Joint Flood Taskforce Report
March 2011

Prepared for Brisbane City Council by the Joint Flood Taskforce

This document has been approved on behalf of the Joint Flood Taskforce by

Name	Professor Colin Apelt		
Position	Joint Food Taskforce Chair		
Signature	C.J. Apelt	Date	8 March 2011

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Executive Summary

In January 2011, Brisbane experienced the second-highest flood of the last 100 years, after January 1974. There was major flooding through most of the Brisbane River catchment, most severely in the Lockyer and Bremer catchments where numerous flood height records were set. The flooding caused substantial loss of life in the Lockyer Valley and thousands of properties were inundated in metropolitan Brisbane, Ipswich and elsewhere.

Joint Flood Taskforce Brief

As with any such event, questions about flood control levels are raised. Given that the flood control levels are theoretical, it is prudent to review them in light of an actual event to assess the reliability of the present theoretical model. To this end a Joint Flood Taskforce (JFTF) was established to report within 30 days, which it has done, on the following three questions.

- How does the January 2011 flood event compare to the Q100 as presently defined and Brisbane City Council's Defined Flood Event?
- Does Q100, as it is currently described, remain the best estimate of a 1 in 100 year event?
- Accordingly, what standard should be used to enable new development and redevelopment to proceed with confidence and certainty?

Findings of Joint Flood Taskforce

In answering these questions the JFTF has focussed on river flooding only. Creek flooding and the impact of Storm Surge are considered to be outside the scope for this review. The JFTF was limited by the data and modelling available and that could be made available. Further the answers provided stress their interim nature given a number of other reviews that are currently underway. These reviews include "Queensland Floods Commission of Inquiry" and Council's Flood Response Review Board.

How does the January 2011 flood event compare to the Q100 as currently defined and Brisbane City Council's Defined Flood Event (DFE)?

In the flood event experienced, the heaviest rains were inland on the western fringe of the Brisbane River catchment and on the Great Dividing Range. Over the Brisbane River catchment as a whole, based on rainfall captured by the BoM's Enviromon rain gauges, the estimated average 5-day rainfall is 322mm, with the major sub-catchments of Wivenhoe Dam, Bremer River and Lockyer Creek receiving 370mm, 223mm and 268mm respectively.

Given the pattern of rainfall, the Brisbane River received significant flows from the upstream catchments of the Lockyer and Bremer. The flow down the upper Brisbane River (above the Lockyer Creek) and Stanley River were mitigated by Wivenhoe Dam. However Brisbane felt the full force of the flows down the Lockyer and Bremer Rivers. As a result of the rainfall, Brisbane experienced a significant river flood. During this flood event, the rainfall over much of Brisbane was not sufficient to cause any significant creek flooding from local runoff. However, creeks that are tributaries of the Brisbane River were flooded deeply in their lower reaches by water backing up from the River.

Based on examination of the rainfall patterns of a number of previous Brisbane River floods, it is concluded that the Brisbane catchment experienced a significant rainfall event with a rain pattern that was different from that experienced in 1974. Full details of the rainfall magnitudes were not available at the date of this Report. However back calculation from recorded releases from Wivenhoe and the record of water level in the dam suggest significantly more flood producing rainfall occurred than indicated by the presently available rainfall data. The calculated dam inflow hydrographs show two inflow peaks, the first of the magnitude of 1974 and the second 36 hours later of greater magnitude than 1974. The level recorded at Savages Crossing was higher than in 1974. Flood inflow volumes to Wivenhoe as calculated from the known releases from Wivenhoe dam and the recorded water levels in the dam total 2,650 GL, as compared to a total of 1,410 GL for that location in 1974 and 2,744 GL in February 1893.

On balance the JFTF considers that the flood runoff resulting from the major rainfall event of January 2011 was greater than the 1974 event but not as great as the 1893 event.

All of the peak flood levels recorded in January 2011 by the gauges along the Brisbane River were higher than the existing Defined Flood Level, ie. the level previously calculated for the 1974 flood event mitigated by Wivenhoe Dam. Therefore, taking into account this fact together with its assessment of the rainfall event, the JFTF considers that the January 2011 flood event was larger than the Brisbane City Council's Defined Flood Event.

The Q100 as presently defined is, in general, a slightly lesser flood than the Defined Flood Event. Therefore the JFTF considers that the January 2011 flood event was larger than the Q100 as presently defined.

Much more detailed work is required to accurately identify the probability of this event for Brisbane. The information needed and the work required to complete this analysis are summarised in the Recommendations below.

Does Q100, as it is currently described, remain the best estimate of a 1 in 100 year event?

The term, Q100, can be misunderstood. Some people mistakenly believe a 1 in 100 year flood will only occur once every 100 years on average. However, Q100 is a probability-based design flood event, aimed to reflect *typical combinations of flood producing and flood modifying factors* which act together to produce a flood event that has a 1 in 100 chance in any one year (or an average recurrence interval of 100 years) of being equalled or exceeded at a specific location of interest. It is a theoretical flood model used to inform planning and policy.

The January 2011 flood has brought a significant amount of new data and information on the nature of flooding in the Brisbane River and about the factors contributing to very large flood events in this catchment. Significant work is required to review Brisbane's Q100 in the light of this new information. This work could not be completed given the data available to the JFTF report, some of which is still being collected.

In light of the available information about the 2011 flood event, the JFTF considers that it is essential that the current Q100 is reviewed. It is not possible to predict the outcome of such review but it is considered more likely than not that this review will lead to an increase in the magnitude of the Q100 and increases in associated flood levels.

Accordingly, what standard should be used to enable new development and redevelopment to proceed with confidence and certainty?

To answer this question five (5) scenarios have been evaluated. These scenarios are:

- Current Q100 (3.3m at City Gauge)
- Current Defined Flood Level, DFL (3.7m AHD[1] at City Gauge)
- January 2011 Flood Event (4.46m AHD at City Gauge)
- 1974 without Wivenhoe Dam (5.45 m AHD at City Gauge)
- 1893 without Somerset and Wivenhoe Dams (8.35m AHD at City Gauge)

On balance, the JFTF believes that, in the absence of results of a detailed flood study review, a precautionary approach should be adopted. Therefore, it considers that the actual January 2011 flood event, as observed during the event, should be used as the **interim** standard on which Brisbane City Council bases its decisions concerning habitable floor levels for new development and should be a consideration for habitable floor levels for redevelopment of existing properties. Wherever the existing DFL is higher than the January 2011 flood event, the existing higher flood level should prevail.

The JFTF notes that, in regions where the interim standard will be applied, the degree of immunity from flood risk will vary with location. This is because the January 2011 flood event is an actual event and will have variable tidal influences along the tidal reach. Consequently variable probabilities will apply along this reach.

The recommendation of an **interim** development standard refers to land use types that are currently assessed against a DFE in the City Plan. This currently excludes industrial development however this should be considered through the current City Plan review.

Further the DFE and resulting flood regulation lines are considered only part of a flood risk management framework for a community. The approach to flood risk management for Brisbane needs to consider a broader range of initiatives if it is to effectively manage flood risk for the City. Flood risk management requires that the consequences of floods be investigated for a range of flood events up to and including the PMF. For land use planning, flood levels as well as flood flows corresponding to specific

[1] AHD - Australian Height Datum - is the national surface level datum corresponding approximately to mean sea level. Levels measured relative to this datum are given as "m" AHD.

probabilities must be considered. This approach must include identification of the benefits of the management of risk, rather than seeing it as all cost.

Recommendations of Joint Flood Taskforce

It is recommended,

That the actual January 2011 flood event, as observed during the event, be used as the **interim** standard, on which Brisbane City Council bases its decisions concerning new development and redevelopment, with the essential condition that, wherever a higher level has been set as the current DFL, the higher level must apply; and that this interim standard apply until conclusion of the Commission of Inquiry and the comprehensive flood study recommended below is completed.

That all data relating to the January 2011 flood event be gathered from all sources and archived so that further analysis can make use of all data available.

That the bathymetry (river bed and banks) of the Brisbane River and its tributaries and the characteristics of the bed material from Wivenhoe dam to the mouth be measured as soon as possible.

That a comprehensive flood study be commissioned to review flood flows and levels within the Brisbane River catchment making full use of the data relating to the January 2011 flood event.

That the effects of morphological (river bed level and cross section) changes due to sediment erosion and deposition during flood events be studied for a range of flood magnitudes to determine their effects on flood levels.

That consideration be given to whether a Monte Carlo approach to the flood risk for the Brisbane Catchment is feasible and, if yes, whether it should be carried out and which influencing factors should be included in the Monte Carlo approach. This may include consideration whether two or more types of rainfall events should be built into the statistical analysis for theoretical floods. In a Monte Carlo analysis the influencing input factors such as rainfall patterns, storm tracks, catchment conditions, tide and storm surge are sampled, either randomly or in accordance with their joint probabilities, to select a large number of different combinations of inputs for simulation with a catchment modelling system to develop many alternative predictions of flood events. These predictions are then analysed statistically to estimate their exceedance probabilities.

That a complete Flood Risk Management analysis for the area of Brisbane affected by flooding by Brisbane River and its tributaries be carried out. It is essential to move from the Q100 mentality and to adopt a risk management approach inline with National Flood Risk Advisory Group (NFRAG) and other relevant guidelines. The risk management approach would require a detailed assessment of the benefits and costs of a full range of flood mitigation options.

1.0 Purpose and Scope of the Report

1.1 Purpose

On the 11 February 2011 the JFTF was established by the Brisbane City Council. Ipswich City Council were then invited to participate in accordance with the Terms of Reference as given in Appendix A. Ipswich City Council chose to adopt an observer status, providing technical input and were not an approval entity. An outcome of the JFTF required by the TOR was the response to the following questions.

1. How does the January 20011 flood event compare to the Q100 as presently defined and Brisbane City Council's Defined Flood Event (DFE)?
2. Does Q100, as it is currently described, remain the best estimate of a 1 in 100 year event?
3. Accordingly, what standard should be used to enable new development and redevelopment to proceed with confidence and certainty?

A Technical Reference Group and an Industry Reference Group were established at the same time, as detailed in the TOR, to provide input to the work of the core JFTF. The role of the Technical Reference Group was focussed essentially on the first two questions while the role of the Industry Reference Group was critical in the response to the third question.

This report provides the response of the JFTF to the TOR including its answers to the three questions.

1.2 Approach

To provide the context for this work, the flood history of the Brisbane River is summarised including the event of January 2011. An overview the catchment in which Brisbane is situated is provided including major dams with their impacts.

Brisbane's Q100 and DFE control levels are discussed as are their role as development standards. The January 2011 event is then compared to the current Q100 event and the current DFE and the appropriateness of the current Q100 is examined.

Five potential DFEs are examined. These scenarios are:

- Current Q100 (3.3m AHD at City Gauge)
- Current Defined Flood Level, DFL (3.7m AHD at City Gauge)
- January 2011 Flood Event (4.46m AHD at City Gauge)
- 1974 without Wivenhoe Dam (5.45 m AHD at City Gauge)
- 1893 without Somerset and Wivenhoe Dams (8.35m AHD at City Gauge)

The effectiveness and impacts of each option are discussed and a conclusion reached as to their suitability from both a hydrological and planning perspective.

1.3 Limitations

This report only considers river flooding within Brisbane. Flooding in the Bremer River is not examined, neither is creek flooding and nor is the impact of storm surge or climate change.

