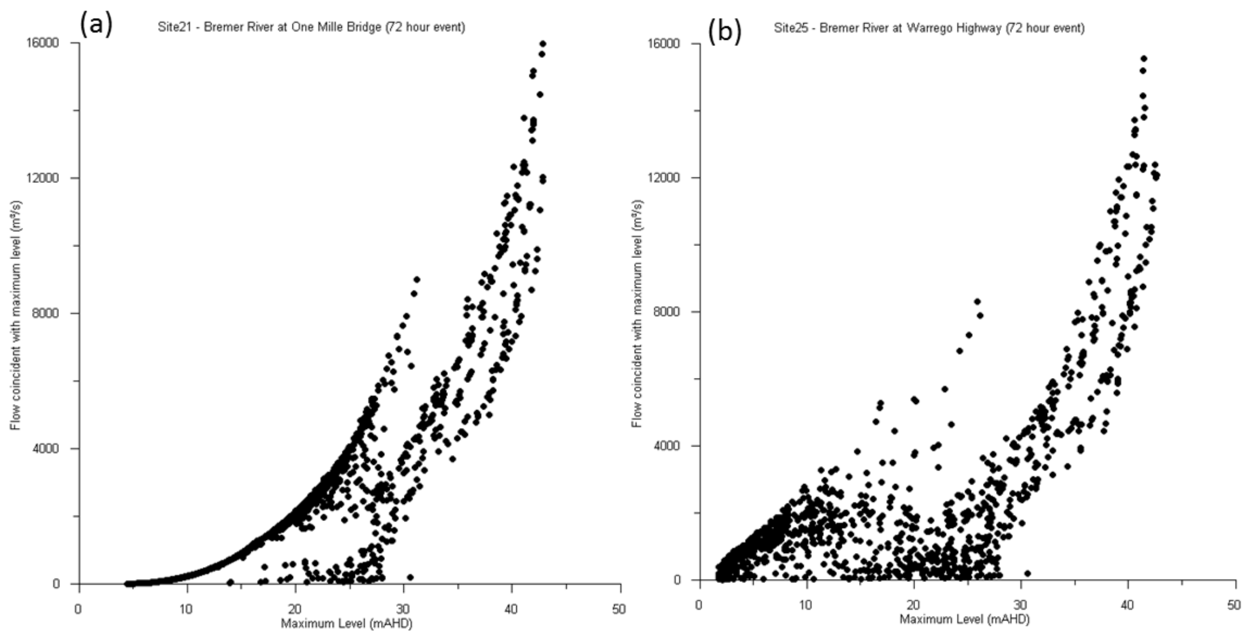


Figure C-3 Relationship between coincident flows at peak levels for 72-hour event at (a) Bremer River at One Mile Bridge and (b) Bremer River at Warrego Highway

These plots raise a number of issues that are not easily reconciled:

- All the flows input to the Fast Model are derived using whole-of-catchment rainfalls, and thus in general it would be expected that rainfalls over the local catchment are associated with more frequent AEPs than those over the whole catchment; however, the left-hand panel of Figure C-2 (and Figure C-4a) reveals only a very slight tendency for this along the Bremer River, and there is a sizeable proportion of the runs where the local catchment rainfalls are more extreme than the whole catchment.

- The frequency curve of flood peak discharges derived by Aurecon (2015a) using the whole-of-catchment rainfalls lie above that obtained for the local catchment (lower panel, Figure C-4); again, this is counter-intuitive as the reverse would be expected. That is, rainfalls over the Bremer River catchment for a given AEP should be higher than those over the whole of the Brisbane River, and accordingly it would be expected that peak flows from the local catchment should also be higher.
- The upper end of the frequency curves for sites along the Bremer River derived using local catchment rainfall AEPs yield levels that are lower than that observed at Moggill, and this is not consistent with expected hydraulic behaviour as the these downstream locations are influenced by backwater effects (Reporting Locations 24, 25, & 26). That is, since the use of local-catchment AEPs does not reflect the influence of Brisbane River levels, they must be unsuited for this purpose.
- The mid-range of the frequency curves derived using local catchment rainfall AEPs (between, say, 1 in 200 and 1 in 2,000) yield levels that are up to 8m higher than that observed at Moggill for the same AEP (Figure C-5);. The differences in results is the most marked for the two most downstream sites (Bundama confluence and Warrego Highway), and use of the local-catchment AEPs would suggest that all flooding up to an AEP of 1:10000 is due solely to local catchment rainfalls and that there is no backwater influence from the Brisbane River. Again, this is not consistent with expected hydraulic behaviour or historical evidence. By contrast, use of whole-of-catchment rainfalls indicates a mix of effects, where local catchment rainfalls are more dominant in frequent events, and backwater effects from Brisbane River becomes progressively more influential for rarer events.

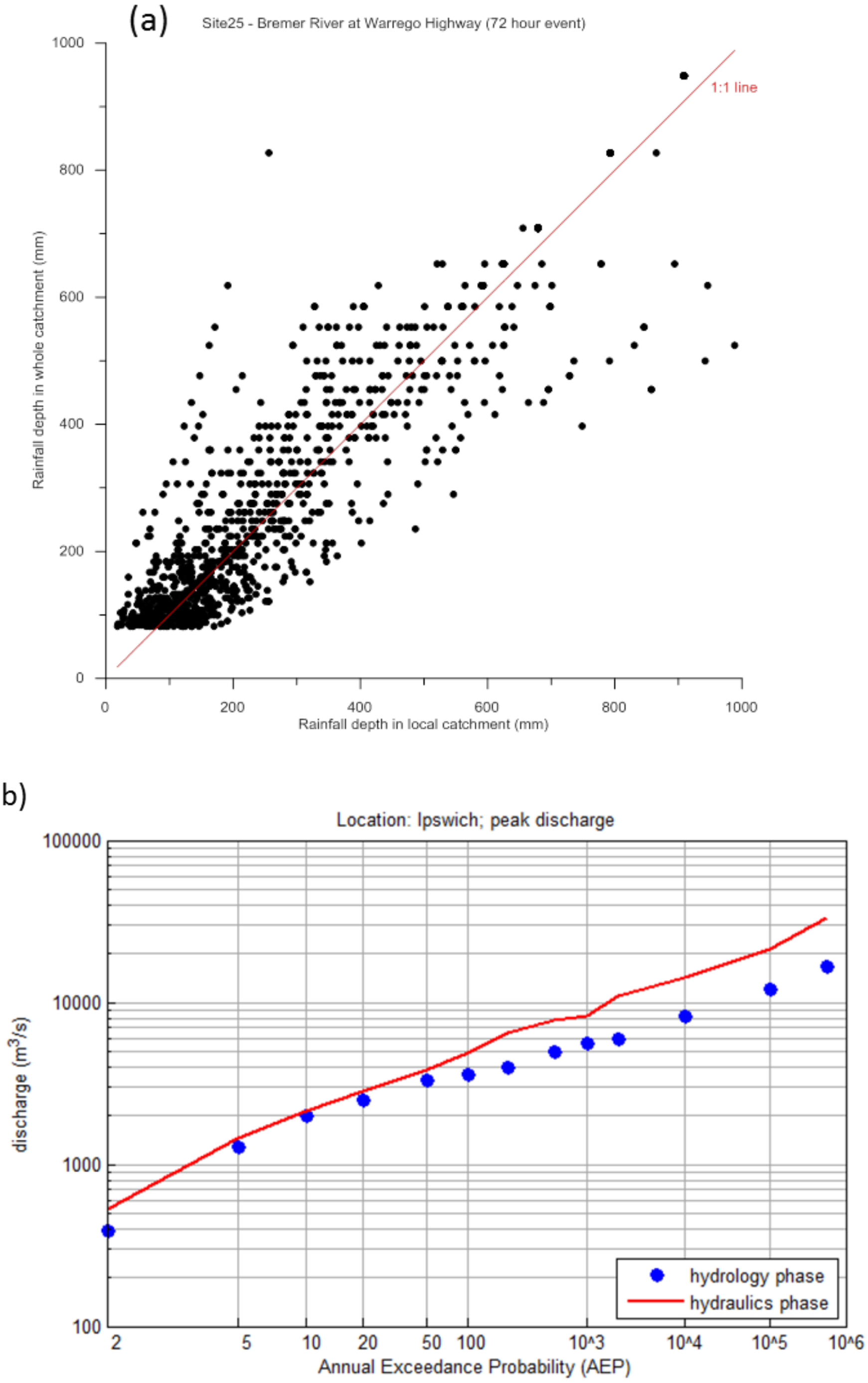


Figure C-4 Relationship between (a) local and whole-of-catchment 72-hour rainfalls for Bremer River at Warrego and (b) flood peaks derived using local (blue symbols) and whole-of-catchment rainfalls (red line) for Ipswich as reported by Aurecon *et al* (2015a)[12]

[12] Note that the legend in Figure C-4 Relationship between (a) local and whole-of-catchment 72-hour rainfalls for Bremer River at Warrego and (b) flood peaks derived using local (blue symbols) and whole-of-catchment rainfalls (red line) for Ipswich as reported by Aurecon *et al* (2015a)

At this stage it would appear difficult to reconcile some of the above issues without better understanding the way in which sub-catchment rainfalls were generated. However, that said, the frequency curves derived using whole-of-catchment rainfall AEPs do appear to be yielding sensible results. At the most downstream site on the Bremer (Reporting Location 25), the 1 in 10 AEP level is around 1m higher than that observed at Moggill, and this level difference gradually reduces with AEP until the two curves are coincident. This is consistent with expected hydraulic behaviour. Results for other sites under different AEP assumptions along the Bremer River are shown in Figure C-5. It is seen that the sensitivity to AEP assumption is only apparent for the four sites along the mid-reaches of the Bremer River, downstream of Hancock Bridge, but not for the sites further upstream.

Further assessment of the assumptions can be made with reference to the estimate of severity of the 2011 event at Ipswich. The AEP of the maximum flood level reached in 2011 at Ipswich estimated using whole-of-catchment rainfalls is 1 in 72, whereas that derived using local rainfalls is 1 in 20. That is, adoption of Option G yields an estimate of the severity of the 2011 flood at Ipswich of 1 in 72; adoption of differing degrees of correlation between the areal rainfalls (as would be required to implement Option H) would yield an estimate of severity that ranges between 1 in 20 and 1 in 72.

Lastly, it is worth noting that another option for the conditioning variate is to use AEPs associated with the upstream peak flows. While this approach might seem attractive in that AEPs are tied to the reconciled frequency curve associated with the flows being used in the model, it does present the difficulty that the reconciled frequency curve is derived from a mix of durations whereas it is necessary to undertake the analyses on individual durations; that is, there is likely to be a mismatch between the AEPs inferred from the frequency curve and the duration of the flood event of interest. That issue aside, a comparison was undertaken using flow AEPs as the conditioning variate. The results for two sites are shown in Figure C-6, where it is seen that the results obtained exhibit similar differences to that shown by use of local catchment rainfalls.

On the basis of the information available at this point in time, it would appear reasonable to adopt the results based on whole-of-catchment rainfalls, which is consistent with Option G (as discussed by the H&H working group & documented in Appendix B. Without better resolving the apparent inconsistencies in the local versus whole-of-catchment rainfalls, there would appear to be little value in considering the computation of conditioning AEPs by weighting of local and whole-of-catchment rainfalls on the basis of correlation between the maxima (ie Option H).

(b) (direct from Aurecon *et al* (2015a), is better considered as follows: Blue symbols represent the flood peaks derived by Aurecon using **local catchment rainfalls** as per Aurecon *et al* (2015c) (referred to in the legend as “hydrology phase”), while the red line represents the flood peaks derived by Aurecon using **whole-of-catchment rainfalls** for the purpose of use in this current hydraulic assessment (referred to in the legend as “hydraulics phase”).

