Brisbane River Catchment Flood Study: Comprehensive Hydraulic Assessment Overview

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Introduction

The Brisbane River Catchment Flood Study (BRCFS) is one of the largest and most complex flood studies embarked upon in Australia. It is governed by a Steering Committee consisting of state and local government representatives, regularly reviewed by both an Independent Panel of Experts and a Technical Working Group, and undertaken by a team of specialist consultants. A different set of specialists is undertaking each of the three major components into which the study is divided: a) data collection; b) a comprehensive hydrologic assessment; and c) a comprehensive hydraulic assessment. This paper will focus on the latter component.

Background

The Brisbane River has a catchment area of over 13,600km^2. The River and its major tributaries have a long history of flooding, with recorded evidence of such dating back almost 200 years. Large flood events have been experienced and recorded in 1893, 1974 and 2011. Peak flood levels recorded for these events at the Brisbane Port Office Gauge are 8.35m AHD, 5.45m AHD and 4.46m AHD respectively. It is of interest that two large distinct flood events occurred in 1893 (one in January and one in February) with peak flood levels exceeding 8m AHD in both events. Following the devastation caused by the 1974 flood event, Wivenhoe Dam was constructed in the Brisbane catchment in 1984 for the dual purpose of water supply and flood mitigation. In addition to a water supply storage capacity of 1.165 million ML, it has 1.967 million ML of flood mitigation volume available to store floodwater and thereby reduce the risk of flooding downstream. Despite the 2011 event peaking approximately 1 metre lower than the 1974 event (and 4 metres lower than the largest 1893 event) in Brisbane City, and approximately 1.5 metres lower than the 1974 event at Moggill and Ipswich, the 2011 flood caused widespread property damage in the catchment. Peak flood levels upstream of Moggill and into Lockyer Creek in 2011 were similar to, and higher than those recorded in 1974.

The Queensland Floods Commission of Inquiry (Qld FCoI, 2012) was established in response to “the scale of the disaster” caused by the 2011 flood event in the Brisbane River catchment. The Qld FCoI recommended that a comprehensive plan to manage Brisbane River flood risk was required (Recommendation 2.2, Qld FCoI, 2012). In response, the Queensland Government instigated the Brisbane River Catchment Floodplain Studies, of which the Comprehensive Hydraulic Assessment is a component.

As shown in Figure 1, the Comprehensive Hydraulic Assessment is the final stage of the Brisbane River Catchment Flood Study (BRCFS). The Hydraulic Assessment utilises outcomes and products of the prior Data Collection Study (Aurecon *et al.,* 2013)), the Disaster Management Tool (DMT) Study (BCC, 2014a) and the Comprehensive Hydrologic Assessment (Aurecon *et al*., 2014c)). There has been interfacing between all of these phases.