The State government's "Queensland Floods Commission of Inquiry" will consider and make recommendations relating to any long term planning changes. However, this will not be available for some time. This report aims to provide certainty to Brisbane's community by providing interim guidance on flood levels and controls. The focus of this report is the next 1 to 2 years. As a result, longer term impacts such as changing sea levels and variations in rainfall patterns and other consequences of climate change are not considered.

Given the interim nature of the report, there are limitations on the data that could be collected, flood modelling that could be completed and the economic analysis that could be completed for the analysis of benefit and cost. Therefore recommendations are made for future work to increase the robustness of the recommendations or revise them if necessary.

Finally, the appropriateness of the Wivenhoe Dam operation procedures and potential improvements in these procedures are a consideration for the State's Judicial Commission. This report assumes Dams were operated inline with current legislated operating procedures. Consequently, Wivenhoe Dam operation is not considered.

2.0 Background

2.1 Flood Risk Management

2.1.1 Introduction

Flood risk is the potential for people or property to suffer damage from flooding. Flood risk at a location depends upon the frequency of flooding at different levels and the associated consequences to the community.

The objective of flood risk management is to reduce a community's flood risk to acceptable levels, either by reducing exposure to flooding or by reducing the vulnerability of people and property to flooding. This involves trading off the economic, social and environmental costs of flooding against the benefits of allowing a broad range of activities to take place on the floodplain. Such trade-off decisions need to be made in a proper risk management framework, based on firstly assessing the probabilities and consequences of flooding at different levels of severity and then considering the benefits and costs of a range of flood risk management options. The benefits of flood risk management options can be expressed in terms of the reduction in expected flood damages; environmental, social and economic, while the costs include the cost of implementing the flood risk management measures as well as associated opportunity costs.

In a broader sense, flood risk management also includes flood response and flood recovery actions but in the context of this report the focus is on the *prevention aspects* of flood risk management.

2.1.2 Flood risk management principles and guidelines

In Australia, flood risk management is guided by principles, policies and guidelines established at the national, state and local government levels. At the national level, the National Flood Risk Advisory Group (NFRAG) has been established to follow up on COAG reform commitments, including the development of National Flood Risk Management Guidelines (see AJEM, 2008). The national guidelines developed by NFRAG describe the vision for flood risk management as:

> *"Floodplains are managed for the long term benefit of the local and wider community such that hazards to people and damages to property and infrastructure are minimised and environmental values are protected."*
> *(AJEM, 2008)*

The Queensland State Planning Policy 1/03 : Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0 (SPP, 2003) and the associated State Planning Policy 1/03 Guideline: Mitigating the Impacts of Flood, Bushfire and Landslide 1.0, which form the basis for development decisions in relation to floods and other natural hazards, are consistent with the flood risk management framework outlined in 'Floodplain Management in Australia – Best Practice Principles and Guidelines' (SCARM, 2000).

2.1.3 Flood risk management options

The range of flood mitigation options available to reduce the exposure of a community to flooding or its vulnerability to flood risk includes the following main groups:

(i) *Land use planning and development controls* (including building regulations) to exclude development from the most hazardous parts of the floodplain and ensure that exposure to flooding and flood damage are minimised for development in fringe areas of the floodplain.

(ii) *Other non-structural measures* such as developing flood warning systems, improving community awareness and readiness by community education on the nature and impacts of flooding.

(iii) *Major structural flood mitigation works* to reduce the frequency of flooding above a given level (e.g. flood control storages) or the extent of flooding (e.g. levees) – these options can be employed to reduce the flood risk to *existing development* in the flood plain

(iv) *Flood proofing measures* to reduce the exposure of property to flood damage (e.g. raising of house floors, flood barriers, use of flood resistant building materials).

This report only concentrates on benefits derived directly or indirectly from the first group, with other potential flood risk management options to be considered as part of a more comprehensive future study. The specific focus of the report is on land use planning and development controls through setting of *defined flood levels for planning and building purposes* in the areas affected by Brisbane River flooding.

2.1.4 Residual flood risk

Flood risk management options are designed to reduce the flood risk for flood events up to a design flood (and the associated defined flood level). There is still a chance of the defined flood level being exceeded by larger floods; this is referred to as '*residual flood risk*'. The larger the average recurrence interval selected for the defined flood event (and thus the higher the defined flood level), the lower the residual flood risk. As an example, if the Q100 is adopted as the defined flood level, then the residual flood risk will consist of the consequences associated with all the floods larger than the Q100 event, weighted by the probability of their occurrence. While floods much larger than the January 2011 event may occur, their low probability of occurrence means that, in the determination of residual flood damages, they will be given a much lower weight than flood events which occur relatively frequently.

2.1.5 Conclusion

Flood Risk Management is a best practice approach and if adopted will provide a framework to mitigate damage from flooding for all properties at risk from flood. No matter what flood DFE is in place it should be considered as only one integral part of the Flood Risk Management framework which needs to be complemented with other flood risk controls as outlined in section 2.1.3

2.2 Details of the river flood event of January 2011

In January 2011, Brisbane experienced the second-highest flood of the last 100 years, after January 1974. There was major flooding through most of the Brisbane River catchment, most severely in the Lockyer and Bremer catchments where numerous flood height records were set. The flooding caused substantial loss of life in the Lockyer Valley and thousands of properties were inundated in metropolitan Brisbane, Ipswich and elsewhere.

2.2.1 Rainfall

For the 2011 event, the heaviest rains were inland on the western fringe of the Brisbane River catchment and on the Great Dividing Range. Recorded gauge levels for this event, show Brisbane's peak three-day rainfall was 166 mm, while the peak one-day total was 110 mm.

Over the Brisbane River catchment as a whole, based on rainfall captured by the BoM's Enviromon rain gauges, the estimated average 5-day rainfall was 322mm, with the major sub-catchments of Wivenhoe Dam, Bremer River and Lockyer Creek receiving 370mm, 223mm and 268mm respectively.

However back-calculation from recorded releases from Wivenhoe and the record of water level in the dam suggest significantly more flood producing rainfall occurred. The calculated dam inflow hydrographs show two peaks, the first of the magnitude of 1974 and the second of greater magnitude than 1974, 36 hours later. The peak level recorded at Savages Crossing was higher than in 1974 but not as great as estimated for the 1893 event. Estimated flood volume inflows to Wivenhoe as calculated from the known Wivenhoe dam releases and the recorded water levels in the dam total 2,650 GL as compared to a total of 1,410 GL for that location in 1974 and 2,744 GL in February 1893

It is thought that the coverage of the existing rain gauge network[2] was insufficient to accurately capture the variation in rainfall intensities for this event. This is supported by evidence from radar imaging which suggested significant falls not recorded in rain gauges. For example, there were large falls observed over Wivenhoe Dam itself that would not be captured by any rain gauge. To obtain a greater understanding of the total rainfall received, further work is required to analyse the recorded radar imaging of the event.

Insufficient rainfall data exist for a comprehensive assessment of the 1893 event. However, the available station data indicate that peak rainfalls in the region during the 1893 event were much heavier than those during either the 1974 or 2011 events. Crohamhurst, in the Glasshouse Mountains inland from the Sunshine Coast, received 907.0 mm on 3 February 1893, which remains an Australian daily record, whilst three-day totals included 1715.0 mm at Mooloolah and 1680 mm at Crohamhurst.

On balance the JFTF considers that the flood runoff caused by the rainfall event of January 2011 was greater than the 1974 event but not as great as the 1893 event.

2.2.2 Flood resulting from Rainfall

In 2011 Brisbane experienced a significant river flood. Given the pattern of rainfall, the Brisbane River received significant flows from the upstream catchments of the Lockyer and Bremer. The flow down the upper Brisbane River above Wivenhoe Dam and Stanley River was mitigated by Wivenhoe Dam. However, Brisbane felt the full force of the flows down Locker Creek and Bremer River

The flooding caused thousands of properties to be inundated in metropolitan Brisbane. It should be noted that the pattern of rainfall experienced caused little to no creek flooding within Brisbane, though creeks were flooded by backwater from the river.

It is reported that the flood levels recorded at Savages Crossing were higher than in 1974. DERM reported the peak level recorded at Savages Crossing was 24.167m AHD at 03.40 am on 12 January 2011, somewhat higher than the peak level of 23.767m AHD in the 1974 flood. The corresponding discharge based on the extrapolated rating curve was 6,900 cubic metres per second (cumecs). It has been suggested that the extrapolated rating curve may have underestimated the actual flow rate. Nevertheless the discharge of 6,900 cumecs is larger than that for the current DFE.

The peak height at the Brisbane Port Office gauge of 4.46 m was less than that in 1974[3]. The flood level in Brisbane in January 2011 was reduced by the mitigating effect of Wivenhoe Dam.

Measurements of flood levels for January 2011 have been based on marks on buildings where available, rather than on debris marks. Levels vary across the river by substantial amounts – up to 0.4m at bends; the water surface is curved generally because of the effects of super-elevation at the outsides and of local reduction at the insides of bends,

[2] The existing rain gauge network is made up mostly of gauges owned by BOM and Seqwater.
[3] There are two gauges at/near the Port Office. The "Port Office gauge" is at the end of Edward Street on the true left side of the river. There is also an 'Alert' gauge on the true right side a little downstream from the Thornton Street ferry pier.

as well as the tendency for the water to be higher towards the centre of a fast flowing river than near the banks. All the measured flood levels are higher than the Defined Flood Levels and these correspond to the levels calculated for a flood with the characteristics of the 1974 flood after the reducing effects of Wivenhoe Dam.

2.2.3 Outstanding Information Required for Description of 2011 Event

A number of important items required for a complete description of the January 2011 event were not available at the time of writing this report. These include the following:

- BoM is still assembling and checking the rainfall data.
- Department of Environment and Resources Management (DERM) gauged the flow at Jindalee Bridge with Acoustic Doppler instrumentation – this data is still awaited.
- There is a strong suspicion that the extrapolated part of the DERM rating curve for the gauging station at Savages Crossing is inaccurate causing some underestimates of flows in the order of 20% or more.
- The bathymetry of the river, from Wivenhoe Dam to the mouth of the river, may have changed substantially and it needs to be measured as soon as possible. There was very extensive erosion of the Lockyer and there is a strong suspicion that much of this was deposited in the Brisbane River. There are suggestions that this may be part of the reason for the apparent "discrepancy" in the differences between the DFLs and 2011 levels upstream from the Tennyson Tennis Centre – further upstream the differences are similar in magnitude but, in some reaches, they decrease before increasing again. However, there are substantial differences in the shapes of the hydrographs for the different flood events and this could be a major contributor.
- The accuracy of the stage/volume relationship for Wivenhoe dam storage needs to be checked.

2.2.4 Comparison of January 2011 with Present DFE

As stated above in 2.2.1, the JFTF considers that the flood runoff caused by the rainfall event of January 2011 was greater than the 1974 event. Further, as noted above in 2.2.2, all the measured flood levels for the January 2011 flood event are higher than the levels calculated for a flood with the characteristics of the 1974 flood after mitigation by the effects of Wivenhoe Dam and these latter levels are the presently Defined Flood Levels (DFLs) for areas where river flooding causes the highest level of flooding.

Consequently, despite the lack of complete data at this time, the JFTF has concluded that the January 2011 flood event, as actually experienced, was larger than a flood similar to that of 1974 after mitigation by Wivenhoe and therefore larger than the Council's presently defined DFE.