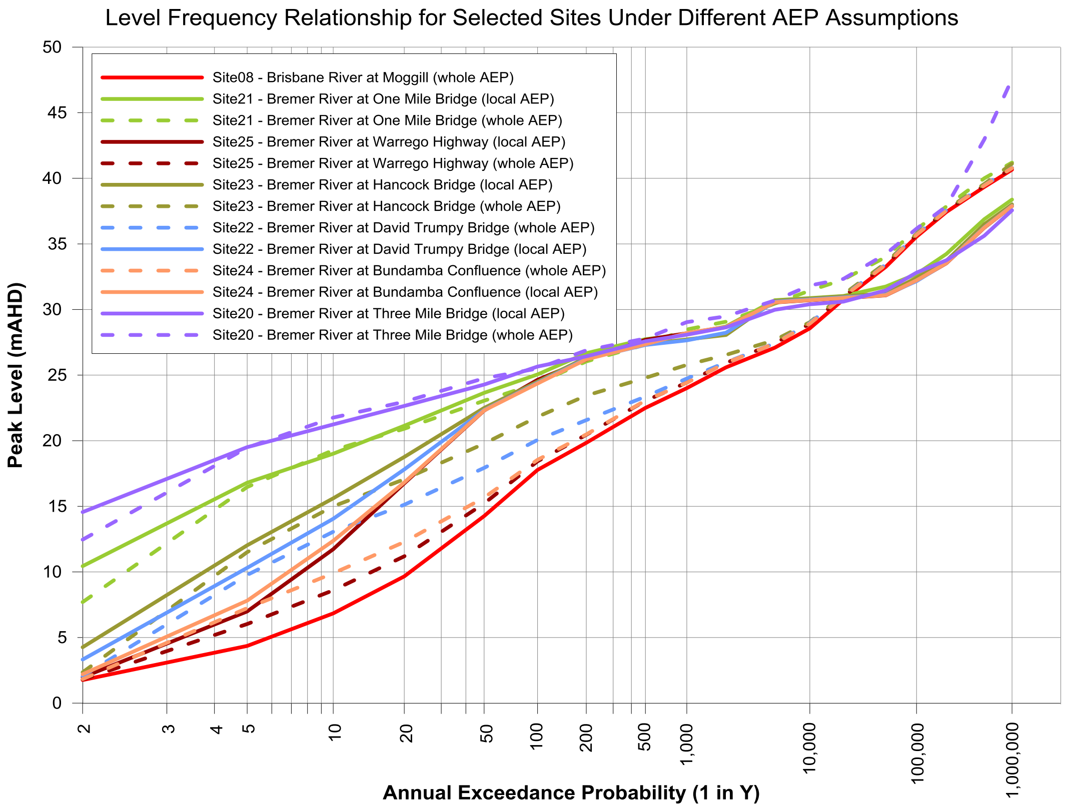


Figure C-5 Comparison of flood frequency relationships based on different conditioning AEP assumptions for most sites along the Bremer River

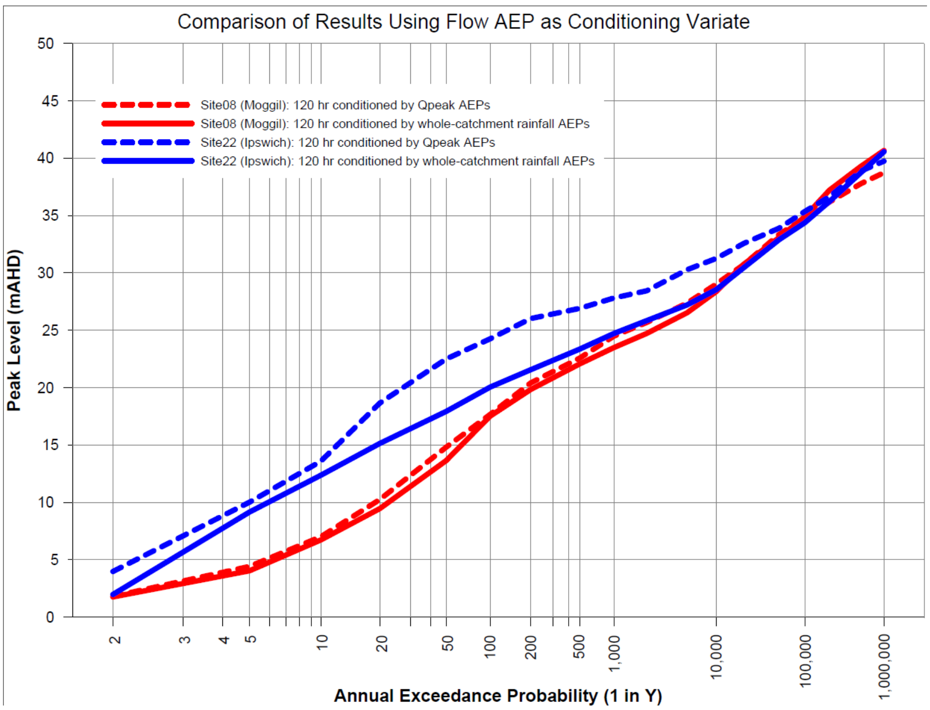


Figure C-6 Comparison of flood frequency relationships derived using peak flow AEPs as the conditioning variate compared to whole-of-catchment rainfall AEPs

Appendix D Flood Level Quantiles (m AHD) for Individual Storm Durations for Each Reporting Site

Results for Site 01: Lockyer Creek at Tarampa

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	45.37	45.39	45.42	45.45	45.49	45.61	45.57	45.71	45.75	45.75	168hr
5	0.8416	53.47	54.97	55.20	56.17	56.78	57.01	56.61	56.78	56.72	57.01	72hr
10	1.2816	56.71	57.96	57.79	58.49	58.92	59.26	58.87	59.35	59.05	59.35	120hr
20	1.6449	58.99	59.80	59.79	60.23	60.41	60.38	60.23	60.52	60.33	60.52	120hr
50	2.0537	60.57	60.71	60.78	60.84	60.93	61.00	60.89	60.98	60.93	61.00	72hr
100	2.3263	60.81	60.97	61.07	61.11	61.18	61.24	61.17	61.28	61.21	61.28	120hr
200	2.5758	61.09	61.20	61.29	61.37	61.39	61.35	61.36	61.40	61.34	61.40	120hr
500	2.8782	61.41	61.52	61.48	61.60	61.61	61.49	61.49	61.53	61.44	61.61	48hr
1000	3.0902	61.60	61.70	61.61	61.69	61.68	61.59	61.59	61.62	61.51	61.70	18hr
2000	3.2905	61.68	61.77	61.73	61.76	61.75	61.68	61.68	61.71	61.58	61.77	18hr
5000	3.5401	61.79	61.85	61.84	61.86	61.84	61.81	61.79	61.82	61.67	61.86	36hr
10000	3.7190	61.86	61.91	61.92	61.93	61.91	61.91	61.90	61.91	61.73	61.93	36hr
20000	3.8906	61.93	61.96	61.99	62.00	61.97	62.01	62.03	62.00	61.85	62.03	96hr
50000	4.1075	62.01	62.04	62.08	62.12	62.04	62.13	62.19	62.11	62.05	62.19	96hr
100000	4.2649	62.07	62.11	62.15	62.45	62.12	62.22	62.30	62.19	62.19	62.45	36hr
200000	4.4172	62.13	62.24	62.44	63.69	64.41	64.85	64.54	62.40	63.79	64.85	72hr
500000	4.6114	62.20	62.41	65.13	67.20	68.40	67.97	67.76	66.28	67.35	68.40	48hr
1000000	4.7534	62.25	64.21	67.92	69.61	70.16	69.91	69.86	69.85	73.80	70.16	48hr

Results for Site 02: Wivenhoe Dam Tailwater

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	23.21	23.28	23.35	23.43	23.54	23.54	23.76	23.54	23.74	23.76	96hr
5	0.8416	28.71	29.92	30.07	30.87	31.42	31.95	32.07	32.08	31.92	32.08	120hr
10	1.2816	31.21	32.24	32.53	33.52	34.30	34.87	35.04	35.09	34.80	35.09	120hr
20	1.6449	33.28	34.49	35.51	36.84	38.06	38.34	38.66	38.35	38.22	38.66	96hr
50	2.0537	35.73	38.12	39.45	40.89	41.91	42.99	43.09	43.03	43.21	43.21	168hr
100	2.3263	38.26	40.99	42.57	43.71	44.79	46.89	46.94	47.16	46.18	47.16	120hr
200	2.5758	40.65	42.85	44.26	46.28	47.43	48.83	48.80	48.83	48.62	48.83	72hr
500	2.8782	42.26	44.77	46.88	48.69	49.14	49.84	49.70	49.71	49.73	49.84	72hr
1000	3.0902	43.58	46.17	48.22	49.54	49.87	50.38	50.19	50.24	50.14	50.38	72hr
2000	3.2905	45.56	47.74	49.06	50.22	50.61	51.11	50.92	50.96	50.58	51.11	72hr
5000	3.5401	47.23	49.49	50.48	51.10	52.12	52.45	52.02	52.09	51.80	52.45	72hr
10000	3.7190	49.17	50.17	51.81	52.87	53.72	53.82	53.76	53.14	53.18	53.82	72hr
20000	3.8906	49.78	51.75	53.65	55.08	55.69	55.67	55.64	55.22	55.44	55.69	48hr
50000	4.1075	51.66	54.47	56.25	58.11	58.70	58.38	58.41	57.39	58.17	58.70	48hr
100000	4.2649	53.98	56.18	59.08	61.51	61.85	61.93	62.07	60.02	60.42	62.07	96hr
200000	4.4172	55.11	58.59	61.85	63.97	64.74	64.99	64.75	62.61	63.74	64.99	72hr
500000	4.6114	56.93	61.76	65.32	67.39	68.59	68.21	67.59	66.43	67.52	68.59	48hr
1000000	4.7534	59.29	64.50	68.06	69.92	70.45	70.36	70.00	69.68	70.09	70.45	48hr

Results for Site 03: Lockyer Creek at Lyons Bridge

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	47.66	47.67	47.69	47.72	47.78	47.90	47.87	47.96	48.01	48.01	168hr
5	0.8416	56.96	58.40	58.56	59.46	60.02	60.22	59.76	60.00	59.95	60.22	72hr
10	1.2816	59.99	61.07	61.02	61.75	62.14	62.49	61.93	62.49	62.22	62.49	72hr
20	1.6449	62.12	62.97	62.82	63.46	63.76	63.81	63.44	64.28	63.55	64.28	120hr
50	2.0537	63.94	64.37	64.47	64.64	64.84	64.94	64.79	64.87	64.81	64.94	72hr
100	2.3263	64.56	64.89	65.01	65.11	65.21	65.29	65.16	65.29	65.22	65.29	72hr
200	2.5758	65.07	65.25	65.42	65.46	65.50	65.53	65.43	65.64	65.47	65.64	120hr
500	2.8782	65.51	65.70	65.84	65.74	65.79	65.81	65.74	65.91	65.82	65.91	120hr
1000	3.0902	65.76	65.91	66.06	65.89	65.98	65.99	65.90	66.10	66.04	66.10	120hr
2000	3.2905	65.95	66.10	66.23	66.03	66.17	66.15	66.05	66.28	66.15	66.28	120hr
5000	3.5401	66.21	66.30	66.42	66.24	66.45	66.34	66.23	66.48	66.29	66.48	120hr
10000	3.7190	66.40	66.44	66.55	66.39	66.60	66.47	66.35	66.57	66.40	66.60	48hr
20000	3.8906	66.56	66.58	66.69	66.54	66.69	66.59	66.47	66.65	66.84	66.84	168hr
50000	4.1075	66.74	66.78	66.87	66.81	66.81	66.76	66.61	66.76	67.01	67.01	168hr
100000	4.2649	66.87	66.93	67.00	67.01	66.90	66.90	66.76	66.83	67.11	67.11	168hr
200000	4.4172	66.99	67.06	67.14	67.18	66.98	67.04	66.93	66.93	67.20	67.20	168hr
500000	4.6114	67.13	67.23	67.32	67.41	68.54	68.01	67.75	67.20	67.59	68.54	48hr
1000000	4.7534	67.24	67.36	67.95	69.66	70.18	69.97	69.89	69.81	73.27	70.18	48hr

Flood Level Quantiles (m AHD) for Individual Storm Durations for Each Reporting Site

Results for Site 04: Brisbane River at Lowood Pump Station

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	20.93	21.07	21.16	21.57	21.54	22.31	22.47	22.64	22.82	22.82	168hr
5	0.8416	27.31	28.20	28.33	29.11	29.79	30.13	30.15	30.22	30.02	30.22	120hr
10	1.2816	29.45	30.61	30.65	31.54	32.29	32.79	32.82	33.02	32.70	33.02	120hr
20	1.6449	31.45	32.52	33.22	34.69	35.79	35.94	36.11	36.09	35.82	36.11	96hr
50	2.0537	33.81	35.95	37.09	38.59	39.31	40.68	40.64	40.72	40.58	40.72	120hr
100	2.3263	35.93	38.36	39.87	41.29	42.74	44.76	44.63	45.31	44.05	45.31	120hr
200	2.5758	38.23	40.35	41.94	44.26	45.52	47.39	47.29	47.33	46.79	47.39	72hr
500	2.8782	39.90	42.66	45.18	47.03	47.63	48.50	48.35	48.30	48.30	48.50	72hr
1000	3.0902	41.47	44.13	46.49	48.17	48.53	49.38	49.05	48.90	48.81	49.38	72hr
2000	3.2905	43.39	45.91	47.63	48.70	49.24	50.31	49.91	49.96	49.81	50.31	72hr
5000	3.5401	44.94	47.74	48.78	50.09	51.41	51.88	51.36	51.34	50.80	51.88	72hr
10000	3.7190	47.49	48.67	50.81	52.06	53.25	53.35	53.24	52.39	52.54	53.35	72hr
20000	3.8906	48.35	50.82	53.01	54.59	55.29	55.38	55.35	54.75	55.03	55.38	72hr
50000	4.1075	50.79	53.68	55.62	57.61	58.26	58.13	58.39	57.12	57.78	58.39	96hr
100000	4.2649	53.37	56.06	58.70	60.97	61.60	61.46	61.80	59.64	60.18	61.80	96hr
200000	4.4172	54.61	58.17	61.69	63.73	64.55	64.85	64.45	62.31	63.57	64.85	72hr
500000	4.6114	56.49	61.38	65.13	67.20	68.30	67.95	67.40	66.16	67.26	68.30	48hr
1000000	4.7534	58.90	64.12	67.71	69.76	70.09	70.05	69.76	69.48	69.78	70.09	48hr

