Review of

BRISBANE RIVER FLOOD STUDY

Report to Brisbane City Council

Independent Review Panel

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Executive Summary

This review was commissioned by the Brisbane City Council, so as to obtain independent and expert advice as to 'whether the August 2003 estimates of the Q100 flow and level at the Brisbane Port Office are reasonable'. [Q100 designates the peak discharge that can be expected to be equalled or exceeded once every 100 years on average].

In the conduct of the review, the Panel had two presentation/discussion sessions with representatives of the prime consultant (Sinclair Knight Merz), City Design, and the Department of Natural Resources and Mines (one session). Two draft reports (SKM, dated 8 and 28 August 2003, respectively) with the latest estimates of the Q100 values were the key documents.

It should be stated at the outset that the estimation of Q100 for a catchment of this size (nearly 14000 sq. km) is a challenging task. The extreme variability of rainfall, the change in catchment response due to the construction of dams, and the variable conditions in the tidal section of the river, are some of the factors which complicate the application of 'standard' flood methodologies. The advent of new techniques for flood frequency analysis and for extreme rainfall estimates, together with much improved hydraulic routing methods for estuaries, has added much to the technologies now available for flood estimation.

The Panel:

(i) have reviewed the methodology used by SKM to determine the Q100 river flow and level

(ii) believe that the appropriate technical processes have been followed in this study

(iii) based on the evidence available to it, is of the view that, for the Brisbane Port Office, the best current estimates for
- the Q100 flow is 6000 m^3/s
- the Q100 level is 3.3 m AHD

There is an inevitable degree of uncertainty in any estimates of this kind; in this case, heightened by the variable influence of the Somerset and Wivenhoe Dams on different storm events on the Brisbane River Catchment. A quite plausible range for the Q100 flow is 5000 to 7000 m^3/s and for the Q100 level, 2.8 to 3.8 m AHD. It seems certain that the position of the best estimates in the respective ranges can be more precisely determined, and the width of these ranges could be significantly reduced, with further investigation as outlined in Section 5.2 of this report.

The Panel notes that the current 'best estimates' of Q100 and the corresponding flood level at the Port Office provide a sufficient basis for a decision on whether the currently adopted flood levels are broadly acceptable. However, for general flood risk assessments and risk-based flood management decisions, more refined flood frequency estimates will ultimately be required.

Acknowledgment

The provision of material from representatives of the Brisbane City Council, City Design, Department of Natural Resources and Mines, and Sinclair Knight Merz greatly helped the Panel in the conduct of this review. It is a pleasure to acknowledge the high level of cooperation accorded to the Panel by these organisations in responses to questions and requests for information. In doing so, it is important to stress that the Panel has reached its conclusions independently, based on its own interpretations of the material supplied to it.

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1. Introduction

1.1 Purpose of report.

The Brisbane City Council (BCC) appointed a Review Panel in July 2003 to provide independent advice to, and make expert assessment of, a study being conducted by Sinclair Knight Merz (SKM) on design flood flows and levels in the Brisbane River. This report provides the Panel's determination as to whether the SKM estimates of the Q100 flow and level (ie. those likely to be equalled or exceeded on an average once in 100 years) are reasonable.

1.2 Background

A number of studies have been carried out in recent years to estimate the risk of flooding of areas of Brisbane from the Brisbane River. Given the size and complexity of the catchment, exacerbated by tidal effects in the downstream river reaches, the task is a challenging one; it is not surprising that there has been considerable variability in the design estimates of both flow and level. These are documented in the "Chronology of Events" prepared by Council (Appendix 1).

There have been major advances in the last five years in the methodology used to estimate extreme floods from rainfall, including design data that was not previously available for large catchments. The 2003 SKM Study was commissioned to provide an updated estimate of design flood with the new technologies, with the Panel providing an independent review role (see Appendix for Terms of Reference). The Panel met with the consultants and others for progress presentations on 31 July and 14 August 2003, and received draft copies of the relevant sections of the SKM report on 22 August.

1.3 Guide to this report

This review begins with a general overview of what can be termed best practice in flood hydrology (Chapter 2). It then highlights the particular characteristics of the catchment and estuarine zone of the Brisbane River which affect flood flows and levels (Chapter 3). Chapter 4 gives the Panel's assessment of the methodology used in the most recent Brisbane Flood Study (SKM, 2003 (a) and (b)), with comments on the results obtained. The Conclusion (Chapter 5) provides a statement as the most likely value of the Q100 flood and level at the Port Office in Brisbane, and the uncertainty that exists in these estimates. Recommendations for the work required to reduce this remaining uncertainty are included.

2. Design flood estimation – aims and best practice methodology

2.1 Introduction

Design flood estimation is not a simple process of following clearly defined standards and guidelines but it involves a considerable degree of judgement by the investigator. Before assessing the different studies and comparing their results, it is therefore useful to discuss more broadly what design flood estimation aims to achieve, what methods are available to achieve these aims and what issues are involved in applying the methods.

This section starts by explaining the aims of design flood estimation and introducing the most important principles and technical terms used in design flood estimation. The introductory description of best practice methodology is divided into three parts: flood frequency analysis, rainfall-based approaches for estimating design flood flows and hydraulic methods for converting design flood flows to design flood levels. The section concludes with a discussion of uncertainty in design flood estimates and its implications.

2.2 Aims and principles of design flood estimation

Flooding is a natural part of the flow regime of the Brisbane River and its tributaries. Its major cause is heavy storm rainfall over parts or all of the Brisbane River catchment. The nature and magnitude of flooding resulting from heavy storms depends also on catchment conditions, with the worst floods occurring when a heavy rainfall occurs over an already wet catchment. Major land use changes in the catchment have the potential to modify the flood response to storm rainfall, as do major storage developments such as the construction of Somerset and Wivenhoe Dams. For planning and floodplain management, design flood estimation must therefore relate to the *current or expected future catchment conditions*.

The distribution of flood events over time is almost random; there is no clearly discernible or predictable pattern of how flood flow periods occur. Similarly, the magnitude of flood events also varies randomly. It is therefore not possible to predict the actual occurrence of the next flood but only to estimate the *average flood frequency,* expressed as the average number of years between occurrences of floods of a given magnitude and referred to as the Average Recurrence Interval (or ARI). The aim of design flood estimation is to establish the *flood frequency curve* for a site of interest, or the relationship between flood magnitude and flood frequency.

The observations from *historic flood events* provide the main source of information for design flood estimation. Because of the great variability of climate and catchment conditions producing floods, each observed flood event differs from the next one with respect to one or several flood characteristics. For the purpose of flood management and design it is therefore necessary to define representative flood events which reflect the most likely combinations of the different flood characteristics for different magnitudes of events. These *defined flood events (DFE)* or *design flood events* are derived from historic flood data by means of statistical frequency analysis or by hydrologic modelling methods.

For a particular flood event, the maximum flood levels reached at different locations along the river are the characteristics of most direct interest to floodplain management. However, these are closely related to the peak flows experienced at those locations, which lend themselves better to frequency analysis. Design flood estimation therefore involves two steps. In the first step, *hydrologic* estimation methods are applied to estimate *design flood flows*, specifically peak flow rates for given ARIs, expressed in m^3/s. In the case of the Brisbane River Flood Study, the design flow of specific interest is Q100, the estimated peak flood flow with an ARI of 100 years. In the second step, *hydraulic* methods are then applied to convert the design flood flows to *design flood levels*. In the case of the lower Brisbane River, which is subject to tidal influences, there is no unique relationship between flood flows and flood levels, and a set of representative design conditions have to be assumed in the hydraulic analysis.