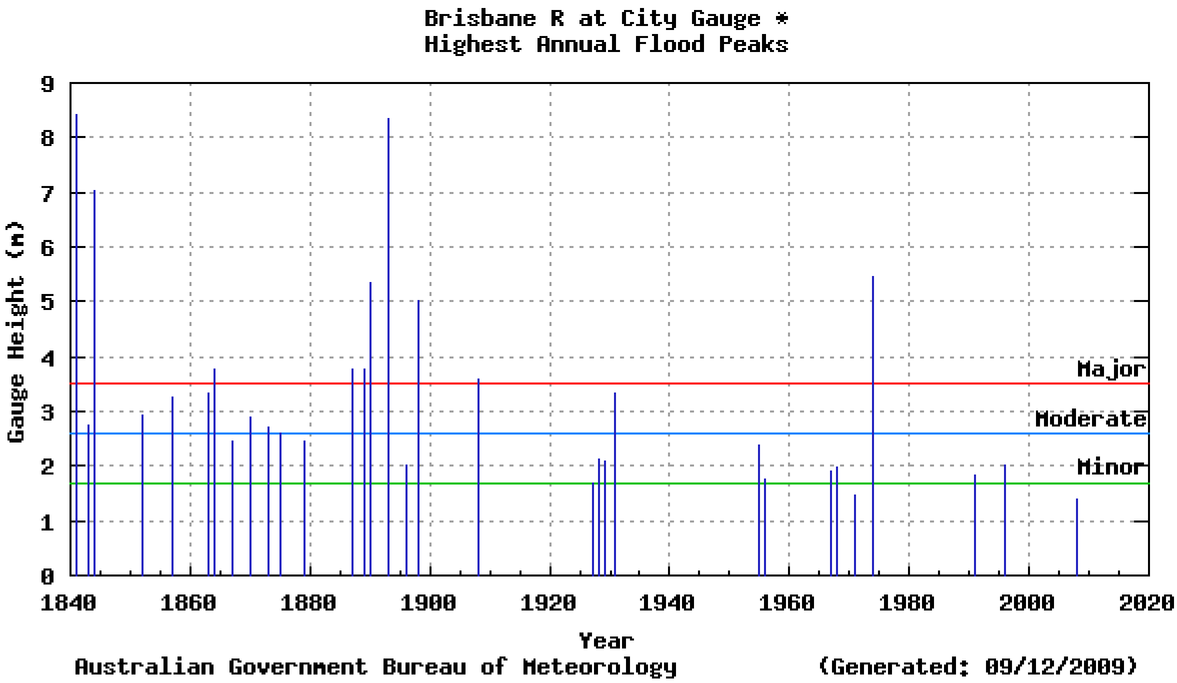
2.3 River Flood history

Flood records held by the Bureau of Meteorology and the Queensland Government extend back as far as the 1840's for Brisbane. These records show Brisbane is a city built on the flood plain of a river with a history of flooding. While flood peaks are referenced to the Brisbane Port Office gauge in Brisbane City, the flood levels reached upstream are significantly higher. The figure below shows the history of the highest annual flood peaks recorded at the City Gauge between 1840 and December 2009 (so it does not include the January 2011 flood). In that period, Brisbane experienced 10 Major, 8 Moderate and 12 Minor flood events. The descriptions of Major, Moderate and Minor as used by the Bureau of Meteorology are given in the Glossary. The table below shows flood levels on the Brisbane River for a selected number of river flood events.

Table 1: Selected Flood events

River Height Station (m AHD)	Feb 1893	Feb 1931	Jan 1974	Jan 2011
Gatton	16.33	n/a	14.63	n/a
Mt Crosby	32.00	21.78	26.74	n/a
Ipswich	24.50	15.50	20.70	19.25
Moggill	24.50	15.40	19.93	17.48
Jindalee	17.90	9.60	14.10	12.91
Brisbane City	8.35	3.32	5.45	4.46

The floods of 1841 and 1893 reached over 8 m AHD in Brisbane City. This represents a depth of approximately 6.5 m above the highest tide level. Since 1893 the largest flood in the Brisbane - Bremer systems was in 1974. In Brisbane the 1974 flood rose to a height of 5.45 m at Brisbane Port Office gauge while Ipswich reached a height of 20.7 m. As the Brisbane River flooded it backed up the Bremer River resulting in 4 to 5 days of record heights in Ipswich. Seqwater has been quoted in the media as saying the 1974 flood saw a river flow rate of 9,500 cubic metres of water per second. Note that the Jan 2011 flood (4.46m at City Gauge) is not included in the graph below, which was prepared in 2009 by the Bureau of Meteorology.



2.4 The Brisbane River Catchment

2.4.1 Geographical Characteristics

The Brisbane River is a large catchment of 14,000 km^2. Numerous creek systems feed the Bremer and Brisbane rivers. Rainfall across the catchment varies for any single event with differences of 1,000mm been observed values in the catchment for historic events.

2.4.2 Catchment Characteristics

Runoff is largely controlled by topography (draining system structure, catchment area, grades, etc.), land classification (land use, soil type, vegetation etc.), waterway capacity (conveyance and storage) and antecedent soil moisture content. These characteristics dictate the catchment's response to rainfall. This includes the depth, rate and duration of runoff.

In the Brisbane catchment, these characteristics have changed significantly since the 1893 events due to progressive settlement and development. This development included two large dams that provide temporary flood storage within the catchment. As a result the catchment's response to rainfall has changed significantly since 1893 and continues to change.

Furthermore, the generation of runoff and hence the development of a flood hydrograph is influenced by the characteristics of an individual storm event. The characteristics include the storm intensity, the spatial and temporal patterns of rainfall and the movement of the storm over the catchment

2.4.3 Flood Mitigation Dams

Two large dams provide temporary flood storage in the Brisbane River catchment, Wivenhoe and Somerset dams. Both dams are upstream of where the Lockyer Creek and the Bremer River joins the Brisbane River. As such where the rain event is centred within this large catchment and how it moves over it, determines their effectiveness as a flood mitigation measure for any event.

Table 2: Major Dams

Dam	Wivenhoe	Somerset
Completed	1985	*1959*
Water supply Storage (GL)	1,150	370
Temporary Flood Storage	1,450	524
Location	Brisbane River Upstream of Lockyer & Bremer	Stanley River upstream of Brisbane River
Catchment (km^2)	7,000 including Somerset Dam	1,330
Reservoir surface area (km^2)	107.5	42.1

While Wivenhoe and Somerset dams are capable of significantly reducing Brisbane River events, they have a limited mitigating effect on the Bremer River acting only to reduce the downstream level of the Bremer River as it enters the Brisbane River.

2.4.4 Creeks

As mentioned above, this report does not consider creek flooding. It is the opinion of the review group that given the power of the flow in the Brisbane River during flood, any creek flooding will have limited impact on the flood levels seen along the river. The more likely scenario is that the Brisbane River will back up any creek causing greater localised flooding or creek flooding**.** Given this, the increased creek flooding is outside the scope of this report but should be considered as part of a more comprehensive flooding review.

2.4.5 Tide and Storm Surge

The Brisbane River is tidal for approximately 86km from its mouth to around Colleges Crossing. Mean High Water Spring Tide in the bay is approximately 0.927 m AHD. Highest Astronomical Tide is 1.487 m AHD.

Storm tide risk in the Bay is significant. The storm tide level on January 1974 was approximately 1.6m AHD while in May 1996 the storm tide level was around 2.8m AHD. It appears that tide and storm surge can account for approximately +/- 2 m range in the Bay. However, the probability of the largest observed storm tide level coinciding with a flood of the magnitude of the January 2011 event is significantly less than 1 in 100.

2.5 Flood control levels in Brisbane

2.5.1 Differences between Design Events and Actual Events

Before any comparative information is presented it is important to understand the difference between actual observed flood events and probability-based design flood events such as Q100.

The flood event experienced in January 2011 is an *actual observed flood event*. It is *one of many possible events* from a large population of flood events that have occurred or could occur in the Brisbane River catchment from a combination of meteorological, hydrological and hydraulic factors. Observations on these factors during actual flood events are the main source of data and information for the derivation of probabilistic design flood events such as the Q100.

The term, Q100, can be misunderstood. Some people believe a 1 in 100 year flood will only occur once every 100 years on average. Rather, Q100 is a probability-based design flood event, aimed to reflect *typical combinations of flood producing and flood modifying factors* which act together to produce a flood event at a specific location of interest that has a 1 in 100 chance of being equalled or exceeded in any one year (1% annual exceedance probability – AEP); it is described as having an Average Recurrence Interval (ARI) of 100 years. It is a theoretical flood model used to inform planning and policy.

Flood event characteristics of interest for flood management considerations are the peak flow, flood event volume and flood duration, and the resulting flood levels at specific locations. Best estimates of Q100, or similar probability-based design floods, together with information on the bounds of uncertainty attached to these estimates, form the basis for the selection of the DFE for a specific location.

As such, any actual flood event will vary in some degree from the theoretical flood model. This is particularly an issue for a large catchment such as the Brisbane-Bremer catchment. In such large catchments there is a greater chance that actual events will have variables that exceed the range used in developing the theoretical flood model.

2.5.2 Q100 for Brisbane

For Brisbane the Q100 for river flood has a history of calculation and review based on specific events. The current Q100 for Brisbane was last estimated in 2003 as a peak flow of 6,000 cumecs (with uncertainty bounds of ± 1000 cumecs) and a corresponding flood level of 3.3 m AHD at Brisbane's Port Office gauge (with uncertainty bounds of ± 0.5 m).

2.5.3 Defined Flood Event (DFE) and Defined Flood Level (DFL) for Brisbane

DFL is the level above Australian Height Datum (AHD)[4] that Council requires habitable floors to be built above to provide protection against floods up to the magnitude of the DFE. DFL is based on the flood levels that are estimated in the DFE. It is a planning control to avoid people building habitable floor levels in locations or at heights that carry greater risk of flooding than that protected against by the DFL. The Brisbane City Plan also requires an additional 500mm of "freeboard" to be added to allow for a factor of safety, uncertainties and localised effects. It should be noted that in unusual circumstances Queensland's performance based planning system under the Sustainable Planning Act 2009 can allow alternate solutions other than set floor levels, to be considered.

It is desired that the floor levels of commercial and industrial uses meet or exceed the DFL, however an applicant may use a risk management approach if adopting the DFL leads to undesirable outcome.. Although this may be worthy of some reconsideration, it is beyond the scope of the TOR for the Joint Flood Taskforce.

State Planning Policy 1/03 states the Queensland Government's default position is that the 1% Annual Exceedance Probability (AEP) flood or Q100 is generally suitable as the DFE for a Local Government. However, there is a provision to allow a Local Government to define the DFE as higher than the Q100.

Brisbane City Council has defined the DFE to be higher than the Q100 due to previous experience with river flooding (1974 floods). Brisbane City Council uses a flow of 6,800 cumecs as its DFE with a resulting level of 3.7 m AHD at Brisbane's City gaugeas its DFL. This was first set in 1978 and was reconfirmed in 2003.

2.5.4 The role DFE and DFL in development

DFE and the resulting DFL are fundamental in setting levels for development. Levels for a development are set from the DFL though they vary with building classification and use (eg. habitable or non-habitable). The DFL reflects the slope of the flood profile and thus increases in level progressively as one moves upstream from the City gauge.

Levels set for development include a 'freeboard' margin which allows for uncertainties in the hydrologic and hydraulic models to determine design flood flows and corresponding flood levels, as well as a range of factors which may raise the flood levels locally. The freeboard margin may vary for different locations and types of development.