Results for Site 05: Brisbane River at Savages Crossing

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	17.44	17.60	17.86	19.78	20.16	20.45	20.26	20.21	20.74	20.74	168hr
5	0.8416	23.41	24.15	24.26	25.11	25.64	26.15	26.20	26.20	25.97	26.20	120hr
10	1.2816	25.55	26.34	26.80	27.54	28.14	28.77	28.81	29.05	28.70	29.05	120hr
20	1.6449	27.24	28.32	29.32	30.39	31.65	31.84	32.05	31.92	31.84	32.05	96hr
50	2.0537	29.70	31.71	32.84	34.41	35.30	36.57	36.52	36.65	36.52	36.65	120hr
100	2.3263	31.75	34.10	35.92	37.40	38.86	41.09	41.16	41.46	40.26	41.46	120hr
200	2.5758	33.92	36.19	37.83	40.38	41.96	44.11	43.97	44.15	43.35	44.15	120hr
500	2.8782	35.46	38.31	41.23	43.56	44.75	46.74	46.59	46.17	46.27	46.74	72hr
1000	3.0902	37.16	40.12	42.63	45.75	46.97	48.41	47.84	47.77	47.44	48.41	72hr
2000	3.2905	39.22	42.07	44.07	47.25	48.17	49.46	48.98	49.14	48.62	49.46	72hr
5000	3.5401	40.68	44.41	47.46	49.31	50.61	51.08	50.55	50.63	50.02	51.08	72hr
10000	3.7190	43.99	46.86	50.06	51.24	52.64	52.51	52.59	51.82	51.92	52.64	48hr
20000	3.8906	45.75	49.91	52.34	53.89	54.56	54.46	54.58	53.82	54.63	54.63	168hr
50000	4.1075	49.91	53.18	55.11	56.93	57.67	57.50	57.53	56.76	57.26	57.67	48hr
100000	4.2649	52.40	55.11	58.12	60.31	60.98	60.99	61.20	59.02	59.85	61.20	96hr
200000	4.4172	53.87	57.48	60.98	63.09	63.88	64.22	63.73	61.71	63.16	64.22	72hr
500000	4.6114	55.98	60.86	64.55	66.61	67.67	67.32	67.14	65.49	66.63	67.67	48hr
1000000	4.7534	58.21	63.48	67.09	69.17	69.51	69.49	69.19	68.92	69.24	69.51	48hr

Results for Site 06: Brisbane River Upstream Mt Crosby Weir

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	6.98	7.00	7.03	6.98	7.15	7.36	7.27	7.21	7.46	7.46	168hr
5	0.8416	9.10	9.42	9.53	9.82	10.18	10.45	10.44	10.40	10.41	10.45	72hr
10	1.2816	10.18	10.56	10.85	11.32	11.86	12.29	12.41	12.23	12.29	12.41	96hr
20	1.6449	11.28	11.84	12.91	13.56	14.86	15.29	15.13	15.24	15.13	15.29	72hr
50	2.0537	13.16	14.75	15.95	17.51	18.75	20.10	20.02	19.92	19.90	20.10	72hr
100	2.3263	14.86	17.09	19.17	21.10	22.80	24.87	24.81	25.35	24.41	25.35	120hr
200	2.5758	16.93	19.30	21.29	24.18	25.90	28.28	28.43	28.30	27.51	28.43	96hr
500	2.8782	18.62	21.58	24.94	27.09	29.34	31.54	31.36	31.11	31.02	31.54	72hr
1000	3.0902	19.87	23.32	26.02	29.89	31.53	33.55	33.08	33.01	32.51	33.55	72hr
2000	3.2905	21.96	25.53	28.18	31.84	33.37	35.04	34.76	34.83	34.03	35.04	72hr
5000	3.5401	24.53	28.05	31.88	34.58	36.49	36.88	36.46	36.36	35.84	36.88	72hr
10000	3.7190	27.41	31.03	35.13	37.05	38.05	38.44	38.39	37.74	38.05	38.44	72hr
20000	3.8906	30.23	35.32	38.01	39.38	40.02	40.25	40.38	39.66	40.20	40.38	96hr
50000	4.1075	35.37	38.89	40.34	41.78	42.48	42.53	42.70	41.96	42.38	42.70	96hr
100000	4.2649	38.18	40.55	42.67	44.28	44.88	45.16	45.22	43.72	44.20	45.22	96hr
200000	4.4172	39.36	42.08	44.39	46.09	46.70	47.14	46.96	45.64	46.62	47.14	72hr
500000	4.6114	40.74	44.27	46.87	48.40	49.19	49.34	48.99	48.20	48.90	49.34	72hr
1000000	4.7534	42.64	46.21	48.65	50.10	50.43	50.55	50.86	50.46	50.59	50.86	96hr

Results for Site 07: Brisbane River downstream Mt Crosby Weir

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	3.10	3.16	3.18	3.20	3.63	4.09	3.90	3.74	4.44	4.44	168hr
5	0.8416	6.98	7.42	7.68	8.07	8.63	9.00	9.13	8.99	8.91	9.13	96hr
10	1.2816	8.51	9.34	9.86	10.41	10.88	11.54	11.69	11.58	11.39	11.69	96hr
20	1.6449	10.22	11.08	12.14	12.95	14.30	14.93	14.73	14.89	14.58	14.93	72hr
50	2.0537	12.40	14.15	15.56	17.15	18.41	19.68	19.52	19.45	19.43	19.68	72hr
100	2.3263	14.58	16.65	18.82	20.75	22.37	24.53	24.42	24.86	24.03	24.86	120hr
200	2.5758	16.48	18.92	21.09	23.78	25.37	27.73	27.90	27.77	26.94	27.90	96hr
500	2.8782	18.21	21.29	24.47	26.73	28.79	30.98	30.80	30.54	30.40	30.98	72hr
1000	3.0902	19.54	22.92	25.59	29.23	30.95	32.99	32.56	32.62	32.06	32.99	72hr
2000	3.2905	21.67	25.04	27.64	31.18	32.79	34.55	34.23	34.33	33.50	34.55	72hr
5000	3.5401	24.03	27.53	31.47	33.99	36.01	36.41	36.02	35.90	35.39	36.41	72hr
10000	3.7190	26.84	30.26	34.53	36.59	37.63	37.76	38.00	37.15	37.68	38.00	96hr
20000	3.8906	29.44	34.79	37.50	39.00	39.70	39.80	39.86	39.37	39.67	39.86	96hr
50000	4.1075	35.02	38.11	40.03	41.49	42.19	41.97	42.23	41.55	42.06	42.23	96hr
100000	4.2649	37.82	39.88	42.03	44.00	44.48	44.76	44.73	43.45	43.68	44.76	72hr
200000	4.4172	38.94	41.67	44.29	45.78	46.18	46.91	46.71	45.05	46.14	46.91	72hr
500000	4.6114	40.40	43.96	46.46	48.14	48.88	48.92	48.66	47.82	48.75	48.92	72hr
1000000	4.7534	42.22	45.83	48.30	49.75	50.09	50.20	50.48	50.16	50.19	50.48	96hr

Flood Level Quantiles (m AHD) for Individual Storm Durations for Each Reporting Site

Results for Site 08: Brisbane River at Moggill

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.66	1.68	1.69	1.68	1.72	1.74	1.74	1.73	1.76	1.76	168hr
5	0.8416	2.53	2.71	3.13	3.24	3.88	4.41	4.33	4.12	4.03	4.41	72hr
10	1.2816	3.90	4.37	5.39	5.75	6.60	7.04	6.99	6.91	6.71	7.04	72hr
20	1.6449	5.20	6.75	7.51	8.18	9.18	9.98	9.74	9.77	9.46	9.98	72hr
50	2.0537	7.69	9.36	10.51	11.57	13.27	14.06	14.11	14.33	13.63	14.33	120hr
100	2.3263	9.98	11.47	13.25	14.83	15.94	17.57	17.78	17.92	17.52	17.92	120hr
200	2.5758	11.40	13.06	15.53	17.20	18.48	19.80	20.14	19.94	19.75	20.14	96hr
500	2.8782	12.99	15.39	17.80	19.23	20.84	22.61	22.42	22.55	22.07	22.61	72hr
1000	3.0902	14.61	17.12	19.23	20.86	22.15	24.11	23.95	23.93	23.50	24.11	72hr
2000	3.2905	16.08	18.51	20.47	22.35	23.92	25.62	25.70	25.51	24.72	25.70	96hr
5000	3.5401	18.27	20.24	22.90	24.77	26.50	27.13	27.17	26.99	26.54	27.17	96hr
10000	3.7190	19.56	22.13	25.05	26.98	28.05	28.64	28.77	28.40	28.38	28.77	96hr
20000	3.8906	21.20	25.63	27.91	29.32	30.10	30.85	30.82	30.34	30.76	30.85	72hr
50000	4.1075	25.18	28.49	30.18	31.58	32.61	33.18	33.53	32.90	33.08	33.53	96hr
100000	4.2649	28.08	30.26	32.11	33.96	34.57	35.53	35.85	34.70	34.92	35.85	96hr
200000	4.4172	29.15	31.60	33.87	35.59	36.54	37.50	37.62	36.16	37.21	37.62	96hr
500000	4.6114	30.45	33.59	36.07	37.75	38.78	39.49	39.15	38.67	39.40	39.49	72hr
1000000	4.7534	31.92	35.52	38.09	39.32	40.12	40.86	40.77	40.51	40.65	40.86	72hr

Results for Site 09: Brisbane River at Jindalee

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.51	1.50	1.53	1.54	1.55	1.57	1.57	1.57	1.55	1.57	72hr
5	0.8416	1.95	2.01	2.12	2.15	2.37	2.55	2.53	2.44	2.41	2.55	72hr
10	1.2816	2.36	2.60	2.92	3.22	3.69	3.96	3.93	3.94	3.88	3.96	72hr
20	1.6449	3.09	3.76	4.33	4.81	5.39	6.04	5.76	6.08	5.77	6.08	120hr
50	2.0537	4.48	5.76	6.47	7.22	8.50	9.23	9.28	9.39	8.85	9.39	120hr
100	2.3263	5.96	7.14	8.53	9.68	10.57	11.96	11.95	12.13	11.85	12.13	120hr
200	2.5758	7.06	8.46	10.24	11.42	12.50	13.59	13.75	13.82	13.52	13.82	120hr
500	2.8782	8.29	10.29	11.93	12.98	14.39	15.65	15.64	15.71	15.27	15.71	120hr
1000	3.0902	9.37	11.17	12.87	14.17	15.34	16.94	16.83	16.79	16.65	16.94	72hr
2000	3.2905	10.62	12.30	14.02	15.44	16.87	18.49	18.72	18.57	17.57	18.72	96hr
5000	3.5401	12.14	13.83	15.64	17.38	19.36	20.28	20.53	20.21	19.88	20.53	96hr
10000	3.7190	13.09	15.30	17.74	19.85	21.24	21.99	22.31	21.76	22.10	22.31	96hr
20000	3.8906	14.55	18.32	20.93	22.77	23.67	24.32	24.53	24.01	24.54	24.54	168hr
50000	4.1075	18.22	21.81	23.69	25.02	25.78	26.47	26.76	26.28	26.60	26.76	96hr
100000	4.2649	21.14	23.71	25.42	26.99	27.59	28.48	28.67	27.60	27.97	28.67	96hr
200000	4.4172	22.63	24.98	26.85	28.34	29.19	30.25	30.31	29.14	30.01	30.31	96hr
500000	4.6114	23.97	26.68	28.83	30.44	31.35	32.07	32.17	31.54	32.17	32.17	168hr
1000000	4.7534	25.29	28.23	30.60	31.87	32.68	33.64	33.48	33.49	33.48	33.64	72hr