The methods applied in design flood estimation should follow best practice guidelines, to the extent that these have been formulated and are applicable to a specific situation. In Australia, the adopted guidelines for design flood estimation are documented in 'Australian Rainfall and Runoff – a Guide to Design Flood Estimation' (ARR, IEAust, 1999). These guidelines are not prescriptive, and in more complex flood estimation situations such as the Brisbane River catchment, they allow for a substantial degree of subjective interpretation by the designer, based on experience and professional judgement.

While designers and decision makers generally require a "best estimate" of the flood magnitude for a given ARI, it must be recognised that usually such estimates involve a considerable degree of uncertainty which may need to be allowed for in the decision making process. An indicative range of uncertainty is provided by confidence limits around the best estimate.

A range of different methods is available to the designer for both the hydrologic and hydraulic analysis components. In each specific case, the selection of the most appropriate method depends on the amount and quality of the data available, the particular characteristics of the catchment and the intended use and importance of the flood estimates. In situations where the design flood estimates are used to support decisions with far-reaching consequences, the approach should make best use of all relevant sources of data and information, and comparative analysis using a number of methods would be desirable. In the case of the Brisbane River Flood Study, the various investigators have followed two main approaches in the hydrologic analysis:

- frequency analysis of flood events extracted from streamflow records, and
- hydrologic modelling approaches to derive simulated design flood events from design rainfall events.

In the following, these two approaches are described in more detail.

2.3 Frequency analysis of observed flood data

The expected frequency of floods of different magnitudes can be assessed by a statistical frequency analysis of observed flood events. For this purpose, a series of annual maximum flood events is extracted from an essentially complete record of streamflow data at a stream gauging station that has operated over a sufficiently long period of time. For this analysis to be meaningful, the data in the flood series have to reasonably satisfy the following basic assumptions:

- the occurrence of flood events is *random* and the events used in the analysis are *independent* of each other
- the events in the flood series are *homogeneous* (from the same population of events), *stationary* (free of any significant time trend) and *consistent* (not affected by any changes in the methods of measuring the data)
- the flood data being analysed are *representative* of the flood conditions of interest

In considering these assumptions it must be recognised that flood flows are not directly observed, but are estimated from observed water levels at the gauging site by means of a rating curve. The rating curve is established from flow velocity measurements (gaugings) for different flow magnitudes, but often the range of gaugings does not extend to the largest observed floods. Flood flow estimates for these larger events thus need to be based on extrapolated rating curves and are of lower accuracy.

Where the flood data do not readily satisfy some of the basic assumptions of statistical frequency analysis, because of changed catchment conditions or different methods of observation, adjustments need to be applied to some data points to render the series more homogeneous. In some cases, additional data on large historical floods may also be available, but these are generally based on less accurate forms of flood observations. Decisions on the use of adjusted and possibly lower quality data involve a trade-off between the benefit of potentially useful additional information and the danger of contaminating a reliable data series with "noise" from lower quality data.

Another potentially useful source of flood data is from other stream gauging stations in the same catchment or from stations in neighbouring catchments that have similar flood characteristics. If the flood data from these stations, after some form of standardisation, satisfy the assumption of homogeneity, they can be combined to undertake a regional flood frequency analysis. Again the balance between additional information and noise introduced by regional data needs to be carefully assessed.

For each data series to be analysed, a theoretical probability distribution is fitted which should reflect the characteristics of the empirical flood frequency distribution defined by the observed floods. The fitted distribution can then be used to estimate flood magnitudes over the full range of ARIs of interest; this often involves some degree of extrapolation beyond the range of observed floods. Many different probability distributions and parameter estimation methods are available for this fitting process, but only a relatively small number of these are used in standard Australian practice. In more complex flood estimation situations, such as the Brisbane River catchment, the choice of distribution and parameter estimation method can have a significant bearing on the resulting design flood estimates.

In practice, the dilemma involved in the selection of the most appropriate data set and analysis method from a range of alternatives is often addressed by undertaking flood frequency analyses for a number of different flood series using a range of methods. The results of these analyses are then carefully evaluated, and the estimates considered to be most plausible and reliable selected as a design basis.

Since the preparation of the current version of the Australian guidelines on flood frequency analysis (ARR, IEAust, 1999), which were originally published in 1987, a number of important developments in flood frequency analysis methodology have taken place. In addition to the Log-Pearson 3 (LP3) distribution recommended in ARR, a range of other generalised distributions are now available for fitting, and the traditional product moment method for determining distribution parameters has been supplemented by the more robust L-moment and LH-moment methods. Bayesian methods of flood frequency analysis (Kuczera, 1999) allow different weights to be assigned to different forms of flood data, so that their influence on the final design flood estimate reflects the different levels of information content. These newer developments not only provide analysts with more powerful and flexible tools for flood frequency analysis, they also give a clearer indication of the uncertainties in design flood estimates (see Section 2.6). The guidelines on flood frequency analysis in Book IV of ARR (IEAust, 1999) are currently being revised, and the revision team has indicated that these newer developments will form an integral part of the new guidelines.

2.4 Rainfall-based approaches

Since floods are generally produced by heavy rainfall, an alternative to flood frequency analysis is to focus the attention on storm rainfalls and their transformation to flood events. Rainfall-based approaches overcome the lack of direct flood observations for the conditions of interest by incorporating knowledge of physical hydrologic and hydraulic processes into models that simulate how floods are generated. Because of the complex nature and high degree of temporal and spatial variability of processes, the models are forced to adopt a simplified, conceptual representation of the catchment and the governing processes. To the extent that the model structure reflects the key catchment characteristics, and the model parameters can be validated against observations, the models provide a reliable and flexible tool to derive design floods for a significantly broader range of conditions than is directly reflected in the observed flood data. However, the reliability of the design flood estimates reduces with increasing degree of extrapolation beyond the range of direct observations.

The basic input to flood estimation models is design rainfall data for the specific catchment and the ARI of interest. The most important design rainfall characteristics for storms of different durations are the average rainfall intensity over the catchment, and the likely distribution of rainfall in time and space. These design rainfall characteristics have been derived from analysis of data from many rainfall stations in a region and are available from design rainfall databases (e.g. ARR99, CRC-FORGE). The different design rainfall characteristics are combined to define a design storm event for a given rainfall duration and ARI.

Design storm events provide the basic probability input to the procedure. The "design event approach" adopted in Australia assumes that the 100-year ARI flood is produced by a 100-year design storm event. For this assumption to be satisfied, all intermediate steps in the transformation of design rainfall to design flood need to be effected in a "probability-neutral" fashion; this means that parameters such as rainfall losses, initial storage contents and other flood modifying factors need to be selected in such a way that they are not biasing the probability of the simulated design flood.

The selection of a representative design storm and associated other design assumptions should be supported by the analysis of catchment-specific data, but in a catchment as large and complex as the Brisbane River catchment, the selection of these design inputs may still involve a considerable degree of professional judgement. In such situations it is desirable to check the appropriateness of the assumptions made by applying the model first to reproduce floods for catchment conditions for which reliable results of flood frequency analysis are available. In the case of the lower Brisbane River under current conditions, special complexity is introduced into the modelling process by the presence of Somerset and Wivenhoe Dams and their operation under flood conditions. It is therefore advisable to apply the hydrologic model to the pre-dam situation first and validate the results against the results of flood frequency analysis for pre-dam conditions.