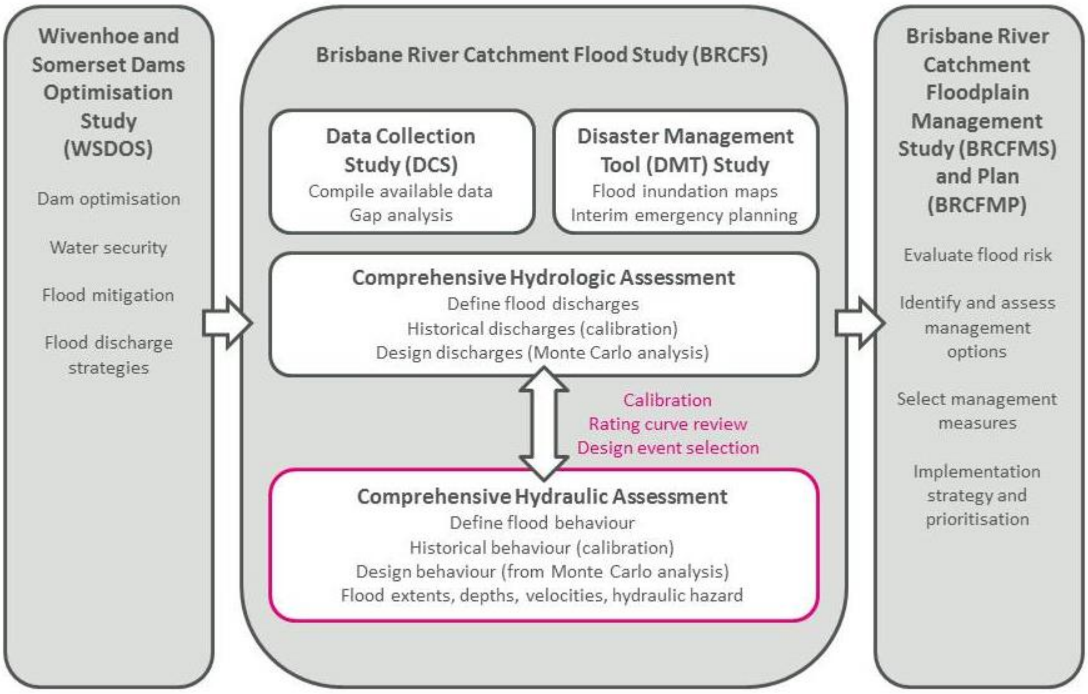

Figure 1 – Positioning of the Hydraulic Assessment within the BRCFS and within the Overall Framework

Hydraulic Assessment Purpose and Extent

The primary objectives 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 over the lower Brisbane River study area.

The study area extends from the mouth of the Brisbane River up to Wivenhoe Dam, from the confluence of the Bremer River into the tributaries above Ipswich, and from the confluence of Lockyer Creek to upstream of Lyons Bridge. The locality of the hydraulic assessment area is shown in Figure 2 and Figure 3.