Results for Site 10: Brisbane River at Tennyson

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.45	1.46	1.50	1.50	1.50	1.52	1.53	1.52	1.51	1.53	96hr
5	0.8416	1.80	1.85	1.92	1.96	2.03	2.08	2.08	2.06	2.05	2.08	72hr
10	1.2816	2.07	2.18	2.34	2.52	2.74	2.89	2.91	2.85	2.83	2.91	96hr
20	1.6449	2.45	2.87	3.22	3.49	3.92	4.42	4.21	4.32	4.18	4.42	72hr
50	2.0537	3.38	4.30	4.81	5.31	6.27	6.81	6.72	7.12	6.62	7.12	120hr
100	2.3263	4.33	5.15	6.24	7.15	8.06	9.05	9.12	9.23	8.96	9.23	120hr
200	2.5758	5.02	6.27	7.57	8.64	9.58	10.53	10.66	10.69	10.49	10.69	120hr
500	2.8782	6.05	7.66	9.05	9.99	11.24	12.52	12.39	12.50	12.18	12.52	72hr
1000	3.0902	6.99	8.46	9.92	11.11	12.14	13.75	13.68	13.75	13.53	13.75	120hr
2000	3.2905	7.83	9.48	10.75	12.18	13.73	15.22	15.46	15.28	14.41	15.46	96hr
5000	3.5401	9.17	10.65	12.57	14.16	16.07	17.16	17.42	17.03	16.83	17.42	96hr
10000	3.7190	9.93	12.04	14.42	16.63	18.35	19.48	19.74	19.36	19.58	19.74	96hr
20000	3.8906	11.33	15.14	17.98	20.32	21.48	22.32	22.51	22.01	22.45	22.51	96hr
50000	4.1075	14.85	19.18	21.43	23.08	23.86	24.60	25.11	24.52	24.97	25.11	96hr
100000	4.2649	18.11	21.52	23.46	25.24	25.85	26.92	27.19	26.02	26.38	27.19	96hr
200000	4.4172	20.10	23.06	25.23	26.76	27.49	28.90	28.85	27.77	28.49	28.90	72hr
500000	4.6114	21.87	24.96	27.33	28.96	29.94	30.79	30.50	30.20	30.90	30.90	168hr
1000000	4.7534	23.39	26.63	29.16	30.50	31.33	32.29	32.19	32.23	32.25	32.29	72hr

Results for Site 11: Brisbane River at Fairfield

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.44	1.46	1.49	1.50	1.50	1.51	1.51	1.51	1.50	1.51	72hr
5	0.8416	1.75	1.80	1.88	1.91	1.99	2.00	2.02	2.00	1.98	2.02	96hr
10	1.2816	1.98	2.00	2.18	2.31	2.56	2.64	2.61	2.62	2.58	2.64	72hr
20	1.6449	2.29	2.58	2.88	3.20	3.54	3.85	3.74	3.79	3.72	3.85	72hr
50	2.0537	2.96	3.81	4.23	4.71	5.50	6.01	5.80	6.29	5.85	6.29	120hr
100	2.3263	3.84	4.63	5.46	6.25	7.06	7.97	8.00	8.13	7.97	8.13	120hr
200	2.5758	4.45	5.55	6.62	7.61	8.36	9.33	9.53	9.55	9.34	9.55	120hr
500	2.8782	5.29	6.78	7.94	8.84	9.99	11.28	11.25	11.43	11.05	11.43	120hr
1000	3.0902	6.14	7.39	8.74	9.88	11.00	12.60	12.45	12.50	12.35	12.60	72hr
2000	3.2905	7.03	8.29	9.50	11.04	12.48	14.01	14.26	14.10	13.25	14.26	96hr
5000	3.5401	8.04	9.40	11.28	13.12	15.06	16.09	16.37	16.00	15.58	16.37	96hr
10000	3.7190	8.81	10.97	13.42	15.40	17.33	18.51	19.14	18.34	18.68	19.14	96hr
20000	3.8906	10.27	13.82	16.95	19.47	20.61	21.47	21.58	21.05	21.67	21.67	168hr
50000	4.1075	13.68	18.17	20.50	22.20	23.14	23.89	24.22	23.66	23.87	24.22	96hr
100000	4.2649	17.04	20.61	22.65	24.10	25.27	26.18	26.39	25.24	25.51	26.39	96hr
200000	4.4172	19.19	22.18	24.26	25.98	26.85	28.00	28.13	26.78	27.74	28.13	96hr
500000	4.6114	20.97	24.15	26.35	28.15	29.23	30.10	29.83	29.39	30.19	30.19	168hr
1000000	4.7534	22.48	25.84	28.44	29.77	30.62	31.59	31.49	31.52	31.57	31.59	72hr

Flood Level Quantiles (m AHD) for Individual Storm Durations for Each Reporting Site

Results for Site 12: Brisbane River at Toowong

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.45	1.45	1.50	1.50	1.51	1.52	1.52	1.52	1.52	1.52	72hr
5	0.8416	1.71	1.74	1.82	1.86	1.92	1.92	1.92	1.90	1.91	1.92	72hr
10	1.2816	1.84	1.89	1.99	2.06	2.27	2.32	2.28	2.25	2.26	2.32	72hr
20	1.6449	2.11	2.30	2.47	2.65	2.95	3.25	3.16	3.17	3.07	3.25	72hr
50	2.0537	2.63	3.17	3.51	3.87	4.40	4.96	4.86	5.07	4.75	5.07	120hr
100	2.3263	3.20	3.85	4.48	5.12	5.77	6.60	6.63	6.69	6.49	6.69	120hr
200	2.5758	3.72	4.49	5.39	6.25	7.01	7.75	7.89	8.01	7.82	8.01	120hr
500	2.8782	4.35	5.52	6.56	7.35	8.44	9.67	9.60	9.82	9.36	9.82	120hr
1000	3.0902	5.04	6.05	7.20	8.26	9.35	11.04	10.84	10.94	10.69	11.04	72hr
2000	3.2905	5.62	6.87	8.00	9.37	10.86	12.55	12.67	12.57	11.67	12.67	96hr
5000	3.5401	6.62	7.87	9.72	11.58	13.37	14.60	15.00	14.49	14.08	15.00	96hr
10000	3.7190	7.35	9.28	11.65	13.92	15.89	17.02	17.59	16.88	17.35	17.59	96hr
20000	3.8906	8.58	12.29	15.39	17.95	19.07	19.80	20.03	19.40	20.08	20.08	168hr
50000	4.1075	12.10	16.73	18.90	20.42	21.31	21.96	22.27	21.75	21.99	22.27	96hr
100000	4.2649	15.60	19.03	20.86	22.20	23.19	24.04	24.27	23.16	23.57	24.27	96hr
200000	4.4172	17.72	20.44	22.30	23.84	24.63	25.74	25.86	24.75	25.44	25.86	96hr
500000	4.6114	19.35	22.20	24.21	25.83	26.83	27.59	27.34	27.00	27.70	27.70	168hr
1000000	4.7534	20.77	23.74	26.12	27.31	28.07	28.93	28.84	28.88	28.91	28.93	72hr

Results for Site 13: Port Office Gauge

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.47	1.48	1.51	1.54	1.54	1.56	1.56	1.56	1.56	1.56	120hr
5	0.8416	1.64	1.68	1.73	1.78	1.80	1.84	1.83	1.83	1.82	1.84	72hr
10	1.2816	1.73	1.78	1.85	1.91	1.94	1.98	1.97	1.97	1.96	1.98	72hr
20	1.6449	1.84	1.87	1.97	2.07	2.17	2.34	2.26	2.32	2.20	2.34	72hr
50	2.0537	2.06	2.30	2.48	2.77	2.99	3.29	3.28	3.45	3.25	3.45	120hr
100	2.3263	2.34	2.75	3.04	3.53	3.86	4.42	4.41	4.52	4.32	4.52	120hr
200	2.5758	2.66	3.15	3.68	4.21	4.71	5.33	5.36	5.40	5.30	5.40	120hr
500	2.8782	3.11	3.75	4.43	5.00	5.78	6.73	6.60	6.77	6.46	6.77	120hr
1000	3.0902	3.45	4.09	4.97	5.71	6.51	7.63	7.60	7.67	7.49	7.67	120hr
2000	3.2905	3.87	4.74	5.54	6.48	7.60	8.78	8.93	8.88	8.17	8.93	96hr
5000	3.5401	4.42	5.31	6.72	8.01	9.50	10.47	10.87	10.46	10.10	10.87	96hr
10000	3.7190	5.11	6.47	8.34	9.87	11.34	12.51	12.73	12.20	12.56	12.73	96hr
20000	3.8906	6.02	8.73	11.12	13.24	14.39	15.36	15.51	15.01	15.45	15.51	96hr
50000	4.1075	8.51	12.08	14.29	16.13	17.04	17.96	18.33	17.69	18.12	18.33	96hr
100000	4.2649	11.24	14.40	16.55	18.46	19.42	20.33	20.59	19.43	19.71	20.59	96hr
200000	4.4172	13.02	16.10	18.41	20.11	21.09	22.19	22.38	21.08	21.95	22.38	96hr
500000	4.6114	14.85	18.21	20.75	22.33	23.40	24.01	24.04	23.62	24.29	24.29	168hr
1000000	4.7534	16.42	20.07	22.61	23.83	24.66	25.45	25.39	25.38	25.47	25.47	168hr

Results for Site 14: Brisbane City Gauge

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.47	1.48	1.51	1.54	1.54	1.56	1.56	1.56	1.56	1.56	120hr
5	0.8416	1.64	1.68	1.73	1.78	1.80	1.84	1.83	1.83	1.82	1.84	72hr
10	1.2816	1.73	1.78	1.85	1.91	1.94	1.98	1.97	1.97	1.96	1.98	72hr
20	1.6449	1.84	1.87	1.97	2.07	2.17	2.34	2.26	2.32	2.20	2.34	72hr
50	2.0537	2.06	2.30	2.48	2.77	2.99	3.29	3.28	3.45	3.25	3.45	120hr
100	2.3263	2.34	2.75	3.04	3.53	3.86	4.42	4.41	4.52	4.32	4.52	120hr
200	2.5758	2.66	3.15	3.68	4.21	4.71	5.33	5.36	5.40	5.30	5.40	120hr
500	2.8782	3.11	3.75	4.43	5.00	5.78	6.73	6.60	6.77	6.46	6.77	120hr
1000	3.0902	3.45	4.09	4.97	5.71	6.51	7.63	7.60	7.67	7.49	7.67	120hr
2000	3.2905	3.87	4.74	5.54	6.48	7.60	8.78	8.93	8.88	8.17	8.93	96hr
5000	3.5401	4.42	5.31	6.72	8.01	9.50	10.47	10.87	10.46	10.10	10.87	96hr
10000	3.7190	5.11	6.47	8.34	9.87	11.34	12.51	12.73	12.20	12.56	12.73	96hr
20000	3.8906	6.02	8.73	11.12	13.24	14.39	15.36	15.51	15.01	15.45	15.51	96hr
50000	4.1075	8.51	12.08	14.29	16.13	17.04	17.96	18.33	17.69	18.12	18.33	96hr
100000	4.2649	11.24	14.40	16.55	18.46	19.42	20.33	20.59	19.43	19.71	20.59	96hr
200000	4.4172	13.02	16.10	18.41	20.11	21.09	22.19	22.38	21.08	21.95	22.38	96hr
500000	4.6114	14.85	18.21	20.75	22.33	23.40	24.01	24.04	23.62	24.29	24.29	168hr
1000000	4.7534	16.42	20.07	22.61	23.83	24.66	25.45	25.39	25.38	25.47	25.47	168hr

Results for Site 15: Brisbane River at Hawthorne

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.46	1.47	1.51	1.54	1.55	1.56	1.56	1.57	1.57	1.57	168hr
5	0.8416	1.61	1.61	1.64	1.69	1.71	1.73	1.73	1.73	1.73	1.73	120hr
10	1.2816	1.69	1.69	1.72	1.77	1.80	1.82	1.82	1.82	1.82	1.82	72hr
20	1.6449	1.76	1.77	1.78	1.83	1.87	1.89	1.89	1.89	1.89	1.89	72hr
50	2.0537	1.84	1.94	1.98	2.11	2.21	2.36	2.27	2.40	2.27	2.40	120hr
100	2.3263	1.96	2.10	2.25	2.47	2.64	2.91	2.90	2.94	2.88	2.94	120hr
200	2.5758	2.15	2.34	2.59	2.80	3.04	3.36	3.39	3.50	3.35	3.50	120hr
500	2.8782	2.49	2.72	2.97	3.22	3.60	4.11	4.05	4.14	3.98	4.14	120hr
1000	3.0902	2.77	2.98	3.23	3.57	4.03	4.76	4.63	4.79	4.55	4.79	120hr
2000	3.2905	3.09	3.16	3.49	4.02	4.68	5.46	5.58	5.55	5.11	5.58	96hr
5000	3.5401	3.25	3.54	4.18	5.03	6.01	6.64	6.82	6.63	6.50	6.82	96hr
10000	3.7190	3.43	4.00	5.23	6.17	7.31	7.98	8.33	7.93	8.22	8.33	96hr
20000	3.8906	3.87	5.53	7.12	8.58	9.46	10.10	10.29	9.81	10.26	10.29	96hr
50000	4.1075	5.42	7.79	9.41	10.66	11.41	12.02	12.38	11.85	12.20	12.38	96hr
100000	4.2649	7.25	9.42	11.02	12.23	12.97	13.85	14.11	13.15	13.44	14.11	96hr
200000	4.4172	8.45	10.62	12.34	13.62	14.43	15.40	15.57	14.51	15.15	15.57	96hr
500000	4.6114	9.80	12.20	14.11	15.46	16.41	17.06	17.05	16.67	17.28	17.28	168hr
1000000	4.7534	10.89	13.59	15.69	16.81	17.53	18.50	18.35	18.32	18.41	18.50	72hr