2.5 Converting design flood flows to design flood levels

Hydraulic calculations are necessary to determine the design flood levels associated with a design flood. These calculations take account of the flow carrying capacity of the river channel and of the resistance to flow, including boundary shear and energy losses due to channel bends, bridges and other obstructions. The effects of tributary streams and of over-bank flooding must also be taken into account.

An appropriate water level must be specified at the downstream end of the river system. This is often referred to as the tailwater level.

The flood travels down the river system as a flood wave and it is modified as it progresses. The changes in the flood wave must be calculated correctly to establish the peak flood levels at different locations along the river.

In current practice, the hydraulic calculations are carried out with a computer software system that takes full account of the dynamics of the flood wave. This is described as the 'hydraulic model'. A number of well established hydraulic model systems are in use currently. The MIKE11 system was used by SKM and the RUBICON system was used by DNRM for the Brisbane River Flood Studies. Each of these hydraulic models is well established and is consistent with current best practice.

It is essential for the hydraulic model to be calibrated before it can be used to calculate design flood levels. In the process of calibration, the model is made to reproduce the observed flood levels for one or more historic floods for which sufficient data have been measured. This is achieved by adjusting the resistance and energy loss parameters in the model until satisfactory agreement is obtained between the flood levels calculated with the hydraulic model and the measured flood data.

2.6 Uncertainty

While designers and decision makers generally require a single valued "best estimate" of the design flood magnitude for a given ARI, it must be recognised that, by necessity, design flood estimates involve a considerable degree of uncertainty which may need to be allowed for in the decision making process.

A substantial degree of uncertainty in flood frequency estimates is inherent from the high degree of variability of hydrologic factors producing floods and the limited sample available from the total population of floods. Additional uncertainty may arise from the following sources of error in the basic data and in the methods of design flood estimation:

- systematic errors and inconsistencies in the basic rainfall and water level observations at gauging sites (e.g. for early historical data and very large events)
- uncertainty in the rating curves used to convert water level observations to flow estimates (particularly for large floods and for sites affected by tidal influences)
- errors introduced by the adjustment of flood data for the effects of changes in hydrologic and hydraulic catchment conditions (e.g. dams and changes to lower Brisbane River cross-sections)
- uncertainty in the choice of the correct model (distribution) for flood frequency analysis and in the estimation of its parameters
- uncertainty introduced by simplified representation of catchment characteristics in hydrologic models and estimation of model parameters

The confidence limits around the 'best estimates' obtained from flood frequency analysis give an indication of how some of these uncertainties affect the resulting design flood estimates, but they generally do not reflect all the uncertainty factors involved in the flood estimation process.

While the band of uncertainty around the 'best estimate' of a design flood may be so large that the decisions made using a lower bound estimate or an upper bound estimate would be substantially different, it should also be recognised that the adopted standards for floodplain management allow for some degree of uncertainty. In situations of unavoidable large uncertainty, consistency of approach in terms of current-best-practice may become the overriding consideration in determining the design basis.

3. The Brisbane River - particular issues for design flood estimation

3.1 Introduction

Chapter 2 set out to explain flood estimation techniques in general. For a specific catchment, it is important to choose techniques suitable for the task in hand, as well as to identify the features that will have a bearing on the flood response.

In the case of the Brisbane River, its large area is of considerable import. Its land-use has changed over the period of record. There are two very large water supply dams that are also operated so as to mitigate floods. In the lower reaches of the Brisbane River, the ocean levels affect flood levels. These aspects are each discussed further in respective sections below, followed by a discussion of the available data of relevance for a flood study.

3.2 Size of catchment

ARR99 defines any catchment that commands an area in excess of 1,000km^2 as being 'large'. The Brisbane River commands a catchment area of approximately 14,000km^2 and clearly sits within the large catchment category.

The variability of rainfall over the catchment is a key influence on floods in the Brisbane River. Differentials in excess of 1,000mm have been observed within the catchment for historical events. Similar gradients are also evident in design rainfall estimates by CRC FORGE estimates of design rainfalls.

Investigations by SKM (2003 (a)), for example, have found that spatial variability in rainfall distribution about the catchment alone can be responsible for variability in design discharges of the order of ±2,000m^3/s under 1% AEP design rainfall conditions. The problem is exacerbated when large dams exist on the catchment, and when rainfall may be centred above or below the dams

Variability of rainfall temporal pattern over the catchment is an added complication, but of lesser importance than spatial variability.

3.3 Catchment characteristics

Within any catchment, runoff response to rainfall is largely controlled by characteristics that fall into the following three general categories: Topography (draining system structure, catchment area, grades etc); Land classification (land use, soil type, vegetation etc); Waterway capacity (conveyance and storage).

These characteristics serve to dictate a catchment's response to rainfall, that is, the depth of rainfall that reports as runoff, the rate of runoff, and its duration of occurrence.

In many instances it is not necessary to explicitly account for key catchment characteristics in detail, as their influences can be adequately defined within a simplified scope of modelling parameters that are determined through a process of calibration against historical records.

Characteristics within the Brisbane River catchment have been continually changing, primarily as a result of progressive settlement and development. These changes will have had an effect on runoff characteristics (flood flow rates and levels), but one considered small in relation to the impact of the large dams, Wivenhoe and Somerset.

Investigations by both BCC and SKM have assumed that the only change in catchment characteristic of importance has been the construction of these dams. Under the circumstances this assumption is considered reasonable, given that most other key catchment characteristics can be considered to have largely remained unchanged over the years. It is noted that although development of the major regional centres of Brisbane and Ipswich Cities will have resulted in substantial change to local runoff characteristics, the overall impact on Brisbane River flooding is expected to be relatively small on account of the relatively small area of the overall catchment occupied. Catchment change has therefore been presented with respect to two scenarios: "No Dams"; and "With Dams".

3.4 Position and size of major storages

As noted previously, there are two major dams located within the catchment that provide both water supply and flood attenuation service:

- Wivenhoe Dam:
  - Completed: 1985
  - Water supply storage capacity: 1,150,000ML (approximately)
  - Regulated temporary flood storage capacity: 1,450,000ML (approximately)
  - Location: Brisbane River upstream from confluence with Bremer River
  - Catchment: approx. 7,000km^2

- Somerset Dam:
  - Completed: 1959
  - Water supply storage capacity: 370,000ML (approximately)
  - Regulated temporary flood storage capacity: 524,000ML (approximately)
  - Location: Stanley River upstream from confluence with Brisbane River

[information extracted from SKM 2003 (b)]

Clearly, the amount of flood storage is these dams is very significant relative to the design runoff volumes, so the correct simulation of these dams (and their operation during events) is of paramount importance.