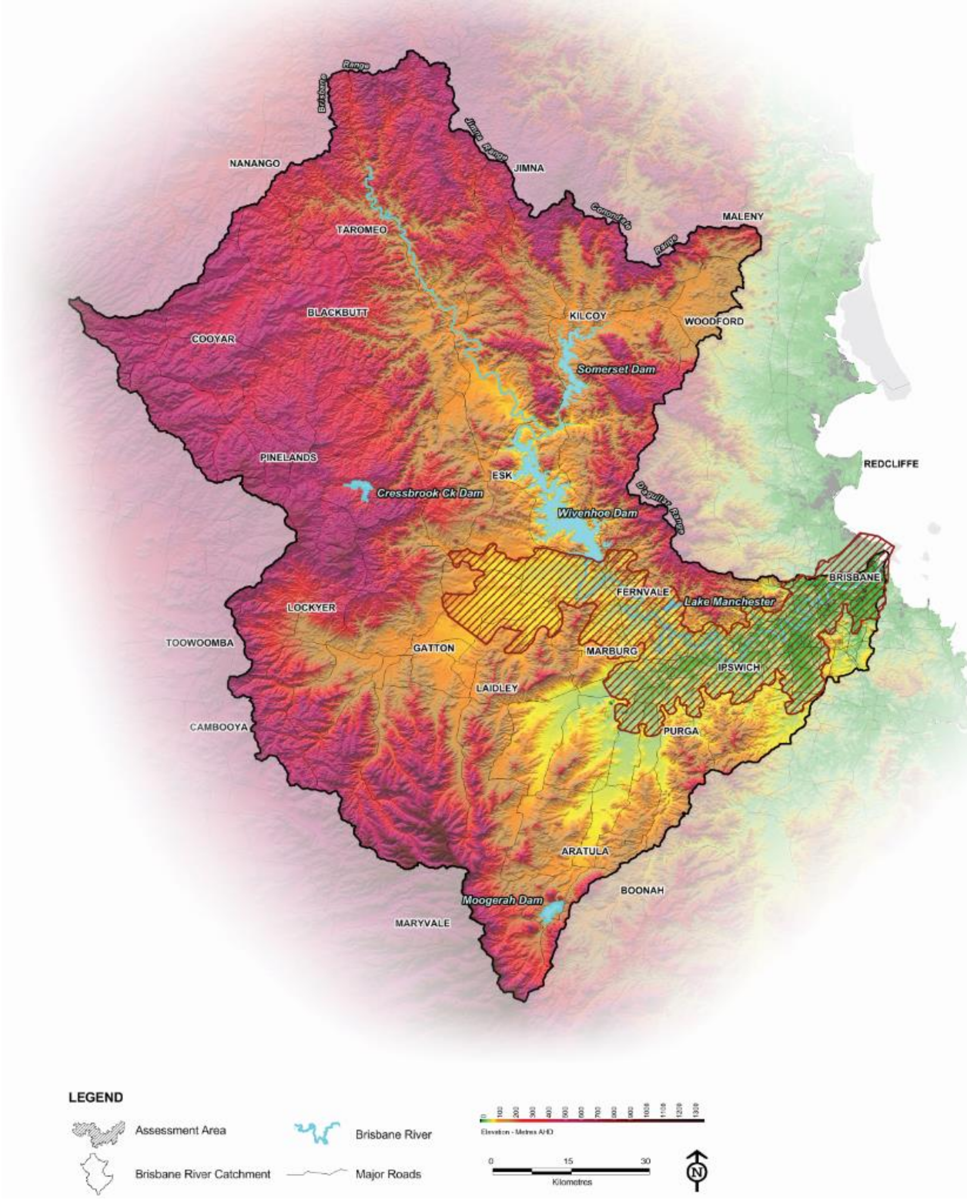

Figure 2 – Hydraulic Assessment Area Locality

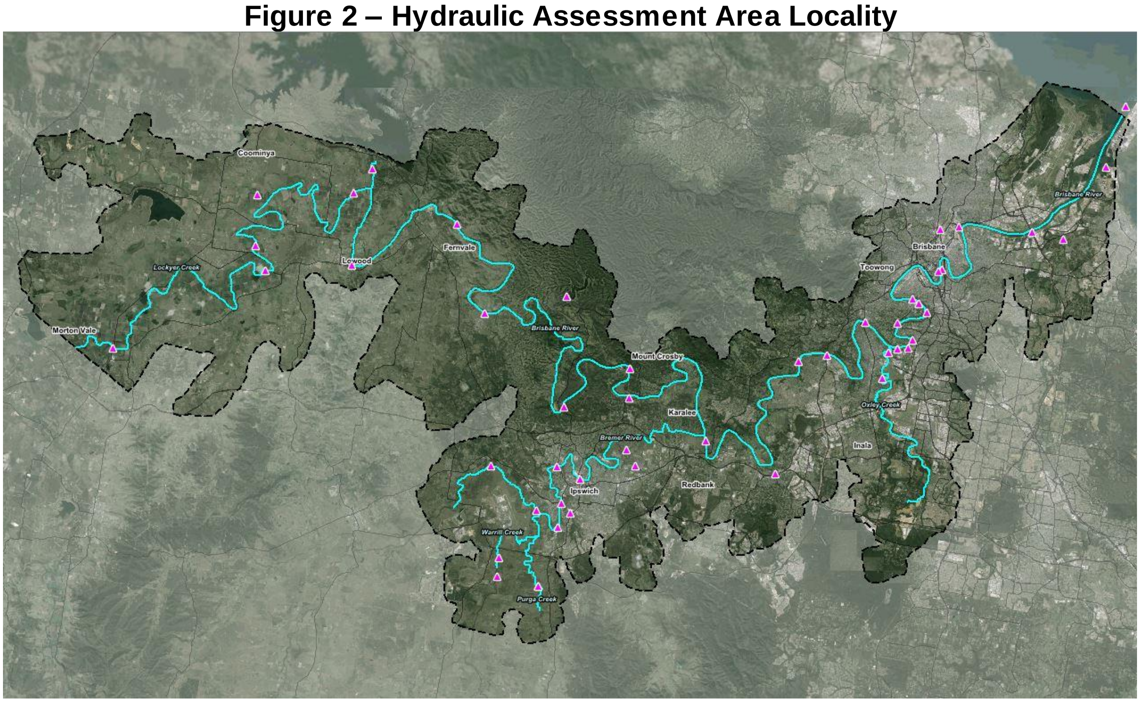

Figure 3 – Hydraulic Assessment Area

Hydraulic Characteristics of the Brisbane River Catchment

Hydraulically, the Brisbane River Valley below Wivenhoe Dam is a mixture of conveyance and storage dominated reaches. Lockyer Creek, due to its flat wide topography is, in a large event, highly storage dominated, with substantial volumes of floodwaters being stored and conveyed on the floodplain. Floodwaters originate from the local catchment of Lockyer Creek, or from Brisbane River floodwater backing up into the creek and floodplains.