3.0 How January 2011 Flood compares to Q 100

As discussed above in 2.4.1, before any comparative information is presented it is important to understand the difference between actual observed flood events and a probability-based design flood event such as Q100. The flood event experienced in January 2011 is an *actual observed flood event*. It is *one sample from many possible events* that have occurred or could occur in the Brisbane River catchment from the combination of meteorological, hydrological and hydraulic factors. Observations on these factors during actual flood events are the main source of data and information for the derivation of probabilistic design flood events such as the Q100. Q100 is a theoretical statistical estimate of flood characteristics used to inform planning and policy.

3.1 Runoff

On balance the JFTF considers that the flood runoff resulting from the major rainfall event of January 2011 was greater than the 1974 event but not as great as the 1893 event. One likely contributing factor is the nearly complete saturation of the ground resulting from the long period of rainfall preceding the flood event.

Two large rainfall events, separated by 36 hours were recorded. Further analysis of the rainfall is required to confirm that the January 2011 event was rarer than the Q100 design event. However, this analysis can be undertaken only after the BoM have collated and checked the rainfall data.

3.2 Antecedent catchment conditions

The Q100 calculation assumes 10 mm initial loss and 1 mm/h continuing loss, uniformly distributed over whole catchment. This reflects the relatively saturated state of the catchment at the start of a 72-hour design storm and the resulting flood event. In the months leading up to January 2011, sustained rainfall was experienced across the catchment resulting in a saturated catchment. It is possible that the initial loss and continuing loss were less than those assumed in the Q100 calculation.

In the Q100 calculation the initial reservoir volume was assumed to be 100 percent of its water supply storage with the corresponding level of 67.0m AHD (the "F.S.L.")
The conditions at the beginning of the Jan 2011 flood were similar. The dam level was at 67.0m AHD on 2nd February 2011 and had risen slightly to 67.3m AHD on 6th February.

3.3 Inflows to Wivenhoe Dam

Flood volumes for Q100 for various rainfall durations are given in Table 4-7 of SKM (2003). The 72-hour volume is 2,180 GL.

The total flood inflow volume to Wivenhoe dam during the Jan 2011 flood event was estimated to be 2,650 GL. This estimated inflow volume exceeds the available flood storage in the Dam of 1,450 GL.

3.4 Flood Routing Effect of Storages

The 2003 review of Q100 estimated that there was a reduction of about 50% in peak flows between pre-dam and post-dam estimates of Q100 in Brisbane. This reduction arose from the attenuation effect of the estimated available flood storage in the dams. A comparison of the magnitude and effectiveness (attenuation capacity) of the available flood storage between the Q100 and the January 2011 event needs to be assessed in future work.

Currently the mitigating effect of the dams on the 2011 flood is not available. The operation of Wivenhoe dam is outside the Terms of Reference of the JFTF and it is expected that it will be one of the matters examined by the State Commission of Inquiry. It is necessary that this mitigating effect is assessed in future work.

3.5 Relative timing of Flood Contributions from different parts of the Catchment

The twin rainfall events separated by 36 hrs created nearly coincident peaks at the confluence of Lockyer Creek. The timing of peak discharge from the dam was separated by only a relatively small time interval from the arrival of the peak flow from the Lockyer at its junction with the Brisbane River. The design parameters used in design Q100 modelling do not consider coincident peaks.

3.6 Interaction with Tides and Storm Surge

The flood peak of January 2011 was influenced by a high tide of 0.46 m AHD at 3.13am on 13 January. In the Q100 design model the downstream control used was a level at the mouth of the Brisbane River corresponding to Mean High Water Spring Tide (MWHS), 0.9m AHD ("the tailwater level").

3.7 Resulting Flood Levels Q100 versus January 2011 Flood Levels

Table 3: Level Difference - Q100 Vs January 2011 Flood

Selected Locations	Jan 2011 Flood Approx. Level (m AHD) #	Q100 Design Level (m AHD)	Difference between 2011 and Q100 (m)	DFE Design Level- DFL (m AHD)	Difference between 2011 and DFL (m)
Brett's Wharf	2.48	1.63	0.85	2.05	0.43
Mouth Breakfast Creek	2.80	1.80	1.00	2.05	0.75
Powerhouse	3.20	2.35	0.85	2.80	0.4
New Farm Park	3.41	2.40	1.1	3.10	0.31
Story Bridge	4.35	3.00	1.35	3.66	0.69
City Gauge	4.46	3.30	1.36	3.70	0.76
SouthBank	5.35	3.70	1.65	4.30	1.05
Park Road	6.63	4.31	2.32	5.11	1.52
West End Ferry	7.42	4.92	2.50	5.79	1.64
Fairfield	8.72	5.97	2.75	6.78	1.94
Tennyson Tennis Centre	9.84	7.00	2.84	7.79	2.05
Mouth Oxley Creek	10.0	7.12	2.88	7.99	2.01
Graceville (Low Side)	10.10	7.18	2.92	8.05	2.05
Sherwood Arboretum	11.61	8.44	3.17	9.51	2.10
Seventeen Mile Rocks	12.57	9.24	3.33	10.30	2.27
Centenary Bridge	12.91	9.51	3.40	10.80	2.11
Westlake	13.80	10.30	3.50	11.88	1.92
Goodna Creek	16.79	13.30	3.49	15.20	1.59
Moggill Ferry	17.48	14.00	3.48	15.90	1.58
Karana Downs	22.98	19.31	3.67	21.10	1.88

Jan 2011 level subject to final verification

3.8 Comparison of January 2011 with Present Q100

Despite the lack of complete data at this time, the JFTF has concluded that the January 2011 flood event was larger than the Q100 as presently defined.

4.0 Q100 Reviewed

4.1 Basis of current Q100 estimate

4.1.1 Overview

Q100 refers to the peak flow rate at a specific location that has a 1 in 100 chance of being equalled or exceeded in any one year (1% Annual Exceedance Probability – AEP) or an Average Recurrence Interval (ARI) of 100 years. There are many alternative characteristics of flood hydrographs that are important in risk management of flood events and for the selection of the DFE at a specific location. These characteristics include the peak flood flow, the peak flood level, the rate of rise in the flood hydrograph and the flood volume among many others.

From the perspective of land use planning, it is usually the peak flood level that is of interest and hence it is the peak flood level quantiles (the levels that correspond to given annual exceedance probabilities) that are desired from the design flood process. In many flood situations, estimation of the peak flood level quantile is achievable by estimation of the peak flood flow quantile. This occurs as a result of the peak flood level being dominated only by the peak flood flow. However, in many estuarine situations, the peak flood level is the result of interaction between coastal and ocean processes and the flood flow. In these situations, there is a need to consider the joint probability between flood flows and ocean conditions in determining the peak flood level quantile.

For the Brisbane River, peak flood levels in the upstream sections of the catchment would be flow dominated while the peak flood levels in downstream sections of the catchment require consideration of the joint probability between flood flows and ocean conditions.

The estimation of Q100 (and flood characteristics for other probabilistic design floods) is based on the application of a range of hydrological methods and tools, using all the available storm rainfall and flood data that are directly relevant to the area of interest. In the particular case of the Brisbane River design flood estimates, the approach adopted in 2003 used the best elements of two methods: statistical flood frequency analysis and simulation modelling of design flood events, with subsequent reconciliation of the results obtained by the individual methods (SKM; Independent Review Panel Report, 2003). The steps involved in the estimation process can be briefly described as follows.

Flood Frequency Analysis (FFA)

This is generally the most direct method for estimating peak flows (or flood volumes), using recorded flood data from many previous flood events of different magnitudes. FFA can be reliably applied where long-term flood records are available and where catchment conditions have remained essentially unchanged over the period of record. In the Brisbane River catchment this applies to flood data from most of the tributaries but for the lower Brisbane River the construction of dams means that pre-dam and post-dam conditions need to be analysed separately. The period of record since the completion of Wivenhoe Dam is quite short and insufficient to allow reliable estimation of Q100 for post-dam conditions. Furthermore, the increased urbanisation downstream of the dam has the potential to modify the flow-probability relationship for the more frequent floods (i.e. the Q2 to Q10 flows).

Rainfall-runoff modelling of design flood events

In this method the processes that convert probability-based design rainfall events to design flood events (hydrographs) of corresponding probability are simulated by means of a rainfall-runoff model of the catchment. This process requires assumptions about typical combinations of flood producing/modifying factors to define design storms and their conversion to flood events of given AEP or ARI (e.g. Q100). Modelling has the advantage that it is quite flexible in allowing different catchment conditions to be simulated. Specifically, the flood mitigation impacts of dams (i.e. the modification of the inflow hydrograph to an attenuated outflow hydrograph) can be modelled quite accurately. However, in the case of a dam spillway that is controlled by flood gates, this also requires assumptions on how the dam is operated during flood conditions.

It is worth noting that the probability based design rainfalls refer to the most intense portion of a storm event. Hence the parameters used in the design modelling process usually are selected with knowledge of this constraint. Where flood volume is an important aspect of the design flood hydrograph, techniques for inclusion of pre and post peak burst rainfall are available; these techniques have been developed since the publication of the last edition of Australian Rainfall and Runoff and therefore are not included in the current document.

Reconciliation of flood estimates from different methods
The approach adopted in the Brisbane River flood studies (SKM, 2003) then combines the strengths of the two estimation methods by using FFA results to verify the model outputs for the pre-dam situation and then applying a modified version of the model (which simulates the effects of the dams) with probability based design storm inputs to derive peak flows and flood hydrographs for the post-dam condition.

4.1.2 Brief summary of flood studies to produce 2003 estimate of Q100

Only a brief summary is given here of the flood studies that were carried out in 2003 to produce the current estimate of Q100; more details are presented in Appendix B. The complete description of the studies and the recommendations drawn from them are given in the SKM (2003) report and the Independent Review Panel Report (2003).

The SKM (2003) study included a broad range of *flood frequency analyses* for a number of sites within the Brisbane River catchment but focussed specifically on the estimation of Q100 at Savages Crossing for the pre-dam conditions. This was based on recorded flood peak data at this site for the period from 1909 to 1958 (prior to completion of Somerset Dam), extension of flood peak data (by DNRM) to cover the period from 1890 to 1909, simulated pre-dam flood peaks for the period from 1959 to 2000 (from modelling studies by DNRM), as well as a regional flood frequency analysis using flood data from Brisbane River tributaries with adequate flood record lengths.
The *rainfall-runoff model* adopted in the SKM (2003) study is the RAFTS runoff routing model, which had earlier been developed by BCC and calibrated in a previous study. The key inputs to the model and assumptions for the estimation of Q100 are listed in Appendix B. Here it is noted that a 72-hour design storm was used, with rainfall distributed over the catchment according to the typical variation of design rainfall intensities and that the design losses assumed were 10 mm initial loss and 1 mm/h continuing loss, uniformly distributed over whole catchment; these losses reflect a relatively saturated state of the catchment at the start of a flood event

For the post-dam situation it was assumed that Wivenhoe dam was at Full Supply Level (RL 67.0 m AHD) at the start of the flood event and that the dam was operated according to operational rules incorporated into the WIVOPS simulation program, provided at that time by DNRM.

The Independent Review Panel noted the relatively wide band of uncertainty about the Q100 estimates from both methods. Taking into account all aspects of the study it recommended that the Q100 (peak flood) values shown in Table 4. be adopted.