3.5 Effect of tides and storm surge on flood levels

Brisbane River remains tidally affected up to around Colledge's Crossing, or approximately 86km upstream from its mouth in Moreton Bay. Mean High Water Spring Tide (MHWS) in the bay is at approximately 0.9mAHD. The potential for storm surge effect in the bay is relatively significant (BCC, Discrepancy in Predicted Flow Rate in Brisbane River, undated):

- MHWS 0.9mAHD
- January 1974 Storm Surge: 1.6mAHD
- May 1996 Storm Surge: 2.8mAHD

Sensitivity investigations undertaken by BCC to assess the likely effect of bay water levels on flood levels at Brisbane Port Office found the following:

- It appears the tidal and storm surge fluctuations can account for approximately a ±2m range in bay levels (ie –0.9mAHD to +2.8mAHD).
- The effects of tidal and/or storm surge influences in the bay diminish as discharges increase:
  - ±2m at zero flow;
  - ±0.8m at around 5,000 m^3/s;
  - ±0.5m at around 10,000 m^3/s (close to BCC estimate of January 1974 flow); and
  - nil (ie. completely drown out) at discharges greater than approximately 14,000 m^3/s.

The stage discharge curve was computed using the calibrated Mike11 Model developed in the 1998 and 2000 flood studies. It was compared with the Bureau of Meteorology data and found to be different. The Bureau of Meteorology discharge-stage information was derived to suit the Bureau of Meteorology flood forecasting model and has not yet been adequately verified.

Forensic investigations by BCC have also attempted to quantify the likely effect of historic dredging and excavation works about the entrance of the river. This work was undertaken to aid with their adjustment historic flood level estimates for an alternative FFA of flood data at river gauge stations to the downstream of Colledge's Crossing.:

- Removal of a bar at the mouth of Brisbane River in around 1864 is estimated to have resulted in lowering "large" flood levels at Port Office by approximately 0.4m;
- Dredging about the port in around 1917 is estimated to have resulted in lowering "small" floods by approximately 1.5m, with little effect on "large" floods. (According to the Bureau of Meteorology, this lowering should be only 0.6 m.)

3.6 Data available

A considerable amount of rainfall and stream flow data is available, and has been accessed in the conduct of the various investigations by BCC, SKM, BOM and DNRM.

Key data sources include:

- AEP 1 in 100 Rainfall Depths, Temporal and Spatial Patterns, Areal Reduction Factors for the Brisbane River Catchment CRC FORGE analysis undertaken by DNRM.
- Long-term daily rainfall totals from a significant number (around 130) of stations through the catchment.
- Daily stage height data and rating curves, utilised by SKM:
    - Brisbane River @ Savages Crossing (143001) – 72 years
    - Warrill Creek @ Amberley (143108) – 40 years
    - Lockyer Creek @ Lyons Bridge (143210) – 22 years
    - Lockyer Creek @ O'Reilly's Weir (143207) – 53 years
  - Daily stage height data and rating curves (calibration), utilised by BCC:
    - Brisbane River @ Brisbane Port Office – data from 1841
    - Brisbane River @ Moggill – data from 1893
    - Brisbane River @ Mt Crosby – data from 1864
    - Brisbane River @ Lowood – data from 1890
- Historic flood levels and estimated flow rates at Lowood, 1893 and 1825
- Peak annual flow series data for Savages Crossing (1890-2000) for assessed adjustments "No Dams" and "With Dams" scenarios.

It is also understood that relatively detailed waterway cross-sectional / bathymetry information is available for Brisbane River from around Moggill Gauge to the entrance.

4. Evaluation of recent studies

4.1 Introduction

Chapters 3 & 4 set out the current best-practice methodology for flood estimation, and the characteristics of the Brisbane River catchment that need special consideration. They thus provide the context for the review of the techniques adopted for, and the results from, the SKM 2003 study.

This chapter looks first at the flood frequency analysis of the flows at Savages crossing (Sect. 4.2), then at the results for the same location (pre-dams) obtained using the rainfall-based method (4.3), before comparing the two (4.4). It then considers the simulation of the catchment response to large storms with the Wivenhoe and Somerset Dams in place, as used to estimate the current Q100 for the Port Office (4.5). The conversion of this design flow to a design level is examined next (4.6). The chapter concludes with consideration of the uncertainty in the estimates (4.7), and a statement of the Panel's views on the recommended values of flood level at the Port Office (4.8).

4.2 Flood frequency analyses (pre-dam)

Among the several stream gauging stations located along the Brisbane River between Wivenhoe Dam and the Brisbane Port Office, the combined record from the gauges at Savages Crossing, Lowood and Vernor (from here on referred to as Savages Crossing) provides the longest record of high quality flood data, and has therefore been adopted by SKM as the key site for flood frequency analysis.

Four different flood data sets have been prepared for the Savages Crossing site and have been used for separate flood frequency analyses by SKM. Data Sets 1 to 3 relate to the pre-dam situation, while Data Set 4 attempts to represent the current situation with Somerset and Wivenhoe Dams providing a substantial degree of flood mitigation for the lower Brisbane River. The continuous record period represented by these data sets varies from 42 to 111 years, with the historical record period extended in some cases to include the large flood of January 1893, and in one case also the similarly large flood thought to have occurred in 1825.

For the *pre-dam* situation, the SKM draft report presents the results from a total of 12 different cases analysed to assess the sensitivity of the Q100 estimates to variations in the following factors:

- Inclusion or omission of January 1893 and 1825 historical floods
- Extension of recorded flood data set by inclusion of the following additional periods:
  - from 1890 to 1909 (extended by DNRM using IQQM model)
  - from 1959 to 1982 (with and without DNRM adjustment for impact of Somerset Dam)
  - from 1983 to 2000 (with DNRM adjustment for impact of Wivenhoe Dam)
- Inclusion or omission of information from regional flood frequency analysis
- Fitting of Generalised Pareto (GP) or Log-Pearson 3 (LP3) distribution

- Application of FLIKE or GetDat flood frequency analysis packages which use different parameter estimation methods

The Q100 estimates obtained from these 12 separate analyses varied from 6,700 m^3/s to 15,700 m^3/s, with the most plausible range given by SKM as 10,000 to 14,000 m^3/s. Based on the results of the two most plausible cases, SKM adopt the 'best estimate' of Q100 as 12,000 m^3/s.

The Panel considers the flood frequency analysis approach taken by SKM to be appropriate and agrees with the conclusion that the 'best estimate' of Q100 for the pre-dam case at Savages Crossing is approximately 12,000 m^3/s. While the 90% confidence limits around the best-case distributions are somewhat wider, the plausible range of uncertainty for the Q100 estimate is about 10,000 to 14,000 m^3/s.

Additional flood frequency analysis work was also undertaken by City Design for a range of sites between Savages Crossing and Brisbane Port Office. For each site, available information from various sources was combined to derive a most plausible rating curve for the full range of flood magnitudes of interest. While this work is not as rigorous in terms of the quality and consistency of the data used and the methods of frequency analysis applied, it nevertheless provides useful confirmation of the SKM estimates. City Design's 'best estimate' of Q100 at Savages Crossing for the pre-dam case is 10,800 m^3/s.

Based on these results, it is of interest to note that, in the absence of Somerset Dam, the January 1974 storm would have produced about a 70-year flood at Savages Crossing, while the January 1893 flood is estimated as having an ARI of 100 to 150 years.

4.3 Rainfall-based flood estimates (pre-dam)

To estimate the runoff generated by rain falling on the catchment, SKM used the RAFTS runoff routing model. They had calibrated this model satisfactorily during previous studies on the catchment of the Brisbane River, so that further calibration effort was considered unnecessary. The Panel were willing to accept the adequacy of the calibrated RAFTS model without specific review.

Design values of 10 mm initial loss and 1 mm/h continuing loss, distributed uniformly over the catchment, were used to estimate the Q100 event. The Panel considers these values acceptable for an extreme event on the Brisbane River catchment. (The assumption of zero losses would increase the Q100 estimate by about 15%).