Between Lockyer Creek and the Bremer River the Brisbane River is largely conveyance dominated, with relatively minor floodplains, and floodwaters largely confined to the river channel. The river experiences high velocities and steep gradients through these reaches.

The Bremer River and the Brisbane River downstream of Colleges Crossing are a mixture of storage and conveyance with both having significant floodplains that store and/or help convey the flood wave. As with Lockyer Creek, flooding in the lower reaches of the Bremer River and its tributaries can be dominated by backwater effects from the Brisbane River.

The lower Brisbane River, unlike most large east coast Australian rivers, has few gentle meanders, with many of the river's reaches controlled by the hilly terrain resulting in sharp bends at numerous locations. The hydraulic consequence is that in some reaches the flood flow is often confined between the river banks and substantially higher velocities develop. Downstream of the Breakfast Creek confluence, the river and floodplain widen to the mouth and inundation is increasingly influenced by Moreton Bay storm tide.

Methodology – Overview

The magnitude of a flood event in the mid to lower Brisbane River and major tributaries below Wivenhoe is dependent on the complex interaction of number of factors, some of which are highly variable. These include the depth and duration of rainfall, spatial and temporal distribution of rainfall, antecedent catchment conditions, downstream boundary conditions, initial water levels in Wivenhoe Dam and operation of the Dam itself. A traditional rainfall-based approach to modelling design flood behavior, which relies on AEP neutrality between rainfall and flow, is not able to replicate the complex interactions between these variables. Hence, a Monte Carlo approach has been used to account for the complex catchment conditions and high degree of variation and interaction of these variables by randomly sampling from a pre-determined set of probability distributions for each variable. Whilst there are indeed challenges in developing and applying new methodologies, it is feasible for a Monte Carlo Simulation (MCS) approach to be used in the field of hydrology, as the generally quick speed of a hydrologic model makes it suitable for the simulation of the many thousands of scenarios required. It is rare for Monte Carlo simulations to be undertaken in the field of hydraulic modelling due to the longer simulation times required, particularly for detailed hydraulic models. However, given the complex behaviour of the Brisbane River, particularly in relation to backwater effects in the tributaries and variability in conditions producing peak flood levels, a Monte Carlo Simulation approach to hydraulic modelling was needed. It is for this reason that two TUFLOW hydraulic models have been developed and used for the Hydraulic Assessment in a two-stage process:

1. Fast Model – a one-dimensional (1D) model, developed as a networked 1D or quasi-2D scheme, and
2. Detailed Model – a two-dimensional (2D) model with some in-bank sections modelled in 1D.

Methodology – Fast Model

The Fast Model, as the name suggests, is designed for speed and is more amenable to computationally demanding Monte Carlo Simulation applications. It is a 1D (quasi-2D) model developed using the 1D solver of the TUFLOW software, which explicitly solves the 2nd order solution of the full 1D St Venant equations. The Fast Model comprises more than 2,500 channel sections representing the Brisbane River, major tributaries and overland flowpaths below Wivenhoe Dam. Development of the Fast Model schematisation was assisted by use of an existing 2D TUFLOW GPU model of the Brisbane River below Wivenhoe Dam. This 2D model was developed as a Disaster Management Tool (DMT) (BCC, 2014a) for the purpose of producing broad-scale disaster management maps. While DMT model results are suitable for the production of such maps, model results are not of sufficient accuracy in some locations for more localised prediction of flood levels. The DMT model was also useful in determining floodways for a range of events up to and including an estimated PMF. This was of great value in the development of the Fast Model as quasi-2D models require the modeller to explicitly define the location and hydraulic properties of floodways as channel sections in the model. The Fast Model was tested against the Updated DMT model for a number of hypothetical extreme events to ensure it appropriately represented the floodways. It was also critical that the Fast Model remained robust in extreme events, and such proofing allowed this to be tested.

The Fast Model is calibrated to a tidal record and calibrated and verified to five historical flood events: 1974, 1996, 1999, 2011 and 2013. Manning's n and bend (form) losses were used to calibrate to the range of event magnitudes (BMT WBM, 2015; Ryan et al., 2015). The calibration of the Fast Model is being reviewed at the time of writing.