Table 4: Recommended Pre - and Post-Dam Q100 flow estimates (m3/s) with indication of plausible range of variability (from Independent Review Panel Report, 2003 and SKM, 2003)

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

4.1.3 Summary

The final outcome from the Independent Review Panel Report (2003), drawing on the SKM 2003 flood study, was the conclusion that, for a flood with 1% Annual Exceedance Probability, the best current (i.e. 2003) estimate are a Q100 flow of 6,000 m3/s at the Brisbane Port Office and a corresponding flood level of 3.3 m AHD. It is very important to stress the inevitable degree of uncertainty in estimates of this kind. The Panel considered the possible range for Q100 at this location to be 5,000 to 7,000 m3/s and the associated range of levels to be 2.8 to 3.8 m AHD.

4.2 Critical factors in estimating Q100

4.2.1 Flood frequency analysis

The Q100 estimate for the pre-dam situation from FFA, as discussed in 4.1.2, is affected by a number of sources of uncertainty. The most basic factor relates to the rating curve that is used to convert the observed flood levels at the gauging site to flood flow estimates. As the flow magnitudes of floods for which gaugings have been undertaken are significantly smaller than the largest observed floods, the estimation of peak flows for these larger floods relies on the uncertain extrapolation of rating curves.

The largest floods in the Brisbane River catchment are likely to have resulted from different combinations of flood producing factors than the more frequent events. The statistical methods for fitting flood frequency distributions use data from the whole range of flood magnitudes and the relatively few observations of large floods may be insufficient to define the shape of the flood frequency curve in the range of large to rare events, resulting in wide uncertainty bounds for the Q100. While some of the analyses have tried to overcome these limitations by extending the record to the floods of the 1890s and by adjusting recorded post-dam floods for the flood mitigating impacts of the dams, these steps introduce additional uncertainty in the basic data used for flood frequency analysis and may thus provide only limited additional information.

Additional flood gauging information collected during the January 2011 flood event may help to redefine rating curves in the extrapolated range and thus reduce the influence of this source of uncertainty on flood estimates. An additional very large observed event also hasthe potential to reduce uncertainty in the extrapolation of the flood frequency curve, but uncertainty in the conversion of post-dam peak flows to pre-dam peak flows still remains.

4.2.2 Rainfall-runoff modelling

The key uncertainty factors in the derivation of Q100 from rainfall-runoff modelling are:

- The spatial pattern of rainfall and the storm movement over the catchment which can be considered typical for producing the flood characteristics of the Q100 in Brisbane under post-dam conditions.
- The typical temporal pattern of rainfall associated with a design storm of 100 years ARI.
- The typical depth of rainfall that occurs in the period prior to the peak burst of rainfall.
- The antecedent conditions (rainfall losses) that would be typical for a Q100 event.
- The expected initial level of the storages at the beginning of the design flood event and the spillway operation during the event.

The flood data and information collected during the January 2011 event can be expected to provide additional insight into the appropriateness of the assumptions made in the 2003 studies, which could lead to a revision of some of these assumptions. However, only part of this data is available at present.

When it becomes available, the additional information on the above five flood producing/modifying factors available from observations of the January 2011 event should be used to assess the sensitivity of the rainfall-runoff model results to key assumptions, and to consider if some of the assumptions made in the 2003 studies should be revised.

In principle, it would also be possible to use the rainfall and flood observations from the January 2011 flood event to check the rainfall-runoff model calibration/validation. This is outside the scope of this interim assessment but should form part of future more detailed studies.

4.2.3 Revision of best estimate of Q100

The analysis of the currently available data from the January 2011 flood event has led to the following observations relevant to a possible revision of assumptions made in the determination of Q100:

- There are additional factors to be considered when defining a 'design storm' and a 'design flood event' that produces design flood levels of corresponding probability in Brisbane.
- The key additional factors include the special characteristics of the temporal rainfall pattern (longer duration, double peak) and spatial distribution of rainfall that tend to be critical for the post-dam flooding situation in Brisbane.
- Both of these factors are highly variable and the Jan 2011 flood indicated a different range of variation than previously assumed.

- The assumed losses in the derivation of the current Q100 event may be higher than what can typically be expected during rare storm events.
- A detailed study of the joint probability of the various flood producing factors (using Monte Carlo simulation) will be necessary to determine the typical combinations of factors that are likely to produce a Q100 event for Brisbane.
- For the determination of flood levels in Brisbane associated with the Q100 event, the joint probability of river flooding, tidal influences and creek flooding will also need to be considered.
- A revised Q100 estimate from a detailed study and the resulting flood levels in Brisbane will still have a significant band of uncertainty associated with them.
- Even without such a detailed study it is clear that any review/revision of Q100 should allow for the special factors experienced during the Jan 2011 flood event which point to an increase in estimated design flood peaks and design flood levels downstream of Wivenhoe Dam compared to the current Q100 event and the DFE.
- In the absence of results of detailed studies, a precautionary approach should be adopted in the revision of previous Q100 estimates as an interim measure.

These observations support the following conclusions on the likely direction and magnitude of a revision of the current Q100 for the Brisbane River:

- The flood hydrograph reaching Brisbane during the Jan 2011 event can be interpreted as providing a likely upper bound estimate of the revised Q100 flood estimate for Brisbane and is thus consistent with a precautionary approach.

4.2.4 Flood level considerations

Estimation of a design flood level can be considered to comprise two components; namely estimation of the design flow and secondly, the conversion of the design flow to a design level at a specific site. Typical approaches for conversion of flows to levels include

- Rating curve;
- Hydrodynamic model.

The use of a rating curve assumes a unique relationship between flow and level. While this approach is applicable for many situations, it is unlikely to be appropriate for the Brisbane River in the tidal region. The 2003 studies recognised this limitation and therefore used the second approach.

The basis of the use of a hydrodynamic model to convert flood flows to flood levels is the numerical solution of the unsteady flow equations for flow over surfaces. There are many factors influencing the local transformation of flow to level with the more important of these being:

- Energy gradient – in general, the steeper the energy gradient, the larger the flow rate. Hence, the same flood flow can result in different flood levels due to different energy gradients which may occur during the rising and falling stages of a flood hydrograph or for different types of flood events.
- Floodplain representation – there is a need to represent the floodplain in a digital form either as a cross section or as a Digital Terrain Model. This digital representation is assumed to be representative of the catchment characteristics.

If the calibrated model is capable of reproducing historical events, then it is assumed that the representation is adequate for the purpose. The 2003 studies used a calibrated Mike-11 model.

- Hydrograph volume – the third parameter is the hydrograph volume. There are two components to the hydrograph volume which are the volume arising from the runoff generated by the rainfall prior to the peak burst and the runoff volume generated from the peak burst of rainfall. It is the former volume which can be important in the transformation of flood flows into flood levels as this prior volume can pre-fill the floodplain thereby reducing the energy gradient and hence increasing the flood level for a given flood flow.
- The bathymetry of the river channels – it is likely this has changed in the Brisbane River and in its major tributaries, possibly substantially, since it was last measured.

Of the four components noted above, it is considered that the flood volume is the most important consideration. The flood hydrograph volume for the January 2011 flood event was far greater than that for the Q100 design hydrograph. The design event was based on a flow dominant problem and not one where volume is a major issue. This greater volume will result in filling of the floodplain prior to arrival of the peak flow thereby limiting the available floodplain storage for attenuation of the flood hydrograph. Hence design flood levels calculated for the same peak flow as for the January 2011 flood event are likely to be biased low in the design event in the regions where floodplain storage was assumed to be available.

The peak ocean level during the Jan 2011 event was 0.46 m AHD compared with the level of 0.9 m AHD used for the design event. This means that, in the downstream reaches, the Jan 2011 levels will be lower than in a design event for the same flow rate but with an ocean level of 0.9 m AHD. In downstream reaches influenced by the ocean levels, there is no direct relationship between flow rates and flood levels.

4.2.5 Unknown information required for new estimate of Q100

Before a new estimate for Q100 can be developed, it will be necessary for the following information to be obtained:

- BoM is still assembling the rainfall data for Jan 2011.
- There is strong suspicion that the extrapolated rating curve for the gauging station at Savages Crossing (owned by DERM) is seriously inaccurate causing underestimates of flows of order 20% or more.
- BoM is finding that large floods often have intense localised rainfall events. These are not adequately recorded by the existing rain gauge network and they may be missed completely.
- BoM suspects that it may be necessary to increase substantially the estimates of peak flows for the 1893 floods, for 1974 and for 2011 because of the previous matter and also because some of the rainfall data is for relatively long periods – up to daily rainfall – and this misses out on high intensity shorter periods within the event.
- There is some belief that the 2011 rainfall event was greater than that in 1974 but this requires clarification when the complete data is available. However there is clear evidence that the runoff volumes were greater than those in 1974 and if

Wivenhoe dam had not been present it is possible that the peak flow and peak levels would have been greater than that in 1974.

4.3 Conclusion

On the basis of the data currently available, the flood levels experienced during the Jan 2011 flood event provide an indication of the levels that may be expected from a revised Q100 event. However, varying tidal influences and creek contributions mean that the probability associated with these levels may be different at different locations.

The January 2011 flood has brought a significant amount of new data and information on the nature of flooding in the Brisbane River and about the factors contributing to very large flood events in this catchment. Significant work is required to review Q100 for the Brisbane River in the light of this new information. This work could not be completed given the data available to the JFTF, some of which is still being collected as detailed in 4.2.5.

In light of the available information it is clear that the current Q100 needs to be reviewed. It is more likely than not that this review will raise the Q100 upwards.

On balance, the JFTF believes that, in the absence of results of a detailed flood study review, a precautionary approach should be adopted. Therefore, it considers that the actual January 2011 flood event, as observed during the event, should be used as the **interim** standard on which Brisbane City Council bases its decisions concerning habitable floor levels for new development and should be a consideration for habitable floor levels for redevelopment of existing properties. Wherever the existing DFL is higher than the January 2011 flood event, the existing higher flood level should prevail.

5.0 Benefits and Cost of New Defined Flood Event

To assist with understanding the consequences of a new DFE, five (5) alternate DFL scenarios have been qualitatively compared. These scenarios are:

- Current Q100 (3.3m at City Gauge),
- Current Defined Flood Level (3.7m AHD at City Gauge),
- January 2011 Flood Event (4.46m AHD at City Gauge),
- 1974 without Wivenhoe Dam (5.45 m AHD at City Gauge), and
- 1893 without Somerset and Wivenhoe Dams (8.35m AHD at City Gauge).

Section 6 of this report then draws conclusions on the overall benefits and consequences of changing the Brisbane River flood standard, for each of the scenarios.

5.1 Flood Risk Management Benefits

5.1.1 Nature of Flood Risk Management Benefits

The benefits of different flood risk management strategies are measured by their potential to reduce expected future flood damages and other flood impacts (including risk of injury and loss of life) compared to a base case. In the Brisbane River flooding context considered here, the benefits of various *defined flood event scenarios* are expressed as marginal benefit in comparison with the flood damage costs and flood impacts associated with the *current DFE* (the 'do nothing' option).

The estimation of the expected future flood damages/impacts has to take into account the full range of possible flood events, weighted by their annual exceedance probability. The benefits of a higher DFE (and associated higher defined flood levels) are then measured by the reduction in residual flood damages (the flood damages that are not avoided by the adoption of a specific DFE).

The types of benefits may include:

(i) Reduction in trauma to the community associated with the occurrence of a flood event that exceeds the adopted habitable flood standard and consequential loss of valued possessions. This is a result of development being more resilient to flood damage. This benefit will accrue over the long term as development and redevelopment occurs. It is generally accepted that as the DFE increases in height, the reduction in trauma to the community would reduce, over a period of time.

(ii) Existing development – gradual reduction of flood damage potential as habitable floor levels are raised through redevelopment of existing buildings. It must be noted this is a long term benefit and depends on the rate of redevelopment and refurbishment of existing building stock. Similar to trauma reduction, higher DFE's will lead to a reduction in flood damage potential.