Flood Level Quantiles (m AHD) for Individual Storm Durations for Each Reporting Site

Results for Site 16: Brisbane River at Gateway Bridge

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.41	1.46	1.50	1.52	1.53	1.54	1.54	1.55	1.55	1.55	120hr
5	0.8416	1.59	1.59	1.59	1.60	1.62	1.63	1.63	1.64	1.64	1.64	168hr
10	1.2816	1.62	1.64	1.64	1.65	1.66	1.68	1.68	1.69	1.69	1.69	168hr
20	1.6449	1.67	1.68	1.70	1.70	1.72	1.76	1.75	1.75	1.76	1.76	168hr
50	2.0537	1.74	1.76	1.77	1.80	1.82	1.86	1.86	1.86	1.86	1.86	120hr
100	2.3263	1.80	1.83	1.86	1.92	1.95	2.04	2.02	2.07	2.04	2.07	120hr
200	2.5758	1.90	1.93	1.99	2.08	2.13	2.31	2.30	2.38	2.28	2.38	120hr
500	2.8782	2.25	2.30	2.38	2.46	2.53	2.77	2.78	2.77	2.77	2.78	96hr
1000	3.0902	2.54	2.64	2.69	2.73	2.89	2.96	3.01	3.08	2.94	3.08	120hr
2000	3.2905	2.98	2.93	2.92	2.95	3.06	3.20	3.37	3.27	3.17	3.37	96hr
5000	3.5401	3.03	3.01	3.02	3.24	3.47	3.85	3.93	3.90	3.92	3.93	96hr
10000	3.7190	3.07	3.30	3.35	3.60	4.16	4.69	4.82	4.56	4.77	4.82	96hr
20000	3.8906	3.33	3.49	4.18	4.97	5.39	5.80	5.87	5.69	5.94	5.94	168hr
50000	4.1075	3.47	4.52	5.38	6.07	6.46	6.72	6.95	6.68	6.84	6.95	96hr
100000	4.2649	4.25	5.38	6.22	6.87	7.17	7.60	7.73	7.29	7.41	7.73	96hr
200000	4.4172	4.90	6.03	6.88	7.49	7.84	8.31	8.35	7.90	8.23	8.35	96hr
500000	4.6114	5.59	6.82	7.68	8.27	8.69	9.02	9.02	8.84	9.16	9.16	168hr
1000000	4.7534	6.15	7.44	8.35	8.94	9.21	9.65	9.60	9.62	9.60	9.65	72hr

Results for Site 17: Warrill Creek at Amberley

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	18.91	18.92	18.98	18.99	19.28	19.79	20.23	20.84	20.83	20.84	120hr
5	0.8416	23.54	24.01	24.79	25.01	25.48	25.79	25.43	25.59	25.55	25.79	72hr
10	1.2816	25.14	25.87	26.15	26.26	26.75	27.01	26.59	26.61	26.50	27.01	72hr
20	1.6449	26.12	26.85	27.38	27.28	27.53	27.71	27.44	27.51	27.47	27.71	72hr
50	2.0537	27.67	27.65	27.89	27.87	27.94	28.11	28.02	28.14	27.97	28.14	120hr
100	2.3263	28.01	28.21	28.20	28.08	28.23	28.31	28.36	28.43	28.29	28.43	120hr
200	2.5758	28.27	28.46	28.42	28.32	28.51	28.51	28.55	28.65	28.49	28.65	120hr
500	2.8782	28.70	28.89	28.66	28.67	28.79	28.76	28.77	28.98	28.74	28.98	120hr
1000	3.0902	28.89	29.10	28.93	28.91	29.04	29.36	28.92	29.33	28.94	29.36	72hr
2000	3.2905	29.03	29.78	29.39	29.17	29.42	29.75	29.06	29.82	29.21	29.82	120hr
5000	3.5401	29.97	31.06	30.63	29.68	30.05	30.12	29.32	30.97	30.06	31.06	18hr
10000	3.7190	31.01	32.02	31.80	30.15	30.86	31.18	30.07	31.24	30.26	32.02	18hr
20000	3.8906	31.11	32.53	32.86	30.83	31.74	31.90	31.67	31.60	31.74	32.86	24hr
50000	4.1075	31.24	33.64	34.25	32.58	33.16	34.10	34.22	33.78	34.20	34.25	24hr
100000	4.2649	31.33	34.41	34.53	34.30	34.99	36.28	36.56	35.45	35.69	36.56	96hr
200000	4.4172	32.12	35.38	36.68	35.87	36.80	38.12	38.21	37.09	37.74	38.21	96hr
500000	4.6114	33.42	37.67	46.97	38.05	39.12	39.91	39.89	39.46	40.01	40.01	168hr
1000000	4.7534	34.78	40.82	54.84	39.59	40.53	41.20	42.83	41.08	41.23	41.23	168hr

Results for Site 18: Purga Creek at Loamside

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	19.91	19.92	19.96	19.99	20.18	21.17	21.14	22.09	22.26	22.26	168hr
5	0.8416	25.09	25.72	26.19	26.07	26.39	26.46	26.40	26.55	26.50	26.55	120hr
10	1.2816	26.46	26.71	26.80	26.77	26.89	27.05	27.04	27.06	27.03	27.06	120hr
20	1.6449	26.96	27.22	27.29	27.24	27.40	27.43	27.48	27.51	27.36	27.51	120hr
50	2.0537	27.49	27.55	27.72	27.60	27.72	27.80	27.85	27.85	27.69	27.85	96hr
100	2.3263	27.80	27.79	27.91	27.82	27.97	28.04	28.13	28.08	27.92	28.13	96hr
200	2.5758	28.10	28.07	28.09	28.05	28.21	28.23	28.34	28.30	28.17	28.34	96hr
500	2.8782	28.41	28.44	28.36	28.59	28.53	28.47	28.55	28.71	28.57	28.71	120hr
1000	3.0902	28.63	28.71	28.59	29.05	28.86	29.35	28.72	28.95	28.89	29.35	72hr
2000	3.2905	28.81	29.52	29.18	29.30	29.33	29.66	28.89	29.78	29.13	29.78	120hr
5000	3.5401	29.70	31.05	30.66	29.61	30.12	30.08	29.26	30.83	30.14	31.05	18hr
10000	3.7190	30.99	32.06	31.78	30.09	30.87	31.15	30.00	31.31	30.45	32.06	18hr
20000	3.8906	31.32	32.48	32.77	30.85	31.73	32.07	31.75	31.67	31.83	32.77	24hr
50000	4.1075	31.44	33.79	34.44	32.61	33.33	34.15	34.36	33.76	34.09	34.44	24hr
100000	4.2649	31.52	34.53	34.71	34.27	35.09	36.33	36.49	35.45	35.70	36.49	96hr
200000	4.4172	32.08	35.46	36.68	35.79	36.75	38.16	38.27	37.01	37.84	38.27	96hr
500000	4.6114	33.50	37.78	46.52	38.01	39.14	39.83	39.87	39.48	40.08	40.08	168hr
1000000	4.7534	34.80	41.13	53.98	39.59	40.51	41.22	42.79	41.06	41.22	41.22	168hr

Results for Site 19: Bremer River at Walloon

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	18.43	18.44	18.52	18.51	18.73	19.11	19.28	19.78	19.71	19.78	120hr
5	0.8416	23.01	23.83	24.02	24.24	24.66	25.18	24.51	24.77	24.75	25.18	72hr
10	1.2816	25.00	25.61	25.43	25.67	26.09	26.25	25.90	26.08	25.99	26.25	72hr
20	1.6449	26.08	26.33	26.38	26.46	26.89	26.94	26.66	27.07	27.00	27.07	120hr
50	2.0537	27.02	27.11	27.25	27.29	27.74	27.55	27.57	27.69	27.65	27.74	48hr
100	2.3263	27.63	27.79	27.62	27.80	28.24	28.00	27.93	28.43	28.06	28.43	120hr
200	2.5758	28.23	28.32	28.29	28.15	28.71	28.47	28.30	28.81	28.55	28.81	120hr
500	2.8782	28.86	28.70	28.81	28.60	29.25	29.04	28.87	29.18	28.85	29.25	48hr
1000	3.0902	29.33	28.99	29.28	29.17	29.43	29.42	29.05	29.51	29.03	29.51	120hr
2000	3.2905	29.62	29.73	29.63	29.56	29.61	29.82	29.22	30.14	29.61	30.14	120hr
5000	3.5401	30.23	31.32	30.85	29.88	30.36	30.20	29.61	30.83	30.54	31.32	18hr
10000	3.7190	30.98	32.08	32.04	30.21	31.10	31.27	30.14	31.13	30.73	32.08	18hr
20000	3.8906	31.35	32.53	32.75	31.01	31.86	32.28	31.77	31.88	31.81	32.75	24hr
50000	4.1075	31.47	33.61	34.55	32.65	33.34	34.12	34.30	33.81	34.25	34.55	24hr
100000	4.2649	31.57	34.41	34.84	34.30	34.93	36.35	36.50	35.42	35.73	36.50	96hr
200000	4.4172	32.15	35.75	36.70	35.80	36.80	38.10	38.14	37.01	37.82	38.14	96hr
500000	4.6114	33.47	37.94	47.20	38.03	39.15	39.96	39.87	39.42	39.94	39.94	168hr
1000000	4.7534	34.80	41.59	55.27	39.59	40.53	41.21	42.96	41.10	41.22	41.22	168hr

Flood Level Quantiles (m AHD) for Individual Storm Durations for Each Reporting Site

Results for Site 20: Bremer River at Three Mile Bridge

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	10.43	10.46	10.69	10.62	11.43	11.73	11.74	12.31	12.46	12.46	168hr
5	0.8416	16.44	17.37	17.91	18.01	18.96	19.56	18.71	19.00	18.93	19.56	72hr
10	1.2816	18.66	19.72	20.40	20.64	21.31	21.81	20.93	21.35	21.21	21.81	72hr
20	1.6449	20.70	21.41	22.24	22.36	22.93	23.01	22.65	23.09	22.74	23.09	120hr
50	2.0537	22.91	23.60	23.98	23.46	24.52	24.48	24.22	24.81	24.23	24.81	120hr
100	2.3263	24.10	24.62	25.04	25.00	25.49	25.23	25.70	25.86	25.22	25.86	120hr
200	2.5758	25.81	25.85	26.11	25.84	26.40	26.36	26.40	27.07	26.33	27.07	120hr
500	2.8782	26.93	27.04	27.15	26.95	27.58	27.71	27.02	28.09	27.29	28.09	120hr
1000	3.0902	27.52	28.38	28.07	27.94	28.26	29.08	27.79	28.76	27.88	29.08	72hr
2000	3.2905	27.99	29.28	28.95	28.87	29.11	29.60	28.20	29.53	28.91	29.60	72hr
5000	3.5401	29.93	31.13	30.71	29.48	29.95	30.13	29.16	30.90	29.95	31.13	18hr
10000	3.7190	30.84	31.95	31.85	29.95	30.89	31.09	30.02	31.28	30.24	31.95	18hr
20000	3.8906	31.15	32.34	32.80	30.79	31.82	31.98	31.76	31.76	31.72	32.80	24hr
50000	4.1075	31.34	33.83	34.24	32.59	33.36	34.11	34.36	33.73	34.23	34.36	96hr
100000	4.2649	31.48	34.50	34.63	34.21	34.96	36.32	36.50	35.40	35.70	36.50	96hr
200000	4.4172	32.01	35.43	36.74	35.79	36.81	38.13	38.18	36.97	37.86	38.18	96hr
500000	4.6114	33.34	37.81	47.63	38.09	39.00	39.88	39.85	39.47	40.01	40.01	168hr
1000000	4.7534	34.60	41.32	56.08	39.59	40.50	41.20	42.93	41.19	41.22	41.22	168hr