Methodology – Monte Carlo Simulation

To ensure that locations affected by both localised flood flows and Brisbane River backwater (e.g. Ipswich), simulated events needed to account for the relative contributions of each of these flooding mechanisms. Substantial discussion and consultation on the methodology required to achieve this led to the Hydrology Assessment simulating a range of whole-of-catchment rainfall events for rainfall burst durations from 12 hours to 168 hours culminating in 11,340 scenarios. These simulations were used to provide inflow hydrographs to the Fast Model Monte Carlo Simulation runs. The Fast Model is currently being used to undertake these simulations.

Once the Fast Model has completed all 11,340 simulations, results will be used to develop peak level and peak flow frequency relationships at a number of reporting locations throughout the catchment. These frequency analyses will enable peak flows and peak levels for a specified probability (AEP) to be estimated at each reporting location. Based on the outcomes of the frequency analyses, approximately 50 stochastic events will be selected from the suite of 11,340 to represent the design events. One design event (e.g. the 1% AEP event) may be represented by an ensemble of Monte Carlo events in order to best replicate the peak flows and peak levels at the reporting locations. The methodology for selecting about 50 representative events is currently being developed. Once these ensemble events have been selected, the design events will be simulated in the Detailed Model.

Methodology – Detailed Model

The Detailed Model is a 2D model developed using TUFLOW with the full 2D hydrodynamic free-surface flow equations solved using TUFLOW's CPU based implicit, unconditional, 2nd order spatial solver. The Detailed Model is fully 2D in the lower and mid-Brisbane River with 1D channels used to represent the in-bank sections of Lockyer Creek, and the upper Bremer River and its tributaries. The Detailed Model provides a more accurate and explicit representation of the floodplain and produces far superior flood maps of flood levels, depths, hazards and risk categories than the Fast Model. It is also far more capable of modelling complex flow behaviour such as in areas of high velocity and sudden changes in flow direction (e.g. at sharp bends, which are prevalent in the Brisbane River). However, the Detailed Model is substantially slower than the Fast Model and is thus unsuitable to be used in the Monte Carlo simulations.

Similar to the Fast Model, the Detailed Model is being calibrated to the 2011 (major) and 2013 (minor) events and verified to the 1974 (major), 1996, 1999 (minor) events. Calibration/verification has been undertaken to recorded historical gauge level hydrographs, measured flow records, flood mark levels and derived inundation extents. The Detailed Model is also being checked against hypothetical extreme events to ensure the model is both sound and robust, and that boundaries extend to include the full extent of an extreme flood.

Once calibration has been accepted and the design event ensembles selected, the Detailed Model will be used to simulate these design events and provide comprehensive design flood information including extents, levels and other parameters of interest. Sensitivity assessments for climate change, bed level changes and future floodplain conditions will be undertaken.

Methodology – Rating Curves

Rating curves at a number of key gauges were developed as part of the Hydrologic Assessment with the intent of future reconciliation and / or refinement as part of the Hydraulic Assessment. These rating curves have been compared to both Fast Model and Detailed Model calibration results. Any significant differences between the rating curves derived during the Hydrologic Assessment and the Detailed Model may require reconciliation. Differences are expected to occur particularly in locations where the stage-discharge curves are dependent on downstream tide levels or flow or levels at other locations. One of the outcomes of this assessment and the reconciliation process will be to develop a consistent and accepted set of rating curves for nominated gauges. Accurate rating curves and understanding the influence of hysteresis on these curves plays a critical role in managing the discharges from Wivenhoe Dam. The Fast and Detailed Models will help further this understanding.

Conclusion

The Brisbane River is a large and complex river system entwined with major urban areas. It has a long history of flooding and recently experienced a significant flood event in 2011 that caused widespread damage. A comprehensive series of assessments is being facilitated by the Queensland Government in order to better understand the flooding mechanisms and risks and to facilitate future planning for the Brisbane River catchment. Due to the complexity and size of the physical system, the methodologies developed and used to undertake the Brisbane River Catchment Flood Study have been innovative by necessity and are more comprehensive than current standard practice. With advances in techniques, software and hardware, it will be increasingly viable to apply such methodologies to other complex flood studies and catchments. The Hydraulics Assessment is not yet complete with Fast Model Monte Carlo simulations currently underway and Detailed Model calibration being reviewed. The outcomes of the study will be of great interest to many.

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