As explained in Sect. 3.2, a particular challenge for design flood estimation on large catchments is the appropriate depth and variability of rainfall to use in the calculation. SKM adopted the recent CRC-FORGE work to get the average depth for each storm duration – with appropriate areal reduction factors (Sect. 3.6). The Panel endorse this.

The critical storm durations of 30 h at Savages Crossing and 72 h at Moggill/Port Office seem reasonable, and accord with other studies. Representative patterns in accordance with ARR (IEAust, 1998) were adopted. To assess sensitivity to temporal patterns, five patterns were applied to the catchment average CRC Forge rainfall 48 hour storm duration. The RAFTS model was used with nil losses. At Savages Crossing and at the Port Office, the ARR standard temporal pattern produced the smallest peak flows. The largest peak flows at these locations were produced by the 1974 historic temporal patterns, these being larger than the ARR peaks by 15% at Savages Crossing and by 10% at the Port Office.

Spatial distribution is a factor which can have a significant effect (especially for the post-dams case – Section 4.5). The Panel suggested using patterns from a number of large storms on the catchment, and SKM have done this for seven events. The result gives an approximate indication of the influence of spatial pattern on flood peaks of the 100 year ARI event (8000 to 11500 m^3/s, pre-dam case at Savages Crossing). The median value (of about 10000 m^3/s) is an appropriate vale for comparison with the flood frequency study (see next section).

4.4 Comparison of FFA and rainfall-based estimates (pre-dam)

The comparison of results from frequency analysis and rainfall-based estimates is a form of check undertaken to assess the degree of consistency in the results using different data sources, methods and assumptions. In the evaluation of the comparative results, allowance has to be made for the different degrees of reliability attached to the estimates from different approaches.

The most recent SKM studies produced the following Q100 estimates for the pre-dam situation at Savages Crossing:

Table 4.1 Summary of Q100 estimates at Savages Crossing (pre-dam conditions)

Method	**Q100 estimates [m^3/s]**		
	Best Estimate	**Plausible Range**	
		Lower Bound	**Upper Bound**
Flood Frequency Analysis	12,000	10,000	14,000
RAFTS Modelling	10,000	8,000	11,500

The comparison indicates that, while the plausible ranges of estimates from the two approaches overlap to some degree, the RAFTS modelling produces estimates that are significantly lower.

In the Panel's judgement, the flood frequency analysis estimates are based on relatively long streamflow records at a number of sites, and while there is considerable doubt on the reliability of large floods at individual sites, there is sufficient confirming information from flood observations at other sites to lend credence to the adopted Q100 estimate.

For the rainfall-based estimates, the design rainfall depths used to define design storms for the catchment are also based on the analysis of a large database of long-term rainfall records from many stations within and around the catchment. However, the RAFTS model converting these design rainfalls to design storms requires many assumptions regarding model parameters and secondary design inputs, such as spatial/temporal patterns of design rainfall and losses, and their variation with storm magnitude. The uncertainty involved in these assumptions may introduce bias into the estimation of the 100-year flood from a 100-year storm rainfall depth.

The Panel therefore considers that the pre-dam Q100 estimate at Savages Crossing from RAFTS modelling estimate may be low by 10 to 20%. It would be desirable to assess, if the tendency for underestimation of peak flows also affects the estimate of flood volumes associated with Q100 in a similar fashion, as the post-dam flood peaks at Brisbane are largely determined by the inflow volumes to the dams. However, at this stage the information available does not allow this to be confirmed.

The expected tendency for underestimation in the rainfall-based approach should be taken into account when the RAFTS model is used to estimate design floods for the lower Brisbane River catchment under post-dam conditions.

4.5 Calculation of the post-dam flood discharges

Both the Somerset and Wivenhoe storages are capable of significantly modifying flood flows from their commanded catchments. The amount of flood attenuation that can be achieved by the structures is dependent upon a range of conditions, including:

- The antecedent storage inventory
- The volume and duration of the flood inflow hydrograph
- The rate of controlled discharge from the storage.

Under flood conditions both storages are operated in accordance with predefined rules controlling discharge to the downstream waterway. It is understood that these rules have been established with the objective of mitigating the potential impact of flooding on downstream communities and infrastructure. These rules are relatively complex and are not amenable to simplification.

In consideration of the significant impact that Wivenhoe and Somerset Dams can potentially have on the timing and magnitude of downstream flood flows it is necessary that proper account be taken of dam operation in any hydrological assessment. To this end, DNRM have established a hydrological model of the Brisbane River catchment for the purpose of simulating the expected performance of dam operation. It is understood that the model functions on a continuous simulation basis and utilised historical time series rainfall data to simulate an associated time series of waterway and dam flows. Although DNRM have made available the outputs from this model, no other details have been documented. This being the case, the Panel cannot comment on the efficacy of the model.

Review of historical dam routing results from the DNRM model for the period 1890 to 2000 has indicated that it should be possible to operate the dams to reduce peak flood flow rates by about 60% on average. It is interesting to note that the model indicates a January 1974 flood attenuation of nearly 50%, with a peak inflow rate of 10,500m^3/s and outflow rate of 5,500m^3/s.

Flood frequency analysis by SKM of the DNRM dam routing time series showed that standard frequency distributions, such as the *Generalised Pareto* and *Log Pearson*

Type III, do not fit the data well. It is expected that this occurrence is largely due to the highly modified and non-linear nature of the flood hydrograph transformation by the dams. The Panel therefore considers the Q100 estimate from this analysis to be unreliable and not suitable as a basis for checking the results of hydrologic modelling for the post-dam case.

Hydrological modelling of the catchment has also been undertaken by SKM. This work has used the RAFTS program to undertake the basic rainfall-runoff-routing process, and a program from DNRM to simulate the routing of flow hydrographs (generated using RAFTS in this instance) through the Somerset and Wivenhoe storages under post-dam scenario conditions. SKM used the models to generate design flood flow rates from synthetically generated design storm events – in this case 1 in 100 AEP design CRC FORGE rainfall events.

The SKM application of the RAFTS hydrological model was used to both make estimates of:

- Design Q100 flow rates at Savages Crossing under both pre- and post-dam conditions
- Typical variability in Q100 flow rates that might reasonably be attributed to differences in the spatial distribution of rainfall across the catchment during the course of the driving storm event.

As noted above, SKM used the CRC FORGE method to establish the design 1 in 100 AEP storm event - comprising total rainfall depth, temporal and spatial rainfall distributions, and associated areal reduction factors. Typical "real event" spatial distributions for rainfall were also extracted from 7 historical storms events of significance. No specific criterion was applied to the selection of events, other than that the data was readily available for utilisation within the relatively limited time constraints afforded by the scope of current investigations.

It is noted that CRC FORGE rainfall was applied to the 7 historical spatial distributions, and not the actual rainfall associated with the event. This approach satisfied the investigation objective that was to sample the typical variability in runoff flow rates as might be produced by different spatial distributions of rainfall under both pre- and post-dams development scenarios.

Outcomes of SKM investigations are summarised in the following tabulation. In reviewing this information it should be noted that the base estimate is derived from RAFTS modelling using the CRC FORGE rainfall spatial distribution (eg 9,600 m^3/s at Savages Crossing for the pre-dams case). An indication of plausible range was obtained from calculation of the difference between the median valuation of the seven historical spatial distributions, and the second highest and second lowest bounding values (ie values at rank positions 2 and 6, with the median being at rank position 4). These ranges were then superimposed upon the RAFTS based estimates to give the plausible ranges listed in Table 4.2.