Results for Site 21: Bremer River at One Mille Bridge

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	4.52	4.57	5.02	4.77	6.42	6.74	6.42	7.71	7.49	7.71	120hr
5	0.8416	12.80	13.98	14.80	14.93	15.96	16.60	15.64	16.02	15.93	16.60	72hr
10	1.2816	15.54	16.90	17.65	17.91	18.64	19.47	18.59	18.88	18.71	19.47	72hr
20	1.6449	18.03	18.97	20.01	20.16	20.80	20.98	20.50	21.07	20.53	21.07	120hr
50	2.0537	20.58	21.57	22.27	21.76	23.07	22.93	22.73	23.24	22.65	23.24	120hr
100	2.3263	22.38	23.10	23.68	23.62	24.28	23.98	24.55	24.65	23.94	24.65	120hr
200	2.5758	24.63	24.66	24.98	24.63	25.45	25.49	25.46	26.26	25.65	26.26	120hr
500	2.8782	25.66	26.26	26.40	25.92	26.98	27.07	26.24	27.44	26.47	27.44	120hr
1000	3.0902	26.69	27.72	27.31	27.24	27.73	28.53	27.18	28.20	27.15	28.53	72hr
2000	3.2905	27.33	28.81	28.41	28.16	28.77	29.13	27.67	29.11	28.41	29.13	72hr
5000	3.5401	29.24	30.47	30.41	28.95	29.45	29.73	28.79	30.64	29.56	30.64	120hr
10000	3.7190	30.61	31.57	31.75	29.54	30.58	30.92	29.94	31.07	29.89	31.75	24hr
20000	3.8906	30.77	31.93	32.38	30.51	31.70	31.88	31.70	31.65	31.81	32.38	24hr
50000	4.1075	30.99	33.22	34.01	32.42	33.06	34.04	34.34	33.81	33.99	34.34	96hr
100000	4.2649	31.14	33.97	34.49	34.18	35.08	36.37	36.41	35.35	35.71	36.41	96hr
200000	4.4172	31.62	35.09	36.53	35.79	36.87	38.12	38.12	37.04	37.84	38.12	72hr
500000	4.6114	33.28	37.46	46.03	37.89	39.09	39.98	39.71	39.31	40.00	40.00	168hr
1000000	4.7534	34.37	40.62	53.10	39.59	40.52	41.20	42.49	41.14	41.20	41.20	168hr

Results for Site 22: Bremer River at David Trumpy Bridge

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.81	1.83	1.84	1.83	1.90	1.94	1.97	2.01	2.06	2.06	168hr
5	0.8416	5.59	6.77	7.65	7.99	9.19	10.05	8.93	9.33	9.15	10.05	72hr
10	1.2816	8.58	10.27	10.98	11.46	12.25	13.19	12.26	12.67	12.33	13.19	72hr
20	1.6449	11.46	12.45	13.63	13.78	14.93	15.12	14.35	15.23	14.48	15.23	120hr
50	2.0537	13.97	15.37	16.19	16.39	17.56	17.58	18.08	18.14	17.34	18.14	120hr
100	2.3263	16.07	17.13	17.73	18.03	19.11	19.81	19.72	20.26	19.54	20.26	120hr
200	2.5758	18.25	18.45	19.25	19.51	20.66	21.47	21.21	21.91	21.14	21.91	120hr
500	2.8782	19.68	20.30	20.90	21.41	22.41	23.51	23.30	23.47	23.18	23.51	72hr
1000	3.0902	20.74	21.85	21.74	22.65	23.30	24.76	24.56	24.83	24.25	24.83	120hr
2000	3.2905	21.42	23.17	23.18	23.29	24.71	26.06	26.11	26.02	25.18	26.11	96hr
5000	3.5401	23.30	24.28	24.62	25.19	26.92	27.58	27.55	27.32	27.06	27.58	72hr
10000	3.7190	24.10	25.00	25.99	27.22	28.33	28.88	29.01	28.68	28.80	29.01	96hr
20000	3.8906	24.46	26.45	28.29	29.54	30.31	31.10	31.01	30.59	31.04	31.10	72hr
50000	4.1075	25.90	28.88	30.30	31.80	32.76	33.34	33.65	33.08	33.32	33.65	96hr
100000	4.2649	28.30	30.46	32.22	34.11	34.67	35.67	35.97	34.84	35.06	35.97	96hr
200000	4.4172	29.33	31.76	33.96	35.67	36.63	37.65	37.73	36.30	37.35	37.73	96hr
500000	4.6114	30.66	33.69	36.17	37.83	38.87	39.61	39.26	38.81	39.47	39.61	72hr
1000000	4.7534	32.14	35.75	38.17	39.40	40.21	40.93	40.88	40.66	40.79	40.93	72hr

Results for Site 23: Bremer River at Hancock Bridge

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.83	1.85	1.87	1.79	1.88	2.06	2.16	2.31	2.31	2.31	120hr
5	0.8416	6.92	8.28	9.07	9.53	10.82	11.66	10.50	10.92	10.71	11.66	72hr
10	1.2816	10.19	11.85	13.05	13.30	14.31	15.22	14.04	14.47	14.13	15.22	72hr
20	1.6449	13.29	14.37	15.84	15.97	16.86	17.13	16.51	17.30	16.61	17.30	120hr
50	2.0537	16.37	17.49	18.42	18.16	19.58	19.57	19.74	20.17	19.24	20.17	120hr
100	2.3263	18.42	19.48	19.94	20.06	21.10	21.10	21.83	21.98	21.05	21.98	120hr
200	2.5758	20.69	20.99	21.67	21.53	22.55	23.07	22.58	23.61	22.68	23.61	120hr
500	2.8782	22.17	22.99	23.49	23.34	24.19	24.90	24.13	24.94	24.27	24.94	120hr
1000	3.0902	23.52	24.57	24.37	24.51	24.99	25.70	24.93	25.92	25.25	25.92	120hr
2000	3.2905	24.00	25.73	25.47	25.28	25.94	26.44	26.28	26.85	26.00	26.85	120hr
5000	3.5401	25.82	26.86	27.10	26.34	27.44	27.88	27.77	27.90	27.16	27.90	120hr
10000	3.7190	26.67	28.05	28.01	27.46	28.75	29.06	29.09	28.79	28.95	29.09	96hr
20000	3.8906	26.87	28.48	29.18	29.55	30.36	31.18	31.10	30.73	31.14	31.18	72hr
50000	4.1075	27.13	29.87	30.87	31.82	32.79	33.50	33.75	33.20	33.45	33.75	96hr
100000	4.2649	28.31	30.77	33.03	34.13	34.69	35.81	36.06	34.95	35.16	36.06	96hr
200000	4.4172	29.38	32.32	33.96	35.68	36.67	37.73	37.80	36.44	37.45	37.80	96hr
500000	4.6114	30.72	33.70	36.18	37.88	38.89	39.75	39.32	38.92	39.57	39.75	72hr
1000000	4.7534	32.15	35.76	38.17	39.41	40.23	41.00	40.94	40.75	41.11	41.11	168hr

Flood Level Quantiles (m AHD) for Individual Storm Durations for Each Reporting Site

Results for Site 24: Bremer River at Bundamba Confluence

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.72	1.74	1.77	1.75	1.82	1.82	1.81	1.82	1.83	1.83	168hr
5	0.8416	3.62	4.52	5.17	5.54	6.45	7.38	6.48	6.69	6.67	7.38	72hr
10	1.2816	6.22	7.20	8.18	8.75	9.54	10.19	9.53	9.86	9.69	10.19	72hr
20	1.6449	8.34	9.66	10.70	10.75	11.77	12.48	11.83	12.38	11.82	12.48	72hr
50	2.0537	10.64	12.46	13.19	13.66	15.12	15.50	15.77	16.02	15.25	16.02	120hr
100	2.3263	12.84	14.16	15.20	16.17	17.23	18.55	18.40	18.66	18.26	18.66	120hr
200	2.5758	14.95	15.59	16.84	18.04	19.18	20.58	20.63	20.92	20.41	20.92	120hr
500	2.8782	15.75	17.21	18.88	20.03	21.54	23.38	23.14	23.26	22.60	23.38	72hr
1000	3.0902	16.82	18.47	20.20	21.50	22.93	24.72	24.47	24.48	24.18	24.72	72hr
2000	3.2905	18.00	19.96	21.43	23.03	24.61	25.98	26.04	26.03	25.13	26.04	96hr
5000	3.5401	19.69	21.53	23.48	25.16	26.90	27.60	27.56	27.30	27.10	27.60	72hr
10000	3.7190	20.42	23.01	25.42	27.20	28.31	28.84	29.01	28.67	28.76	29.01	96hr
20000	3.8906	22.05	26.01	28.31	29.52	30.29	31.07	30.98	30.57	31.00	31.07	72hr
50000	4.1075	25.88	28.76	30.31	31.84	32.73	33.31	33.63	33.04	33.28	33.63	96hr
100000	4.2649	28.29	30.45	32.20	34.10	34.66	35.65	35.95	34.81	35.04	35.95	96hr
200000	4.4172	29.32	31.76	33.95	35.67	36.62	37.63	37.72	36.28	37.33	37.72	96hr
500000	4.6114	30.70	33.68	36.16	37.83	38.86	39.58	39.25	38.79	39.45	39.58	72hr
1000000	4.7534	32.06	35.61	38.16	39.40	40.21	40.92	40.87	40.63	40.78	40.92	72hr

Results for Site 25: Bremer River at Warrego Highway

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.70	1.72	1.74	1.69	1.78	1.80	1.79	1.75	1.80	1.80	72hr
5	0.8416	3.08	3.68	4.30	4.49	5.42	6.13	5.67	5.48	5.70	6.13	72hr
10	1.2816	5.23	6.00	7.02	7.38	8.16	8.66	8.46	8.72	8.35	8.72	120hr
20	1.6449	7.11	8.61	9.25	9.60	10.56	11.53	10.86	11.16	10.84	11.53	72hr
50	2.0537	9.57	11.32	12.21	12.75	14.49	15.17	15.26	15.53	14.64	15.53	120hr
100	2.3263	11.53	12.69	14.52	15.75	16.80	18.54	18.37	18.61	18.20	18.61	120hr
200	2.5758	13.51	14.71	16.59	17.94	19.17	20.58	20.65	20.92	20.37	20.92	120hr
500	2.8782	14.66	16.75	18.75	19.98	21.52	23.32	23.12	23.25	22.58	23.32	72hr
1000	3.0902	16.14	18.41	20.14	21.50	22.91	24.70	24.46	24.46	24.17	24.70	72hr
2000	3.2905	17.54	19.56	21.42	23.04	24.60	25.97	26.03	26.01	25.14	26.03	96hr
5000	3.5401	19.44	21.38	23.46	25.15	26.89	27.59	27.55	27.33	27.10	27.59	72hr
10000	3.7190	20.32	22.98	25.40	27.19	28.32	28.87	28.99	28.65	28.88	28.99	96hr
20000	3.8906	22.05	26.01	28.30	29.51	30.31	31.06	30.96	30.56	30.98	31.06	72hr
50000	4.1075	25.87	28.78	30.30	31.78	32.74	33.31	33.63	33.03	33.27	33.63	96hr
100000	4.2649	28.29	30.46	32.19	34.10	34.65	35.64	35.94	34.80	35.03	35.94	96hr
200000	4.4172	29.32	31.76	33.94	35.66	36.62	37.61	37.71	36.27	37.32	37.71	96hr
500000	4.6114	30.70	33.68	36.16	37.83	38.86	39.58	39.25	38.79	39.45	39.58	72hr
1000000	4.7534	32.06	35.61	38.16	39.40	40.20	40.92	40.87	40.64	40.77	40.92	72hr

Results for Site 26: Bundamba Creek at Hanlon St Alert

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	0.49	0.49	0.54	0.53	0.56	0.66	0.67	0.78	0.72	0.78	120hr
5	0.8416	3.75	3.96	4.18	4.48	5.03	5.62	5.30	5.51	5.34	5.62	72hr
10	1.2816	5.12	5.61	5.63	6.57	9.36	10.09	9.31	9.70	9.40	10.09	72hr
20	1.6449	7.00	9.34	10.59	10.79	11.74	12.53	11.77	12.37	11.89	12.53	72hr
50	2.0537	10.66	12.38	13.19	13.67	15.08	15.47	15.76	16.01	15.20	16.01	120hr
100	2.3263	12.73	14.07	15.15	16.15	17.23	18.57	18.41	18.69	18.24	18.69	120hr
200	2.5758	14.90	15.55	16.83	18.02	19.25	20.59	20.64	20.70	20.38	20.70	120hr
500	2.8782	15.73	17.20	18.86	20.00	21.66	23.23	23.05	23.21	22.61	23.23	72hr
1000	3.0902	16.80	18.52	20.21	21.38	22.95	24.61	24.42	24.51	24.22	24.61	72hr
2000	3.2905	18.04	19.63	21.53	22.97	24.54	26.06	26.13	25.93	25.22	26.13	96hr
5000	3.5401	19.61	21.50	23.41	25.21	26.84	27.52	27.58	27.36	26.92	27.58	96hr
10000	3.7190	20.41	23.23	25.64	27.41	28.38	28.87	29.05	28.64	28.83	29.05	96hr
20000	3.8906	22.13	26.07	28.30	29.45	30.35	30.90	31.22	30.64	31.16	31.22	96hr
50000	4.1075	25.66	28.82	30.24	31.78	32.63	33.25	33.75	32.90	33.50	33.75	96hr
100000	4.2649	28.16	30.39	32.32	33.94	34.77	35.71	35.85	34.74	35.05	35.85	96hr
200000	4.4172	29.32	31.72	33.90	35.69	36.56	37.55	37.62	36.50	37.34	37.62	96hr
500000	4.6114	30.72	33.72	36.15	37.92	38.83	39.63	39.21	38.76	39.49	39.63	72hr
1000000	4.7534	32.06	35.60	38.16	39.40	40.21	40.92	40.88	40.60	40.77	40.92	72hr