(iii) Future development – reduction in residual flood damage cost in areas subject to the new flood level regulations. This effect provides benefits from the commencement of a new flood standard and continues to accrue as new development comes on line ie. it is a long term benefit.

(iv) Reduced cost of flood response and flood recovery measures when an event that exceeds the current DFE occurs. This benefit occurs over the long term through the overall accrual of higher flood protection afforded to people, buildings and infrastructure through development and redevelopment.

These benefits associated with setting defined flood levels for planning and building purposes can be enhanced by other flood risk management measures that raise public awareness of the flood risk, helping the affected community to reduce its exposure to flood risk by preventative measures, flood warning systems, flood mitigation and improved flood resilience. Through the Lord Mayor's Task Force on Suburban Flooding, Council has initiated many such measures since 2005.

5.2 Flood Risk Management Costs

In determining costs of alternate DFE scenarios a descriptive methodology has been used as described below.

5.2.1 Impact Assessment Descriptors

To help determine how these costs can be assessed, three key descriptors have been developed. The criteria are listed below and shown in more detail in Appendix B.

1. Urban Fabric – the impact upon infrastructure and development costs to deliver the desired urban growth patterns for Brisbane ie. the SEQ Regional Plan and CityShape 2026.

2. Social Fabric – the number of people affected, impacts upon their built environment, community facilities, amenity and the amount of change they will be required to manage in their day to day lives. For example, where a property owner's home was not previously included with the DFE, once included there may be consequences for insurance, the value of the dwelling and even community facilities may no longer be able to be located close by.
3. Economic Fabric – relates primarily to the impacts upon businesses such as development costs to achieve flood resilience. Changes in flood standards can also impact upon the decisions about locations of commercial operations that may have higher levels of flood risk e.g. private schools or a manufacturing industry with low ability to relocate expensive machinery quickly at a time of flood.

5.2.2 Limitations of Methodology

Given the data available for this investigation, there are known impacts which were not possible to consider. Some of these are listed below, but there may be others:

- Precise knowledge of cost to each property,
- Property market response,
- Housing affordability,
- Development costs, and
- Social wellbeing and health.

Additionally, habitable floor level information was not available for the various scenarios, so inundation of part or all of a property was used as a proxy in Section 5.3.3.

5.3 Assessment of Individual Criteria

Where data was available it has been used in the following assessment of impacts. Where data was not available, impact has been classified from "low" to "extreme" with reference to the descriptors in Section 5.2.1.

5.3.1 Impact on growth centres & corridors

Significant planning has been undertaken in Brisbane City through Neighbourhood Planning to deliver the CityShape 2026 and support the SEQ Regional Plan 2009-2031 growth framework and housing targets. This section aims to give an indication of the potential magnitude of impact of the various DFE scenarios on these planning initiatives.

The growth corridors and centres listed in the table below are those which could be physically affected by some form of inundation from one or more of the various DFE scenarios.

Table 5: Possible consequence of DFL scenarios on growth centres and corridors

DFE Scenario	Current Q100	Current DFE	Jan 2011	5.45m (1974)	8.35m (1893)
Albion	Low	Minor	Medium	High	Extreme
Eastern Corridor	Low	Low	Low	Minor	Medium
City Centre	Low	Low	Minor	Medium	Extreme
South Brisbane Riverside	Low	Low	Medium	High	Extreme
Woolloongabba	Low	Low	Low	Low	Minor
Milton	Low	Low	Medium	High	Extreme
Towong-Taringa	Low	Low	Minor	High	High
South West Rail Corridor	Low	Low	Medium	Medium	High
Overall Impact	Low	Low	Minor	Medium	High

5.3.2 Transport Network

Brisbane and Ipswich are to a large degree established areas with much of the transport network already in place. The consequences of new DFEs are the ability of the transport network to improve its flood immunity without significant impacts on the surrounding area in terms of amenity or functionality with other parts of the network. On this basis the consequence has been assessed subjectively on a number of elements of the transport network.

Table 6: Transport Network Consequences

DFE Scenario	Current Q100	Current DFE	Jan 2011	5.45m (1974)	8.35m (1893)
Local Roads	Minor	Medium	High	High	Extreme
Arterial Roads	Low	Low	Minor	Medium	Medium
Rail Network	Low	Low	Low	Minor	Medium
Overall Impact	Low	Minor	Medium	High	Extreme

5.3.3 Additional number of properties within DFE area

For the purpose of this exercise, properties within the DFE area are defined as those properties situated on land that shows any level of inundation during the peak of these selected flood event scenarios. Where land parcels are held together these are counted as one property. For multi-unit residential development the total number of units on that property has been counted, as they all are affected in some way, if not from direct inundation. For example, a community title development with 150 individual dwelling units may have received flood waters in its basement, though no flooding of habitable areas within any of the individual units may have occurred. In some instances, the flooding impact would have been immaterial, affecting vacant land only.

For residential properties it would have been preferable to compare the number of dwellings that would receive inundation of the habitable floor level, but this information was not available.

Table 7: Numbers of properties within DFE area

DFE Scenario	Current Q100	Current DFE	Jan 2011	5.45m (1974)	8.35m# (1893)	Jan 2011- Current DFE
Commercial	1,171	1,178	2,759	2,907	n/a	1,581
Industrial	783	1,589	2,000	2,482	n/a	411
Community	24	34	46	48	n/a	12
Multi-Unit Residential	6,814	10,756	15,834	18,025	n/a	5,078
Single Dwelling Residential	4,666	7,543	10,228	12,306	n/a	2,685
Total	13,445	21,100	30,867	35,768	n/a	9,767

This measure is not available at this time.

5.3.4 Impact on streetscapes

In determining the impact on residential streetscapes, the additional depth of inundation for each DFE scenario, compared to the current DFE is shown in Table 8. In many areas, such as Fairfield and Rocklea, the existing level of inundation currently causes difficulties with achieving house design under 8.5m. The additional consequence is dealing with the amenity issues of bulk and scale in the local setting of isolated houses over 8.5m. Therefore the assessment of this measure also factors in this consequence.

To assess this impact it is considered a typical two (2) storey house of timber and tin construction may be between 7.5 and 8.3 m in height (including 0.5m flood freeboard).

Since a large proportion of these types of houses affected during the January 2011 event are located between West End/Milton and Graceville, the average relative difference in level between Park Road and Graceville has been used. The reason for this is the effect of a rise at the City Gauge is magnified upstream. This effect is shown in the comparison of river heights in Table 8.

Table 8: Height difference of DFE scenarios from current DFE and impact on residential design.

DFE Scenario	Q100	Current DFE	Jan 2011	5.45m (1974)	8.35m (1893)
Height Difference to DFL at Park Road	-0.8	0.00	1.52	2.01	5.59
Height Difference to DFL m at Graceville	-0.87	0.00	2.05	2.75	6.73
Average Difference	-0.84	0.00	1.79	2.38	6.16
Relative Impact	Low	Nil	Medium	High	Extreme

The effective interface of a use and the street is a key factor in achieving street activation and amenity. As the height difference between the street and active building uses increases, safety, activation and amenity become harder to successfully achieve. While small differences can be accommodated, greater increases may only be accommodated by graduated design and potentially flood resistant uses.

Many inner city commercial streetscapes are situated between Teneriffe and West End, including the lower city centre and Southbank. As the majority of new development is currently occurring from the City to West End, the difference between the current DFE and the scenario DFEs at the City Gauge and West End Ferry are used as a guide to average consequence as seen in Table 9.

Table 9: Height difference (m) of DFE scenarios from current DFE and impact on streetscape

DFE Scenario	Q100	Current DFE	Jan 2011	5.45m (1974)	8.35m (1893)
Height Difference to DFE Scenario Level (m) at City Gauge	-0.4	0.00	0.76	1.75	4.76
Height Difference to DFE Scenario Level (m) at West End Ferry	-0.87	0.00	1.64	2.16	5.90
Average Difference	-0.64	0.00	1.20	1.96	5.33
Relative Impact	Low	Nil	Medium	High	Extreme

5.3.5 Impact on community infrastructure

Community infrastructure such as medical facilities, schools and the like are particularly susceptible to flood risk and many received some level of inundation during the January 2011 event. For comparative purposes, Table 10 shows the number of community facilities that would receive some level of inundation at the various scenarios.

Table 10: Potential impact on community infrastructure – medical & schools

DFE Scenario Event	Q100	Current DFE	Jan2011	5.45m (1974)	8.35m (1893)#
Facilities Affected	24	34	46	49	n/a
Relative impact	Low	Low	Minor	Medium	High

Information not available at this point of time however it is considered the impact is likely to be at least high.

5.3.7 Industry and commercial development

The principal industrial area affected by the January 2011 event is at Rocklea. This is an established area which reuses or rebuilds sites. Much of the area is under the current DFE and consequently risk management solutions are often required to manage the impacts of flooding on individual sites. As a risk management approach may be applied to development applications for industrial uses, in-depth investigation of the impacts on industry is considered outside the scope of the Terms of Reference. It is hoped however that property and business owners in these areas will choose to manage their own flood risk, using a new DFE as a guide. Table 11 shows the height difference between the current DFE and the various scenarios at Rocklea.

Table 11: DFE comparisons at Rocklea

DFE Scenario	Q100	Current DFE	Jan2011	1974	1893
Relative Difference in DFL scenarios compared to current DFL at Rocklea (m)	-087	0.0	2.05	2.99	7.05
Relative impact	Low	Nil	High	High	Extreme

Commercial development along the River is concentrated generally between the CBD and Toowong/West End. The impact on these activities will be measured by its ability to adapt to a new DFE over time. This may be through built form/design changes and/or risk and disaster management approaches, such as locating essential building services out of basements and in upper parts of buildings. As the change in DFE increases the process of adaptation becomes more challenging. Therefore, as flood restrictions on built form increase, flexibility in design decreases with potential adverse impact on building utility and costs. There is however a positive benefit over the long term as commercial precincts would become more flood resilient. The difference in level from City Gauge to West End Ferry has been used for comparison. The impact is then applied as per the discussion above, as shown below in Table 12.

Table 12: DFE comparisons in several commercial areas

Flood Scenario	Current Q100	DFE	Jan 2011	5.45m (1974)	8.35m (1893)
Height Difference to DFE Scenario Level (m) at City Gauge	-0.4	0.00	0.76	1.75	4.76
Height Difference to DFE Scenario Level (m) at West End Ferry	-0.87	0.00	1.63	2.16	5.9
Average Difference (m)	-0.64	0.00	1.20	1.96	5.33
Relative Impact	Low	Nil	Medium	High	Extreme

6.0 Discussion of DFE Scenarios

In the limited time available, the assessment of the benefits and costs of the different options could only be undertaken in a qualitative way but it is important that a full flood risk management study should be undertaken as soon as possible.

6.1 Current Q100 of 3.3m AHD at City Gauge

As can be seen from the tables throughout Section 5, the current Q100 is a theoretical flood level that is below the current DFE. Given the research undertaken into the January 2011 flood event and the advice of the expert hydrologists, it is not advisable to reduce the current DFE for the Brisbane River. Due to a lack of available information, the JFTF was unable to redefine the Q100 for the River in the time frame available although this work clearly needs to be done. Adopting the current Q100 as a new DFE would have a negative benefit in terms of improving Brisbane's flood risk management.