Table 4.2 RAFTS based Pre- and Post-Dam Q100 flow estimates (m^3/s) with indication of plausible range of variability

Location	Pre-Dams			Post-Dams			Reduction (%)
	RAFTS Q100	Plausible Bound		RAFTS Q100	Plausible Bound		
		Lower	Upper		Lower	Upper	
Savages Crossing	9,600	8,100	10,800	5,400	3,900	6,600	40
Moggill	10,100	9,500	10,800	5,000	4,200	6,000	50
Port Office	10,100	9,500	10,800	5,000	4,200	6,000	50

Review of the above outcomes indicates:

- The pre-dams best estimate of peak discharge at Savages Crossing (9,600 m^3/s) is 20% lower than that derived by SKM using FFA (see Section 4.2). This being the case it is probable that the estimate of post-dams peak discharge is also low.
- The variability indicated by analysis of historical spatial rainfall distributions appears to be generally consistent with that concluded by SKM on the basis of FFA work. This may be taken to indicate that the noted variance is probably physically realistic.
- Variability in post-dam flow estimates is significant, being of the order of 40% of the design base discharge value.
- The attenuated peak flood flow rate factors are generally consistent with that reflected in the source DNRM data.
- There appears to be little attenuation of flood flow rates between Moggill and Port Office. This characteristic is totally consistent with independent observations as reported by BCC.
- Savages Crossing peak discharges are of the same order as those further downstream.

The issue of variance between FFA and RAFTS model results has not yet been fully addressed by SKM. Nevertheless, SKM have investigated the sensitivity of estimated Q100 flow rates to assumed loss rates. The key outcome of this sensitivity appraisal was that the noted variance could not be fully explained by the influence of assumed rainfall losses. The cause for this variance warrants further investigation.

SKM also undertook investigations to assess the effect of antecedent dam storage inventory levels on the attenuation of flood flow rate. Analyses using antecedent inventories of 50% and 75% full supply volume indicated significant impact. However, prior analysis by BCC of the likelihood of the occurrence of antecedent drawdown was small, and that a FSL assumption is justified.

As a check on design flows, SKM used the RAFTS model to simulate the 1893 and 1974 historical flood events with both dams in place and with dam operating procedures applied. The peak flow calculated at the Port Office for the 1974 flood event was 6800 m^3/s. It is difficult to relate this result with those obtained from systematic study of 1 in 100 AEP rainfall events discussed above.

The Panel considers that flow estimates based on flood frequency analyses (Section 4.2) presents a fair assessment of *Best Estimates* under pre-dam conditions (ie Q100 of 12,000m^3/s with a plausible range between 10,000m^3/s and 14,000m^3/s). As noted above, RAFTS flow estimates are considered low, around 20% under pre-dam conditions. Under post-dam conditions the Panel would expect Q100 flows downstream of Wivenhoe dam to be of the order of 50% of those under pre-dam (as found by RAFTS, Table 4.3) – that is, 50% of 12,000m^3/s, or 6,000m^3/s.

In consideration of the above, the Panel considers that Q100 flow values presented in Table 4.3 below presents a fair and reasonable assessment of Q100 flow rates for design purposes – *on the basis of information currently made available to the Panel.*

Table 4.3 Panel Recommended Pre- and Post-Dam Q100 flow estimates (m^3/s) with indication of plausible range of variability

Location	Pre-Dams			Post-Dams		
	Q100	Plausible Bound		Q100	Plausible Bound	
		Lower	Upper		Lower	Upper
Savages Crossing	12,000	10,000	14,000	6,000	4,000	8,000
Moggill	12,000	11,000	13,000	6,000	5,000	7,000
Port Office	12,000	11,000	13,000	6,000	5,000	7,000

4.6 Estimation of design flood levels

Flood levels along the Brisbane River were calculated with the MIKE11 hydraulic model. The model extends upstream from the Brisbane bar to approximately 15km downstream from Savages Crossing. The inflow hydrograph at the upstream end was provided from a RAFTS hydrological model that has its output approximately 2 km upstream from the end of the MIKE11 model. The DNRM dam operations have been applied in producing this hydrograph and it includes Lockyer Creek flows. Downstream from this point, there are approximately 150 inflow locations in the MIKE11 model. At the downstream end the water level was set at MHWS (0.92 m AHD) and held constant throughout the entire flood simulation.

The MIKE11 hydraulic model that was developed for the Ipswich Rivers Flood Studies was used to calculate design flood levels in the Brisbane River. The Panel has not examined the calibration of the model. SKM reports that the calibration at the Port Office and at Moggill is considered good but that calibration has not been done at other locations along the Brisbane River within Brisbane City. Consequently, flood levels estimated for locations other than at the Port Office and at Moggill must be treated with care. It is noted also that the need to extrapolate the rating curves causes some uncertainty in the calibration of the hydraulic model, because of the uncertainty that attaches to the estimates of the flows of large floods used in calibration.

The hydraulic model was run with input flows calculated from CRC Forge rainfall estimates, spatially distributed with areal reduction factors, for the 1% AEP design rainfall, for seven durations. The critical duration was 72 hours and for this case, the peak flow calculated at the Port Office is 5060 m^3/s and the peak flood level is 2.68 m AHD.

The peak flow at the Port Office calculated with the hydraulic model is similar to that calculated with the RAFTS model (5,000 m^3/s, Section 4.5). However, the Panel considers that the values of Q100 estimated from RAFTS modelling may be low by 10 to 20% (see Sections 4.4, 4.5) and it has formed the opinion that the current best estimate for the Q100 flow at the Port Office is 6,000 m^3/s, as explained in section 4.8. It follows that the flood level, 2.68 m AHD, may be low and it would be desirable to calculate the flood level corresponding to a peak flow of 6,000 m^3/s. From simple interpolation in an approximate rating based on the MIKE11 results in the 2003 SKM study, the flood level for this flow is estimated at 3.3 m AHD.

The use of a constant water level at MHWS at the downstream end of the hydraulic model is consistent with what was adopted for the original Brisbane River Study. This may appear to result in slightly high estimates of flood levels in the tidally affected reaches of the river. However, the flood hydrograph is of long duration and the flow in the tidal reaches will be very close to the peak for a time interval similar to or greater than the interval between low tide and high tide. Therefore, the use of a constant water level at MHWS may not be conservative. It is known also that storm surges are often associated with the severe large weather patterns that produce large flood events. The Panel considers that a Monte Carlo analysis to examine the joint probabilities of flow rates and tide levels, including influences of storm surges, is required to resolve this issue.

4.7 Sources of remaining uncertainty

Rating curve extrapolation

At all of the flow gauging stations the maximum gauged flow is substantially smaller than the maximum estimated flow. For example, at Savages the maximum gauged flow is of order 30 - 45% of the estimated 1974 peak flow (SKM, 2003 (b)). Extrapolation of the rating curve to such an extent is a source of considerable uncertainty in the estimates of the larger flows that influence the FFA in the range of the Q100.

The need to extrapolate the rating curves also causes uncertainty in the calibration of the hydraulic model, because of the uncertainty that attaches to the estimates of the flows of large floods used in the calibration.

Unfortunately, little can be done to reduce these uncertainties until gaugings can be obtained during larger flood events.