Results for Site 27: Woogaroo Creek at Brisbane Road Alert

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.28	1.28	1.29	1.30	1.33	1.35	1.34	1.33	1.33	1.35	72hr
5	0.8416	2.24	2.42	2.62	2.72	3.19	3.50	3.41	3.27	3.28	3.50	72hr
10	1.2816	3.11	3.54	4.22	4.61	5.34	5.69	5.65	5.64	5.53	5.69	72hr
20	1.6449	4.20	5.42	6.12	6.66	7.75	8.34	8.07	8.25	7.97	8.34	72hr
50	2.0537	6.31	7.87	8.95	9.70	11.41	12.46	12.29	12.55	11.82	12.55	120hr
100	2.3263	8.34	9.73	11.48	12.99	14.09	15.49	15.71	15.92	15.50	15.92	120hr
200	2.5758	9.65	11.45	13.61	15.12	16.38	17.71	17.94	17.88	17.65	17.94	96hr
500	2.8782	11.28	13.52	15.74	17.07	18.67	20.38	20.23	20.34	19.92	20.38	72hr
1000	3.0902	12.76	15.12	16.96	18.52	19.84	21.90	21.60	21.49	21.29	21.90	72hr
2000	3.2905	14.18	16.31	18.33	20.11	21.74	23.39	23.55	23.33	22.31	23.55	96hr
5000	3.5401	15.89	18.10	20.37	22.30	24.43	25.41	25.50	25.13	24.73	25.50	96hr
10000	3.7190	17.41	19.88	22.66	24.92	26.51	27.34	27.41	26.85	27.06	27.41	96hr
20000	3.8906	18.94	23.13	26.20	28.02	29.07	29.80	30.08	29.27	30.08	30.08	96hr
50000	4.1075	23.17	27.17	28.97	30.73	31.70	32.64	32.77	32.17	32.56	32.77	96hr
100000	4.2649	26.24	29.18	31.36	33.19	34.09	34.93	35.13	33.87	34.36	35.13	96hr
200000	4.4172	27.83	30.77	33.27	34.99	36.03	37.01	37.14	35.68	36.72	37.14	96hr
500000	4.6114	29.52	32.98	35.55	37.22	38.30	39.00	38.67	38.19	38.91	39.00	72hr
1000000	4.7534	31.10	34.93	37.58	38.84	39.58	40.37	40.29	40.03	40.16	40.37	72hr

Flood Level Quantiles (m AHD) for Individual Storm Durations for Each Reporting Site

Results for Site 28: Oxley Creek at Rocklea

AEP(1inY)	Zstd	12hr	18hr	24hr	36hr	48hr	72hr	96hr	120hr	168hr	Maximum	TCrit
2	0.0000	1.43	1.43	1.47	1.47	1.47	1.50	1.50	1.49	1.47	1.50	96hr
5	0.8416	1.91	1.94	2.06	2.05	2.31	2.43	2.38	2.34	2.44	2.44	168hr
10	1.2816	2.32	2.57	2.64	2.80	3.18	3.34	3.28	3.30	3.56	3.56	168hr
20	1.6449	3.09	3.40	3.53	3.88	4.13	4.61	4.60	4.80	4.61	4.80	120hr
50	2.0537	4.14	4.67	5.06	5.49	6.30	6.92	6.93	7.34	6.81	7.34	120hr
100	2.3263	4.82	5.68	6.46	7.27	8.10	9.24	9.23	9.37	9.22	9.37	120hr
200	2.5758	5.35	6.70	7.76	8.78	9.68	10.61	10.79	10.93	10.64	10.93	120hr
500	2.8782	6.45	7.93	9.15	10.10	11.38	12.58	12.57	12.73	12.35	12.73	120hr
1000	3.0902	7.12	8.51	10.01	11.17	12.30	13.84	13.80	13.82	13.55	13.84	72hr
2000	3.2905	8.16	9.53	10.84	12.38	13.83	15.29	15.53	15.40	14.50	15.53	96hr
5000	3.5401	9.22	10.71	12.67	14.35	16.16	17.29	17.54	17.18	16.92	17.54	96hr
10000	3.7190	10.34	12.31	14.51	16.65	18.40	19.59	20.21	19.40	19.69	20.21	96hr
20000	3.8906	11.57	15.24	18.09	20.37	21.56	22.36	22.58	22.04	22.50	22.58	96hr
50000	4.1075	14.91	19.26	21.49	23.14	23.95	24.64	25.16	24.57	25.01	25.16	96hr
100000	4.2649	18.32	21.56	23.52	25.28	25.89	26.97	27.24	26.06	26.43	27.24	96hr
200000	4.4172	20.15	23.10	25.28	26.83	27.54	28.96	28.95	27.84	28.53	28.96	72hr
500000	4.6114	21.92	25.02	27.39	28.98	30.00	30.85	30.62	30.26	30.94	30.94	168hr
1000000	4.7534	23.45	26.69	29.22	30.56	31.40	32.35	32.25	32.29	32.35	32.35	72hr

Appendix E Sensitivity Assessment of AEP Level Frequency Results

An analysis was undertaken in which various features of the statistical analysis were varied within reasonable limits. It should be noted that the assessment of different analysis parameterisations are all equally valid: there is no “right” or “wrong” value to adopt (with reasonable bounds). Such variations are usually avoided by increasing the size of the sample used in the analysis (an option that cannot be adopted here for practical reasons).

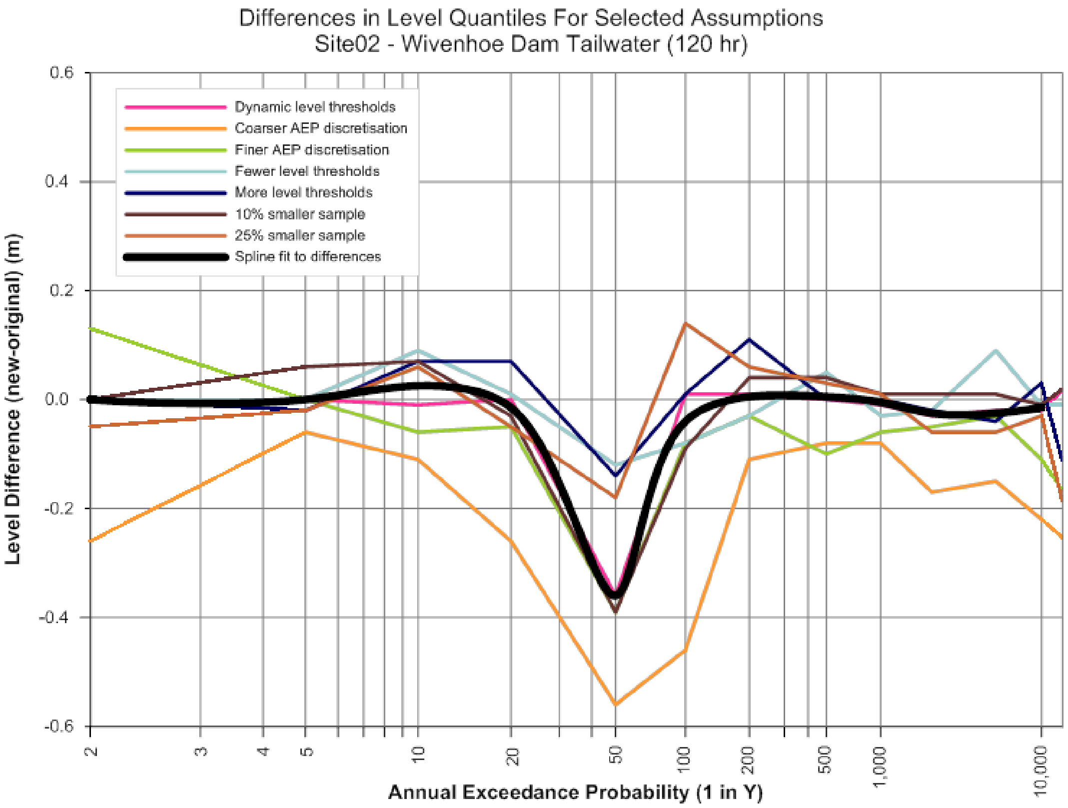
The various sensitivity analyses undertaken include:

- “Dynamic threshold levels” – threshold levels are varied with range of individual sample (rather than fixed to what was originally used)
- “More level thresholds” – Number of (dynamic) thresholds are increased from 50 to 60
- “Fewer level thresholds” – Number of (dynamic) thresholds are decreased from 50 to 40
- “Coarser AEP discretisation” – a smaller number of AEP bins are considered (20 rather than 25)
- “Finer AEP discretisation” – a larger number of AEP bins are considered (30 rather than 25)
- “25% smaller sample” – the size of sample is reduced by 25%
- “10% smaller sample” – the size of sample is reduced by 10%
- “Spline fit to differences” – spline function fitted to median of differences (ie all of the above).

The results of these sensitivity analyses for 120 hours duration at selected sites are shown in Figure E-1 to Figure E-3.

In general it is concluded that sample size (“sampling uncertainty”) means that results are sensitive to the adopted discretisation (ie the number and width of selected thresholds & interpolation), noting that this sensitivity is less than 1% of flow depth; this sensitivity can only be reduced by increasing the number of runs undertaken for each duration.

Importantly, it needs to be recognised that no effort has been made to characterise the uncertainty of any of the factors that this analysis is dependent on. In reality, the notional 1% uncertainty identified by these sensitivity tests due to the discretisation of the sample size of this aspect of the study is of negligible importance compared to the uncertainty in the estimation of the design rainfalls, their conversion to flood hydrographs, and the uncertainty inherent in the sample of events contained in a historic record that is very much shorter than the extrapolated extremes of interest. However, given that there is some sensitivity demonstrated to differing sampling approaches; it is recommended that the same threshold and bin discretisation sampling strategies used in this assessment are also used in potential future assessments to provide consistency. Should there be a justifiable reason to change the future sampling strategy, any issues associated with possible inconsistencies in results need to be considered and addressed as appropriate.



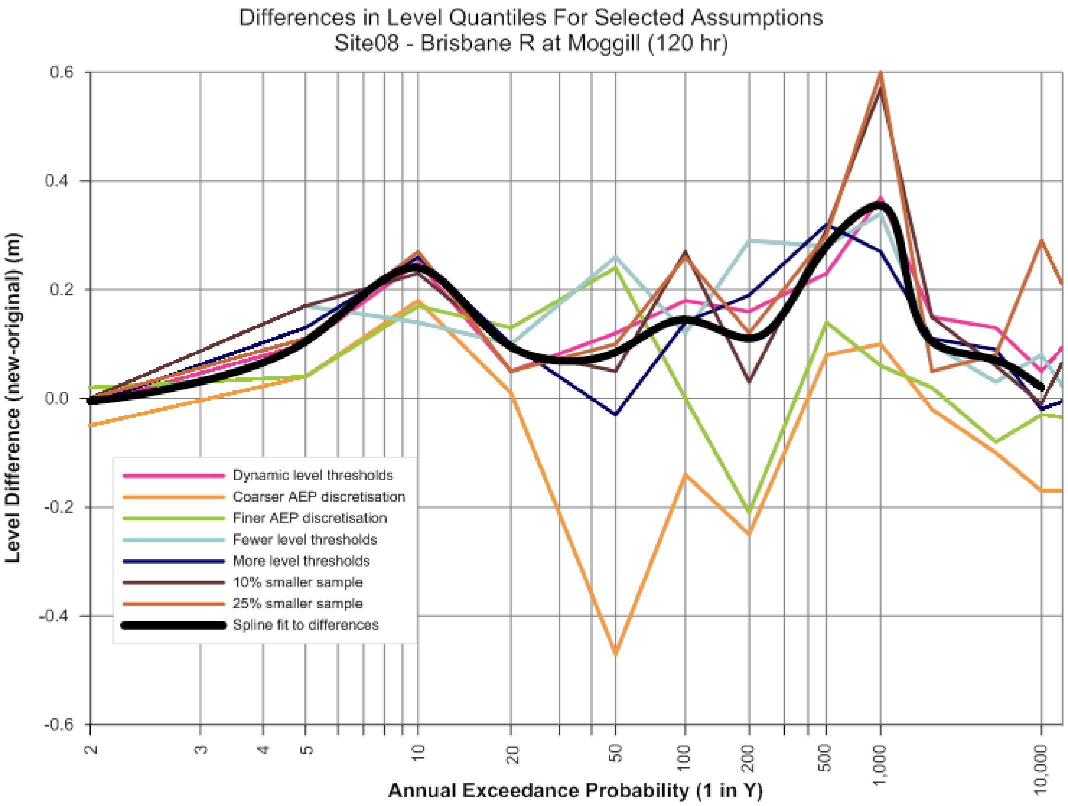
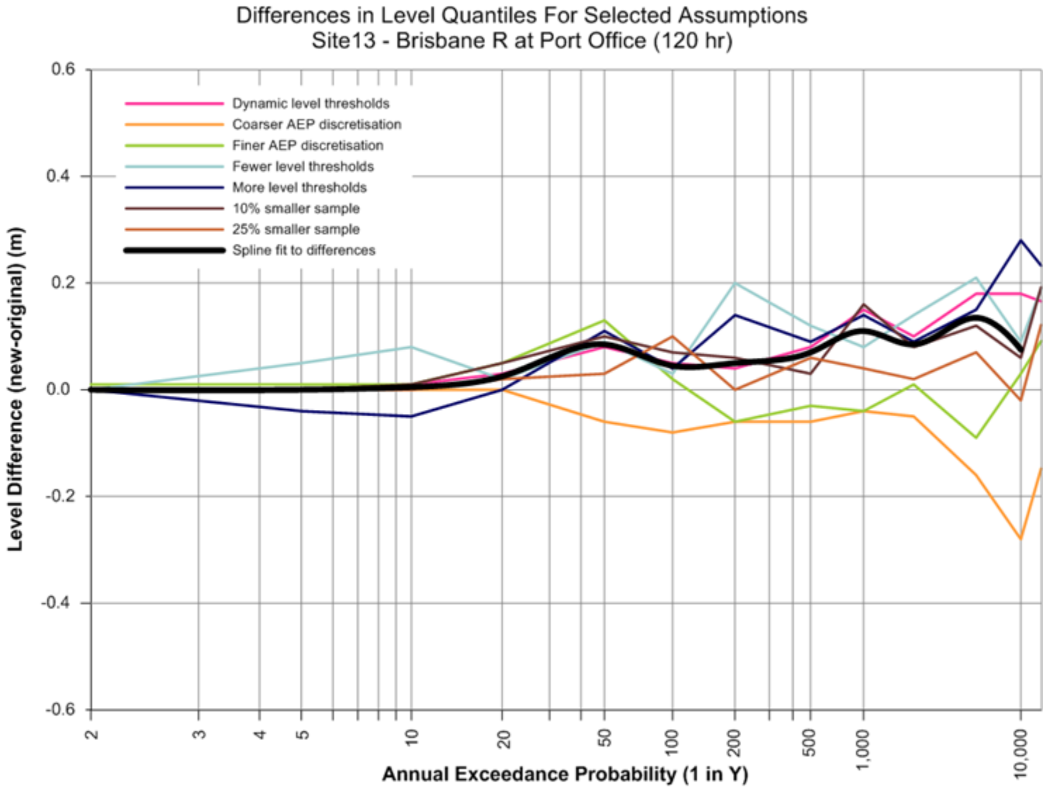