6.2 Current DFE of 3.7m AHD at City Gauge

The current DFE is a theoretical event that has been in place for the Brisbane River since 1978. The January 2011 flood was significantly higher than the current DFE by 0.76m at the City Gauge, encompassing an estimated 9,767 additional properties. This height difference is amplified as the distance from the river mouth increases (with some local variations), demonstrated by a height difference of approximately 2.05m at Rocklea and Graceville. Given the recommendations of the expert hydrologists, maintaining the current DFE as an interim development standard would not change the current flood risk and damage profile of the city and is not recommended.

6.3 January 2011 Flood Event Level of 4.46m AHD at City Gauge

As can be seen by looking at the history of Brisbane River annual flood peaks dating back to 1840 (refer to Section 2.3), this event of 4.46m at the City Gauge is very significant. Prior to the January 2011 flood event, only 6 other events have exceeded 4m at the City Gauge since the 1840s. All of these events occurred prior to the construction of Wivenhoe Dam.

The effect of adopting an interim DFE equal to the 2011 flood level has been assessed against the impact on the urban, social and economic fabric as defined in Section 5.2.1. Where possible the effect has been quantified. The overall impact has been assessed as Minor to Medium, with significant benefits for flood risk management accruing over time, as redevelopment and new development occurs.

Due to the limited time available, accurate financial cost implications of this option were not able to be quantified. One notable feature is that if the DFE was to move to such a level, there would be a significant impact on those communities affected by the change. Predominant matters are building heights in the suburbs upstream of West End and difficulty in maintaining streetscape in some local areas with a risk management approach. It does however set the City on a path for achieving a long term outcome of proportions approaching a medium value of flood risk management benefit. It also provides greater protection against a possible trend of more frequent large flood events.

6.4 1974 Flood level of 5.45 m AHD at City Gauge

As a comparison, the pre-Wivenhoe Dam 1974 flood event was assessed. It was used because the level was already modelled making it possible to draw the comparisons to other events.

A DFE of this level would have a High consequence on the city's urban, social and economic fabric. It would be difficult for many areas to develop properly with land sterilisation for certain uses locally, a real prospect. It would also have an impact on house raising options with this becoming an unrealistic option in many locations such as Rocklea where the habitable floor level could increase by an estimated 2.99m. In addition to the practicalities of achieving habitable floor levels above this height, detrimental impacts on both residential and commercial streetscapes should be considered.

At this level, some reconsideration of land uses may be necessary. Notably however the overall impact on growth centres and community facilities is limited, though transport networks implications will be high. Long term flood risk and damage profile of the city is likely to be significantly reduced but the costs would outweigh the benefits.

6.5 1893 Flood Level of 8.35m AHD at City Gauge

This level was assessed to provide a feeling for what an extreme event may do. In summary, a DFE of such a magnitude would require a complete reappraisal of how the city is planned, its transport network security and location of community facilities, however long term flood risk and damage profile of the city would likely be significantly reduced.

7.0 Conclusion

How does the January 2011 flood event compare to the Q100 as currently defined and Brisbane City Council's Defined Flood Event (DFE)?

In the January 2011 flood event experienced, the heaviest rains were inland on the western fringe of the Brisbane River catchment and on the Great Dividing Range. Over the Brisbane River catchment as a whole, based on rainfall captured by BoM's Enviromon rain gauges, the estimated average 5-day rainfall is 322mm, with the major sub-catchments of Wivenhoe Dam, Bremer River and Lockyer Creek receiving 370mm, 223mm and 268mm respectively.

Given the pattern of rainfall, the Brisbane River received significant flows from the upstream catchments of the Lockyer and Bremer. The flow down the upper Brisbane River (above the Lockyer Creek) and Stanley River were mitigated by Wivenhoe Dam. However Brisbane felt the full force of the flows down the Lockyer and Bremer Rivers. As a result of the rainfall, Brisbane experienced a significant river flood.

Based on examination of the rainfall patterns of a number of previous Brisbane River floods, it is concluded that the Brisbane catchment experienced a significant rainfall event with a rain pattern that was different from that experienced in 1974. Full details of the rainfall magnitudes were not available at the date of this Report. However back calculations from recorded releases from Wivenhoe and the record of water level in the dam suggest significantly more flood producing rainfall occurred than indicated by the presently available rainfall data. The calculated dam inflow hydrographs show two peaks, the first of the magnitude of 1974 and the second of greater magnitude than 1974, 36 hours later. The level recorded at Savages Crossing was higher than in 1974. Flood inflow volumes to Wivenhoe as calculated from the known releases from Wivenhoe dam and the recorded water levels in the dam total 2,650 GL as compared to a total of 1,410 GL for that location in 1974 and 2,744 GL in February 1893.

On balance the JFTF considers that the flood runoff resulting from the major rainfall event of January 2011 was greater than the 1974 event but not as great as the 1893 event.

All of the peak flood levels recorded in January 2011 by the gauges along the Brisbane River were higher than the existing Defined Flood Levels, ie. levels previously calculated for the 1974 flood event mitigated by Wivenhoe Dam. Therefore, taking into account this fact together with its assessment of the rainfall event, the JFTF considers that the January 2011 flood event was larger than the Brisbane City Council's Defined Flood Event.

The Q100 as presently defined is, in general, a slightly lesser flood than the Defined Flood Event. Therefore the JFTF considers that the January 2011 flood event was larger than the Q100 as presently defined.

Much more detailed work is required to accurately identify the probability of this event for Brisbane.

Does Q100, as it is currently described, remain the best estimate of a 1 in 100 year event?

Q100 is a theoretical flood model used to inform planning and policy. This probability-based design flood event aims to reflect typical combinations of flood producing and flood modifying factors which act together to produce a flood event that has a 1 in 100 chance in any one year of occurring at a specific location of interest.

The January 2011 flood has brought a significant amount of new data and information on the nature of flooding in the Brisbane River and about the factors contributing to very large flood events in this catchment. Significant work is required to review Brisbane's Q100 in the light of this new information. This work could not be completed given the data available to the JFTF report, some of which is still being collected.

In light of the available information about the 2011 flood event, the JFTF considers that it is essential that the current Q100 is reviewed. It is not possible to predict the outcome of such review but it is considered more likely than not that this review will lead to an increase in the magnitude of the Q100 and increases in associated flood levels.

Accordingly, what standard should be used to enable new development and redevelopment to proceed with confidence and certainty?

To answer this question five (5) scenarios have been evaluated. These scenarios are:

- Current Q100 (3.3m at City Gauge),
- Current Defined Flood Level,DFL (3.7m AHD at City Gauge),
- January 2011 Flood Event (4.46m AHD at City Gauge),
- 1974 without Wivenhoe Dam (5.45 m AHD at City Gauge),and
- 1893 without Somerset and Wivenhoe Dams (8.35m AHD at City Gauge).

On balance, the JFTF believes that, in the absence of results of a detailed flood study review, a precautionary approach should be adopted. Therefore, it considers that the actual January 2011 flood event, as observed during the event, should be used as the **interim** standard on which Brisbane City Council bases its decisions concerning habitable floor levels for new development and should be a consideration for habitable floor levels for redevelopment of existing properties. Wherever the existing DFL is higher than the January 2011 flood event, the existing higher flood level should prevail.

The JFTF notes that, in regions where the interim standard will be applied, the degree of immunity from flood risk will vary with location. This is because the January 2011 flood event is an actual event and will have variable tidal influences along the tidal reach. Consequently variable probabilities will apply along this reach.

The recommendation of a new development standard refers to land use types that are currently assessed against a DFE in the City Plan. This currently excludes industrial development however this should be considered through the current City Plan review.

Further the DFE and resulting flood regulation lines are considered only part of a flood risk management framework for a community. The approach to flood risk management for Brisbane needs to consider a broader range of initiatives if it is to effectively manage flood risk for the City. Flood risk management requires that the consequences of floods be investigated for a range of flood events up to and including the PMF. For land use planning, flood levels as well as flood flows corresponding to specific probabilities must be considered. This approach must include identification of the benefits of the management of risk, rather than seeing it as all cost.

8.0 Recommendations

It is recommended,

That the actual January 2011 flood event, as observed during the event, be used as the **interim** standard, on which Brisbane City Council bases its decisions concerning new development and redevelopment, with the essential condition that, wherever a higher level has been set as the current DFL, the higher level must apply; and that this interim standard apply until conclusion of the Commission of Inquiry and the comprehensive flood study recommended below is completed.

That all data relating to the January 2011 flood event be gathered from all sources and archived so that further analysis can make use of all data available.

That the bathymetry (river bed and banks) of the Brisbane River and its tributaries and the characteristics of the bed material from Wivenhoe dam to the mouth be measured as soon as possible.

That a comprehensive flood study be commissioned to review flood flows and levels within the Brisbane River catchment making full use of the data relating to the January 2011 flood event.

That the effects of morphological (river bed level and cross section) changes due to sediment erosion and deposition during flood events be studied for a range of flood magnitudes to determine their effects on flood levels.

That consideration be given to whether a Monte Carlo approach to the flood risk for the Brisbane Catchment is feasible and if yes, whether it should be carried out and which influencing factors should be included in the Monte Carlo approach. This may include consideration whether two or more types of rainfall events should be built into the statistical analysis for theoretical floods (In a Monte Carlo analysis the influencing input factors such as rainfall patterns, storm tracks, catchment conditions, tide and storm surge are sampled, either randomly or in accordance with their joint probabilities, to select a large number of different combinations of inputs for simulation with a catchment modelling system to develop many alternative predictions of flood events. These predictions are then analysed statistically to estimate their exceedance probabilities).

That a complete Flood Risk Management analysis for the area of Brisbane affected by flooding from the Brisbane River and its tributaries be carried out. It is essential to move from the Q100 mentality and to adopt a risk management approach in line with National Flood Risk Advisory Group (NFRAG) and other relevant guidelines. The risk management approach would require a detailed assessment of the benefits and costs of a full range of flood mitigation options.

Appendix A: Terms of Reference

Joint Flood Taskforce

TERMS OF REFERENCE (TOR)

TABLE OF CONTENTS

Document Purpose

The purpose of this document is to clearly define the Terms of Reference (TOR) for a Brisbane City Council/Ipswich City Council Joint Flood Taskforce.

Role of the Joint Flood taskforce

Brisbane City Council, in partnership with Ipswich City Council will form a Joint Flood Taskforce to investigate the January 2011 flooding events. The Taskforce will recommend interim flood immunity standards and development guidelines to manage redevelopment of flood affected properties and new development activity within the Brisbane River floodplain.

Operation of Joint Flood taskforce

The Taskforce will utilise available information to make its recommendations on the questions posed in 3.3 *Outcomes of the Joint Flood Taskforce*

The Taskforce shall provide recommendations to the Lord Mayor's Recovery Task Group by **Thursday 10 March**.

Relationship to State Commission of Inquiry

The Joint Flood Taskforce does not form part of the State's Commission of Inquiry.

The recommendations of the Joint Flood Taskforce are interim and their application may be validated or varied dependant on the outcome of the State's Commission of Inquiry. The recommendations of the Joint Flood Taskforce will be provided to the Commission of Inquiry and Flood Response Review Board.

Relationship to Lord Mayor's Flood Response Review Board and Lord mayor's Recovery Task Group (LMRTG)

The Lord Mayor has established an independent Flood Response Review Board. This Board will review the effectiveness of Council's response and disaster management arrangements, the impact of planning regulations in flood affected areas and the effectiveness of public warnings and advice, as well as the effectiveness of storm water and flood prevention infrastructure, and failure of river-based infrastructure. This Board will report in May 2011 to the Lord Mayor and the LMRTG. The progressive minutes and final recommendations of the Joint Flood Taskforce will be provided to the Lord Mayor's Flood Response Review Board.