Spatial and temporal pattern variability

The results obtained with seven historical spatial distributions of rainfall in the hydrological modelling show that the estimate of Q100 is substantially affected by the spatial distribution used. At Savages, the pre-dams estimates of Q100 ranged from 11507 to 8005 m^3/s and the post dams estimates ranged from 7847 to 5279 m^3/s (SKM, 2003 (a)).

The results from a limited assessment of the effects of different temporal patterns for the pre-dam case showed variations in peak flows of 15% at Savages Crossing and of 10% at the Port Office.

Larger estimates of Q100 may result from spatial and temporal patterns of rainfall other than those modelled. This question could be resolved by a full Monte Carlo analysis.

Correlation of losses with storm occurrence

In the hydrological modelling the initial loss was set at 10mm and the continuing loss at 1.0mm/hr (SKM, 2003 (a)). These losses are within the ranges that are considered reasonable for eastern Queensland. It has been stated that 'A Q100 event ... generally occurs in a season of wet winters and high rainfall summers' (BCC, 1999). This has provided the basis for the use of relatively low losses in the hydrological modelling. Nevertheless, this has not been examined rigorously. Further, it is uncertain whether pre-event wetting of the catchment prior to large storm events may result in even smaller losses and larger peak flows.

These issues would be clarified by a correlation analysis of pre-event catchment soil moisture levels with storm occurrences.

Correlation of pre-event dam levels with storm occurrence

The set of post-dams estimates of flows downstream from Wivenhoe dam were calculated with the assumption that the dam was at FSL, RL 67.0 m AHD, in all cases. Sensitivity tests showed that the estimated peak flow at the Port Office Gauge is reduced by about 13% if Wivenhoe dam is 75% full with SWL at RL 64.0 m AHD at the start of the flood event (SKM, 2003 (a)). Data sets are available that would enable a correlation analysis to establish the most likely pre-event dam level.

Calibration of hydraulic model

The MIKE11 hydraulic model that was developed for the Ipswich Rivers Flood Studies was used to calculate design flood levels in the Brisbane River. The model calibration at the Port Office and at Moggill is considered good but it has not been calibrated at other locations along the Brisbane River within Brisbane City. The model should be calibrated throughout the length of the river within Brisbane City to provide good estimates of flood levels throughout.

4.8 Best estimates of the 100 year ARI at the Port Office

As noted in previous section, the spatial distribution of the design storm used to calculate the Q100 is critical. For this reason, the Panel requested SKM to calculate Q100 estimates using the spatial distributions from seven historical large storms. The range of Q100 for the Port Office was 3400 to 7121 m^3/s. The Panel considers this to be an extreme range, it is unlikely to be a fair indication of the likely uncertainty of the Q100 flood flow.

If the outermost two are 'dropped', the range reduces to 5000 to 6800 m^3/s, with the median being 5900 m^3/s (SKM, 2003(a), Table 7). After rounding these values in recognition of their approximate nature, the Panel regard 6000 m^3/s as the best current estimate of the Q100 flow-rate, with 5000 m^3/s being the lower estimate of Q100, and 7000 m^3/s being the upper. [As noted in the Conclusion, further work is needed to refine the position of this estimate in the range, and to reduce the size of the range itself]

The Q100 level calculated at the Port Office with the hydraulic model is 2.68 m AHD. However, the flow associated with this level is 5060 m^3/s, while the Panel regard 6000 m^3/s as the best current estimate of the Q100 flow. The best estimate of the Q100 level corresponding to this flow is 3.3 m AHD, with 2.8 and 3.8 m AHD being the levels corresponding to the lower and upper estimates of flow.

5. Conclusion

5.1 Panel findings

The estimation of Q100 for a catchment of this size (13570 sq. km) is a challenging task. The extreme variability of rainfall, the change in catchment response due to the construction of dams, and the variable conditions in the tidal section of the river, are some of the factors which complicate the application of 'standard' flood methodologies. The advent of new techniques for flood frequency analysis and for extreme rainfall estimates, together with much improved hydraulic routing methods for estuaries, has added much to the technologies now available for flood estimation. The Panel notes that the further studies done by SKM, in conjunction with City Design, took advantage of these new techniques.

With respect to its Terms of Reference, the Panel:

(i) have reviewed the methodology used by SKM to determine the Q100 river flow and level;

(ii) believe that the appropriate technical processes have been followed in this study;

(iii) based on the evidence available, is of the view that, for the Brisbane Port Office, the best current estimates for

- the Q100 flow is 6000 m^3/s
- the Q100 level is 3.3 m AHD

There is an inevitable degree of uncertainty in any estimates of this kind. The Panel believes the possible range for flow to be 5000 to 7000 m^3/s; for level to be 2.8 to 3.8 m AHD.

The Panel notes that the current 'best estimates' of Q100 and of the corresponding flood level at the Port Office, provide a sufficient basis for a decision on whether the currently adopted flood levels are broadly acceptable. However, for general flood risk assessments and risk-based flood management decisions, more refined flood frequency estimates will ultimately be required.

5.2 Recommendations for Further Work

a) The SKM 2003 study has demonstrated the very significant effect of assumed storm variability on the estimated post-dams flows at the Port Office. The Panel believes that this variability could be reduced if a similar study was conducted, but using Monte Carlo methodology to simulate the possible combinations of storm temporal and spatial patterns (instead of seven observed storms). Such a study could also properly estimate and account for the correlations between event occurrence, losses and reservoir drawdown (instead of using fixed average values). The Panel strongly recommends that such a study be done as Council moves towards a risk-based approach to flood management.

b) More confidence would be engendered in the results if there was a better match between the flood frequency analysis of observed data and the estimates obtained from the rainfall-based RAFTS model. The current variance of around 20% is not desirable. Given the importance of runoff volume in a situation involving large dams, the Panel recommend that:

(i) Calibration of the RAFTS model be re-visited with the view to reducing the variance with FFA outcomes to within acceptable bounds.
(ii) Frequency analysis of event volumes be carried out, and compared with runoff volumes predicted by the RAFTS model from design rainfalls of corresponding frequency.

c) The MIKE11 model of the Brisbane River should be calibrated throughout the length of the river within Brisbane City to provide good estimates of flood levels throughout.

d) Consideration should be given to including the effect of tidal variation on flood levels in the estuarine zone. This would involve a Monte Carlo type analysis to examine the joint probabilities of flow-rates and tide height.

e) The DNRM model for simulating the expected operation and effect of Wivenhoe and Somerset Dams on flood flows, and associated data, should be independently reviewed when the DNRM final report is made available.

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6. References

BCC (1999) Report, Further Investigations for the Brisbane River Flood Study (Draft), December 1999.

IEAust (1999) Australian Rainfall and Runoff – A Guide to Flood Estimation, (Reprinted Edition), Institution of Engineers, Australia, Barton ACT.

Kuczera, G. (1999) Comprehensive at-site flood frequency analysis using Monte Carlo Bayesian inference, Water Resources Research, 35(5), 1551-1558.

SKM (2003(a)) Report, Further Investigations of Hydrology & Hydraulics Incorporating Dam Operations and CRC Forge Rainfall Estimated (Draft), 28 August 2003.

SKM (2003(b)) Report, Flood Frequency Analysis of Brisbane River (Draft), 8 August 2003.