Figure E-1 Selected Sensitivity Analyses



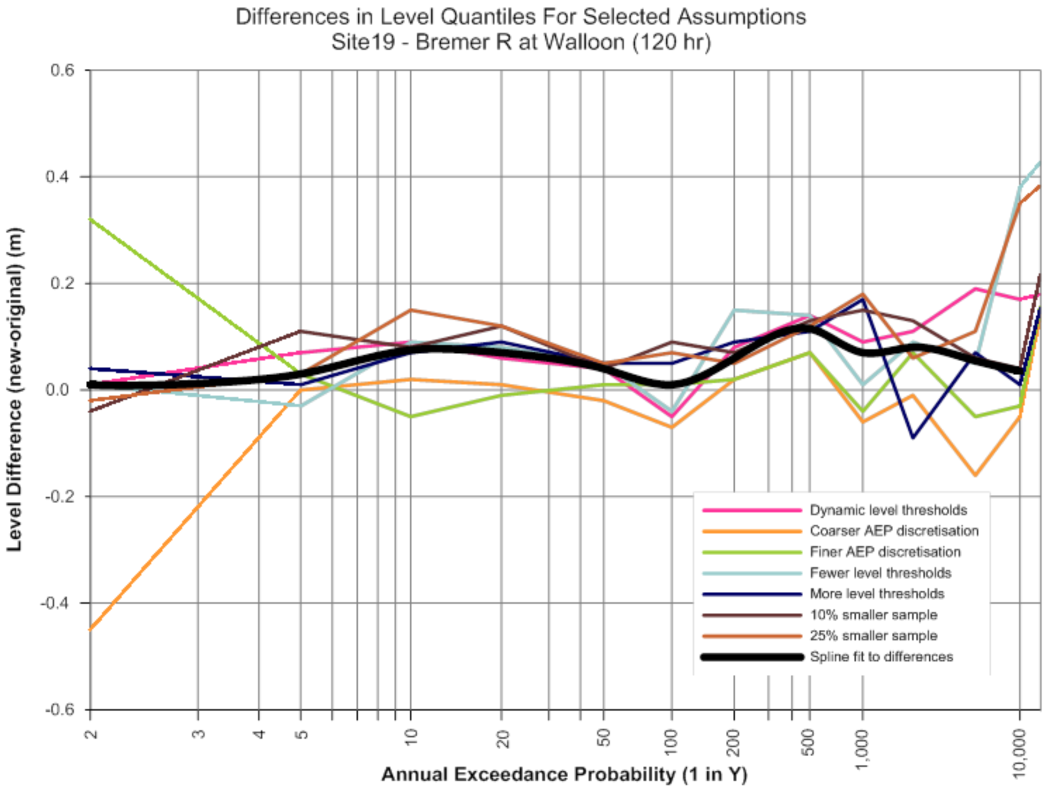


Figure E-2 Selected Sensitivity Analyses

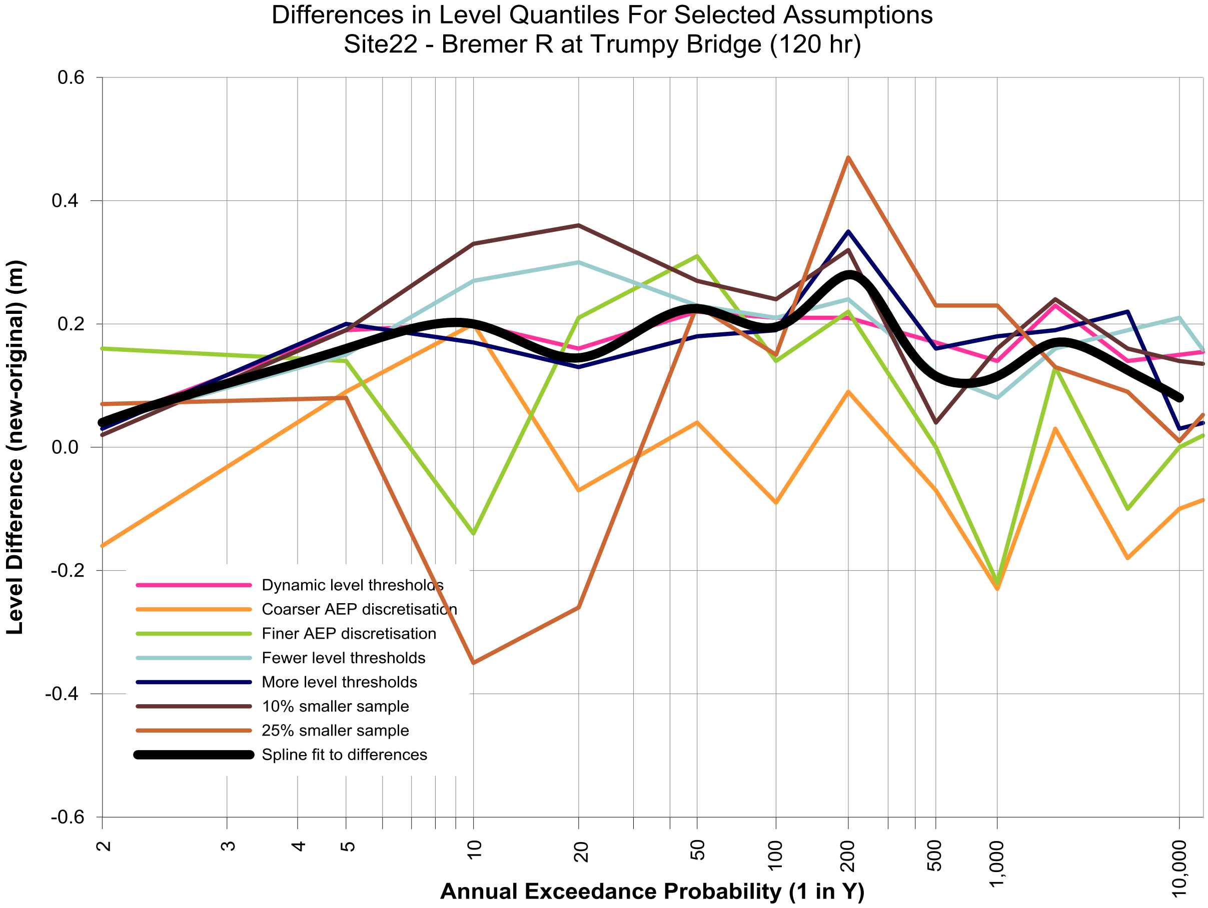


Figure E-3 Selected Sensitivity Analyses

Appendix F Comments from IPE

Review of Updated Milestone Report 4 (Fast Model Results and Design Events Selection) dated 17 June 2016

Introduction

This report presents the IPE's review of the updated Milestone Report 4, 17 June 2016. The report covers the complex process required for the Monte Carlo assessment of flood levels at 28 reporting locations using the fast hydraulic model. This complex task requires the fast model to run 11,340 model simulations for events Ranging between the 1 in 2 (50%) Annual exceedance probability (AEP) and 1 in 100,000 (0.001%) AEP. Results where extracted at the 28 reporting locations and after a series of consistency checks where used to carry out Monte Carlo frequency assessment. The final section of the report outlines the selection of a small ensemble of events that can be used to reproduce design flood levels thought the catchment and be subsequently used in the detailed hydraulic model. The IPE has previously reviewed the first draft of this report dated 7 August 2015 and the second draft dated February 2016. The updated report addresses all of the IPE's earlier comments. This review focuses on those sections that have changed and purpose of the overall document

The IPE is very satisfied with the technical work carried out and documented in this report. While the IPE endorses the technical work, some comments are provided below. These comments are aimed at addressing consistency issues and ensuring future users of the work properly understand the work carried out and any assumption's used.

Specific Comments

Some minor issues have been noted in the Updated MR4 Report. These are all listed in the TWG Template in Appendix A. Those that require some elaboration are discussed below.

MR4.Fast Model Results and Design Events Selection Draft Final

Page 59 Section 6.2.1 Local tributary inflows

"The expectation is that this is likely to have negligible influence on model results as local tributary flows tend to occur well before, and are of much lower magnitude, than the main peak of the Brisbane and Bremer Rivers. In total, 22 tributary inflows were adjusted in this manner."

- It would be helpful to list the locations of these.

Pages 67, 68 Figs 6-1 and 6-2 2011 and 1974 (respectively) *Detailed Model Check - Statistical assessment of Differences between Observed & Modelled Peak Flood Levels.*

- For the reader who wishes to compare these Figs 6-1 and 6-2 with corresponding Figs 3-2 and 3-3 in MR Report 3 it would help if these Figures were included here for easy comparison.

R.B20702.004.03.MR4.Fast Model Results Plot Addendum

All of the plots have been reviewed and are satisfactory with two exceptions:

- Plot 51 - Brisbane River Longitudinal Profiles Maximums - All AEPs.

AEP 200 is above AEP 500 at the downstream end of Lower Brisbane River

- Plot 63 - Bremer/Lockyer Longitudinal Profiles Maximums - All AEPs.

AEP 20 is above AEP 50 at the upstream end of Lockyer

(These problems have been rectified in the corresponding Plots in the MR5 Report).

Conclusions

The IPE endorses Milestone Report 4- fast model and design results dated 17 June 2016.

11 July 2016

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Review of Updated Milestone Report 4 (Fast Model Results and Design Events Selection)

- TWG Template

Item No.	Page No.	Section	Para/Line/Dot Point/Table etc	Issue/Comments	Suggestion
1	59	6.2.1	Para 5, line 8	*"In total, 22 tributary inflows were adjusted in this manner."*	It would be helpful to list the locations of these.
2	67		Fig 6-1 DM verification 2011		Suggest include Fig 3-2 from MR Report 3 for ease of comparison
3	68		Fig 6-2 DM verification 1974		Suggest include Fig 3-3 from MR Report 3 for ease of comparison
4	MR4.Fast Model Results Plot Addendum	Plot 51 Brisbane River Long Profiles Maxs - All AEPs.	Lower Brisbane	AEP 200 is above AEP 500 at downstream end of Lower Brisbane River	Any comment? This problem has been fixed in the corresponding MR5 profiles
5	MR4.Fast Model Results Plot Addendum	Plot 63 Bremer/ Lockyer Long Profiles Maxs - All AEPs.	Lockyer	AEP 20 is above AEP 50 at upstream end Lockyer	Any comment? This problem has been fixed in the corresponding MR5 profiles

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