The LMRTG, and the Town Planning Recovery Sub-Committee, will oversee the Joint Flood Taskforce and implement its recommendations on an interim basis.

Outcomes of the joint flood taskforce

The primary goal of the Taskforce is to provide expert advice and develop interim recommendations guiding development and redevelopment in Brisbane and Ipswich.

Key questions the Taskforce will need to answer are:

1. How does the January 2011 flood event compare to the Q100 as presently defined and BCC's Defined Flood Event?
2. Does Q100, as it is currently described, remain the best estimate of a 1 in 100 year event?
3. Accordingly, what standard should be used to enable new development and redevelopment to proceed with confidence and certainty?

Membership – Joint Flood Taskforce

The proposed Joint Flood Taskforce shall be comprised of:

- Chair - Emeritus Professor Colin Apelt
- Shane Hackett – Acting Manager Water Resources Branch, Brisbane City Council
- Quinton Underwood – Senior Engineer, Hydraulics, Ipswich City Council
- Erwin Weinmann - Experience: Senior Lecturer in water subjects at Monash University, Former Deputy Director CRC for Catchment Hydrology (Monash Node), and Co-author of Book VI (Estimation of Large and Extreme Floods)
- Professor James Ball - University of Technology Sydney

Membership – Technical Reference Group

In addition to the Joint Flood Taskforce, a Technical Reference Group will be established for the Taskforce to interface with as required.

It is expected the Joint Flood Taskforce would establish smaller expert technical working groups for input into the recommendations (formed from amongst the members of the Technical Reference Group).

Internal

- Kerry Doss – Manager City Planning
- Andrea Kenafake – Manager Development Assessment
- Richard Sivell – Manager Major Development
- Don Carroll – Group Manager Water – City Design
- Ken Morris – Principal Engineer Flood Management – City Design
- Bevan Lynch – Chair Urban Futures Brisbane

External (subject to confirmation)

- Water CRC, Canberra
- BMT
- Bureau of Meteorology
- Department of Infrastructure and Planning
- Department of Environment and Resource Management
- SEQ Water Grid Manager
- SEQ Water

Membership- Industry reference Group

The Taskforce will establish, consult and advise an Industry Reference Group on the proceedings of the taskforce. The Industry Reference Group will have the opportunity to provide comment and advice to the Taskforce on the release of their interim recommendations.

The Industry Reference Group will provide external advice on the needs of industry to respond to the flood in terms of redevelopment and new development standards. The group will also provide industry perspective on the potential impact of the implementation of new standards on practicality, affordability and implantation needs.

The proposed Industry Reference Group will comprise;

- Chair - Bevan Lynch – Urban Futures Brisbane
- BDO Kendalls - Mark Gray
- Commonwealth Bank - Leon Allen
- MIRVAC - Matthew Wallace
- Pradella - Brett Lentz
- UDIA – Brian Stewart
- HIA - Mike Roberts
- Property Council of Australia – Justin Goddard
- Lend Lease - Guy Gibson
- Insurance Council of Australia – Robert Wheaton
- UDIA - Brian Stewart (replacement for Martin Zaltron)
- PIA – Audra Caler
- Master Plumbers – Ernie Kratschrier
- AIA President - Peter Skinner

- BDA – Matthew Miller
- UDAL - Andrew Hammonds
- Others tbc

Role of the Joint Taskforce members

The Joint Flood taskforce Chairman will be responsible for day to day decision making within the scope of the Terms of Reference and be responsible for decision making where;

- Any significant variation to scope.
- Any change in schedule that will have an impact on delivery
- Any significant issues or risks which they are not able to deal with.

If the designated Chair is not available, then the BCC Manager Water Resources will act as proxy. The acting Chair will be responsible for convening and conducting that meeting. The Acting Chair is responsible for informing the Chair as to the salient points/decisions raised or agreed to at that meeting.

Administration

Agenda

All agenda items for each Taskforce meeting must be forwarded to the Joint Flood Taskforce secretariat by C.O.B. 2 working days prior to the next scheduled meeting.

The agenda, with attached meeting papers will be distributed at least 1 working day prior to the next scheduled meeting. The Chair has the right to refuse to list an item on the formal agenda, but members may raise an item under 'Other Business' if necessary and as time permits.

Minutes & Meeting Papers

The minutes of each Taskforce will be prepared by the Joint Flood Taskforce secretariat. The secretariat will be supported by Brisbane City Council's Water Resources Branch.

Meeting Agendas will include:

- Minutes and actions from previous meeting
- Update from the last Meeting
- Update on progress of the activities
- Key upcoming events, activities, changes
- Any Other Business
- Action summary and next meeting date

Action items arising from the meeting minutes will be forwarded to the relevant Divisional Manager and Taskforce member within two working days following each meeting.

Frequency of Meetings

Meetings are held weekly or at the determination of the Chair.

Proxies to Meetings

Members of the Taskforce will only have a proxy in exceptional circumstances. Where an extended period of absence is anticipated or known, a proxy shall be nominated with the approval of the Chairman.

The nominated proxy shall have voting rights at the attended meeting. The nominated proxy shall provide relevant comments/feedback to the Taskforce member they are representing of the salient points from the meetings they have attended

Quorum Requirements

The Taskforce members are key advisors to the Chair in their decision making capacity, however all decisions lie with the Chair.

A minimum of 4 Taskforce members is required for the meeting to be recognised as an authorised meeting and for the recommendations or resolutions to be valid.

Review Timetable

TBC

Appendix B: Details of Flood Studies that produced the 2003 Estimate of Q100

B.1 Results of flood frequency analyses

The SKM (2003) study included a broad range of flood frequency analyses for a number of sites within the Brisbane River catchment but focussed specifically on the estimation of Q100 at Savages Crossing for the pre-dam conditions. This was based on recorded flood peak data at this site for the period from 1909 to 1958 (prior to completion of Somerset Dam), extension of flood peak data (by DNRM) to cover the period from 1890 to 1909, simulated pre-dam flood peaks for the period from 1959 to 2000 (from modelling studies by DNRM), as well as a regional flood frequency analysis using flood data from Brisbane River tributaries with adequate flood record lengths.

The Q100 estimate from flood frequency analysis for the pre-dam situation is given in Table B1, together with nominal upper and lower bounds.

Table B1: Summary of Q100 estimates from FFA at Savages Crossing – pre-dam conditions (from Review Panel Report, 2003 and SKM, 2003)

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

B.2 Results of rainfall-runoff modelling

A number of different rainfall-runoff models of the Brisbane River catchment have been developed for a range of purposes. The model adopted by SKM is the RAFTS runoff routing model, which had earlier been developed by BCC and calibrated in a previous study.

The key inputs to the model and assumptions for the estimation of Q100 for the pre-dam situation are:

- Design rainfall depths for an ARI of 100 years and for a range of durations (adopted average rainfall depth over catchment = 308 mm, based on CRC-FORGE design rainfalls for a critical duration of 72-hours, with allowance for an areal reduction factor)
- Rainfall temporal pattern – standard ARR87 temporal pattern for this location, duration and ARI applied over whole catchment (with a sensitivity analysis of temporal patterns based on 4 other patterns)
- Rainfall spatial pattern – based on the spatial variation of CRC-FORGE point design rainfall estimates (with a sensitivity analysis of spatial patterns based on rainfall distributions experience during 7 historical storms); storm assumed to be stationary over the catchment
- Design losses – 10 mm initial loss and 1 mm/h continuing loss, uniformly distributed over whole catchment – these losses reflect a relatively saturated state of the catchment at the start of a flood event

For the post-dam situation two further inputs/assumptions were necessary:

- Initial state of storages – assumed to be at FSL (RL 67.0 m AHD) at the start of the flood event
- Flood operation of dams – Wivenhoe assumed to be operated according to operational rules incorporated into WIVOPS simulation program

The best estimates of Q100 for the pre-dam and post-dam situation at three key locations are given in Table B2, together with nominal upper and lower bounds.

Table B2: RAFTS based Pre- and Post-Dam Q100 flow estimates (m3/s) with indication of plausible range of variability (from Review Panel report, 2003, and SKM, 2003)

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	60
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

B.3 Adopted Q100 estimate and uncertainty bounds

The Review Panel noted the relatively wide band of uncertainty about the Q100 estimates from both methods but considered that the pre-dam flood peak estimates at Savages Crossing derived by flood frequency analysis were more reliable than the RAFTS model-based estimates, which involved a range of additional assumptions. The post-dam estimates from RAFTS modelling were thus adjusted accordingly to give the recommended Q100 (peak flood) values shown in Table B3.

Table B3: Recommended Pre- and Post-Dam Q100 flow estimates (m3/s) with indication of plausible range of variability (from Review Panel Report, 2003 and SKM, 2003)

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

Glossary

ARI- Average Recurrence Interval - the expectation (or average over many occurrences) of the interval (years) between flood events with a similar magnitude

AEP – Average Exceedance Probability, the likelihood of occurrence of a flood of given size or larger in any one year, usually expressed as a percentage

AHD - Australian Height Datum - is the national surface level datum corresponding approximately to mean sea level. Levels measured relative to this datum are given as "m AHD".

Bathymetry – Bed levels and cross sectional dimensions of a river channel

COAG – The Council of Australian Governments

CRC-FORGE- Cooperative Research Centre Focussed Rainfall Growth Estimation. The CRC-FORGE method is a regional analytical method for point rainfall estimates of low Average Exceedance Probability (AEP) from data records on average less than 100 years duration. The method is a development of the FORGE method (UK) by the Cooperative Research Centre for Catchment Hydrology

DFE - Defined Flood Event - The flood event from which defined flood levels are developed and ultimately the flood control lines for development

DFL- Defined Flood Level- The flood level resulting from the Defined Flood Event

DTM- Digital Terrain Model

Environmon – a network of rain gauges owned by BoM

Flood hydrograph- Expresses peak flow, flood event volume and flood duration in a graph.

Flood quantiles – the values of a flood characteristic (peak flow, flood volume, flood level at a site) that correspond to specified ARIs

Freeboard – a margin above a defined flood level set to provide a factor of safety for uncertainties in flood level estimates and localised flood effects

Mike-11- A computer program for simulation of channel flows using one dimensional equations

Monte Carlo methods (or Monte Carlo experiments) - a class of computational algorithms that rely on repeated random sampling to compute their results. With respect to catchment simulation, the influencing factors are sampled (either randomly or in accordance with their joint probabilities) for simulation with a catchment modelling system to develop alternative predictions. These predictions are then analysed statistically to estimate their exceedance probabilities

Minor, Moderate and Major flooding- as defined by BoM:

- minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.
- moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.
- major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

NFRAG- National Flood Risk Advisory Group

PMF- Probable Maximum Flood- PMF cannot be assigned a probability
of occurrence but may be considered as the largest flood that could possibly occur and never be exceeded

Q100- the peak flow rate at a specific location that has a 1 in 100 chance of being equalled or exceeded in any one year (1% annual exceedance probability – AEP; or an average recurrence interval (ARI) of 100 years).

SCARM - the Standing Committee on Agriculture and Resource Management, a committee of the Agriculture and Resource Council of Australia and New Zealand (ARMCANZ)

RAFTS - an acronym for a catchment simulation model - River And Flow Training System

Rating Curve - a rating curve is used to convert a recorded flood level at a gauging station to the equivalent discharge at the gauging station.

WIVOPS- Wivenhoe Dam Operations Systems

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