Appendix – Terms of Reference and Chronology of Events
(Documents from Brisbane City Council)

TERMS OF REFERENCE

for

Brisbane River Flood Study

Independent Expert Review Panel

Background

A chronology of events to date has been included at the end of this document. It outlines the work undertaken so far to determine the Q100 Brisbane River flood level. The Brisbane City Plan 2000 uses the Q100 as the key input in the determination of development control levels adjacent to the river. The Q100 currently used is based on a study that was completed about the same time as Wivenhoe Dam was constructed. This 1984 figure of 6,800 m^3/s has been used as the basis for setting development control levels for nearly twenty years.

Council commenced extensive work into hydrologic and hydraulic aspects of the catchment after the 1993 DNR study indicated that the Q100 flow at the Brisbane Port Office may be as high as 9,380 m^3/s. The 1998 study undertaken for Council by SKM recommended a Q100 of 9,560 m^3/s. In June and December 1999 BCC's City Design produced draft reports that recommended Q100's of 8,600 m^3/s and 8,000 m^3/s respectively.

Preliminary results from the 2003 DNRM study on flows in the Brisbane River indicate a Q100 of 6,000-7,000 m^3/s at the Brisbane Port Office. BCC is undertaking further work to assess the results of the various methods.

BCC and SKM are now using updated information (including the DNRM results) to review the flood frequency analysis and determine the revised Q100 flood level at the Brisbane Port Office.

Even if the Q100 changes from 6,800 m^3/s, it is likely that the Development Control Level will remain the same as is currently used in the Brisbane City Plan.

Role

The role of this expert panel is to determine whether the August 2003 estimates of Q100 flow and level at the Brisbane Port Office are reasonable.

Objectives

1. Review the methodology that has been used to calculate estimates of Q100 river flow (1998 – 2003)
2. Ensure that the appropriate technical process has been followed for the 2003 Q100 river flow / level at the Brisbane Port Office.
3. If required, provide specific recommendations on further work be undertaken
4. Assess the suitability of the 2003 Q100 river flow / level for design purposes..

Outcome sought

It is expected that the expert panel will produce a report providing opinions, recommendations and advice on the technical process followed and the estimated Q100 river flow / level at the Brisbane Port Office

Membership of Panel

- Professor **Russell Mein** (Chair) – Experience: Former CEO of CRC for Catchment Hydrology and former Chairman of ARR Advisory Panel
- Professor **Colin Apelt** – Experience: Former Head of the Department of Civil Engineering, University of Queensland
- Dr **John Macintosh** – Experience: Chairman Engineers Australia National Committee on Water Engineering, and Director / Principal Water Engineer with consultants Water Solutions Pty Ltd
- **Erwin Weinmann** – Experience: Deputy Director CRC for Catchment Hydrology (Monash Node), Senior Lecturer in water subjects at Monash University and Co-author of Book VI (Estimation of Large and Extreme Floods)

Responsibilities of Members

- To read briefing materials provided prior to meetings.
- To attend and participate in meetings of the expert panel.
- To assess and report on the methodology and process used to determine the Q100 flow / level at the Brisbane Port Office.

Timing

It is initially anticipated that there will be two meetings of the expert panel:

- Thursday 31 July – to review the work done to date and agree on the process to finalise the Q100.
- Mid August – to consider the findings of the Q100 investigation and to critically assess the Q100 determined at the Brisbane Port Office

The objective is to deliver a brief report to the Manager Water Resources outlining the findings by 25 August 2003.

Brisbane River Flood Study
Chronology of Events

1984 Reports for Brisbane City Council and Water Resources Commission. Q100 river flow set at 6,800 m^3/s (or cubic metres per second). This flow was used as the basis for flood levels for development control level.

1993 DNR study undertaken for the (now) South East Queensland Water Corporation to examine operating rules for the dam. The study determined that Q100 flow was 9,380 m^3/s. The report recommended that further work be undertaken to determine areal reduction factors. DNR consider this flow volume was seen as an overestimation as it was not specifically produced for the Q100 event in Brisbane. This prompted Council to re-examine flood levels in the river and led to commissioning the SKM report, which commenced in November1996.

1998 Model developed and draft SKM report received by Council, proposing Q100 flow of 9,560 m^3/s.

1998 Report and results reviewed by Council officers who determined that this flow was based on assumptions that equated to a lower probability of flooding than the Q100. This resulted in Council commissioning Professor Russell Mein, eminent hydrologist, to undertake an independent review of the work to date.

1998 December, received Professor Mein's review of the draft SKM report. This review stated;

> The overall approach for the hydrologic component of the study ... is appropriate. However ... conservative assumptions in key input variables point to the likelihood

that the magnitude of the Q100 obtained in this Study is an over-estimate." Professor Mein made six recommendations for work needed to address the issues of concern.

1999 June, draft review by City Design. Note that this revised downwards the Q100 flow to 8,600 m3/s as a result of the additional analysis–a reduction of 10% on the SKM report (This draft report did not fully address Professor Mein's review recommendations). This is the report referred to by the Courier Mail in its stories on flooding which appeared in the newspaper from 24 June 2003 to 5 July 2003.

1999 December, review by City Design. This draft report entitled "Further Investigations for the Brisbane River Flood Study" was to fully incorporate Professor Mein's recommendations and revised the Q100 flood discharge down again to 8,000 m^3/s as the analysis was refined. It should be noted that this report again did not fully address Professor Mein's peer review analysis.

2000 January to September, review of all these reports, discussions with external stakeholders, including South East Queensland Water Corporation, Department of Natural Resources, Bureau of Meteorology. Council continued to review the draft June and December reports as the peer review recommendations had not been fully addressed.

2000 October, Brisbane River Flood Study Technical Workshop held. Purpose – to ensure that the definitive flood study report would be technically rigorous and adopt an approach / methodology that is consistent with the current practices, using the latest available information. Participants included Professor Mein, BCC Waterways and City Design, Department of Natural Resources, Bureau of Meteorology, South East Queensland Water Corporation, Institution of Engineers National Committee on Water Engineering and Ipswich City Council.

Action plan arising from October workshop identifies FORGE Study being undertaken by DNR for SEQ Water Corporation. At this time, the continuous simulation study was due to be finalised by December 2000 and was consistent with Professor Mein's comments, as well as the current approach by the CRC for Catchment Hydrology.

Preliminary results showed the DNR Q100 level as closer to the BCC 1984 study than the 1992 DNR study, which reinforced our position on the over-estimation of the Q100 flood flows. The workshop concluded that the FORGE work being done would need to be taken into account. In addition, the workshop suggested that we take into account the areal reduction factors, which it was estimated may produce a 20% reduction in total rainfall at the Brisbane Port Office gauge.

Since 2000 Council has been in contact with DNRM every few months to check on the progress of the report. Officers of DNRM have consistently reassured us as to the probability of the Q100 flow figure being close to, or at the level of the 1984 Q100 figure.

Council has been taking other actions as well, for example, raising community awareness of flooding issues with tools such:

- Council's flood information system which predicts flood levels in the river during major flood events,
- Upgraded system which will automate and improve the accuracy of Q100 on individual properties,
- Fact sheets and articles in publications and information on Council's website.

On Friday 27 June 2003 BCC received preliminary advice from DNRM that the Q100 flood flows at the Brisbane Port Office would be between 6,000 and 7,000 m^3/s. This affirmed that the preliminary estimate from early reports was likely to be an over-estimate. This is consistent with their advice from the October 2000 workshop and from contacts with DNRM since then.

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