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ENVIRONMENTAL

SUBMISSION TO QUEENSLAND FLOODS COMMISSION OF INQUIRY

THE NEED FOR A REVISED HYDRODYNAMIC MODELLING SYSTEM TO PROVIDE A BASIS FOR OPTIMISING CONTROLLED RELEASES FROM WIVENHOE DAM FOR FLOOD MITIGATION

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10 March 2011

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CONTENTS TABLE

Page

1.0 BACKGROUND 3
1.1 Geographical Context 3
1.2 Background to this Submission 3

2.0 COMMUNITY EXPECTATIONS REGARDING THE FLOOD MITIGATION POTENTIAL OF WIVENHOE DAM 4
2.1 Expectations Prior to the Completion of Construction of Wivenhoe Dam 4
2.2 Expectations Post Completion of Wivenhoe Dam 5

3.0 OPERATING THE FLOOD GATES FOR OPTIMAL FLOOD MITIGATION 8
3.1 Overview of the Existing System 8
3.2 Review of the Current Primary Objectives of the *Manual of Operational Procedures* 8
3.3 Review of Strategies Included in the *Operational Procedures* 9
3.5 Measures Taken in 2005 Upgrade to Protect the Structural Integrity of Wivenhoe Dam 12

4.0 EXAMINATION OF THE SUITABILITY OF THE REAL TIME FLOOD MODEL FOR MINIMISING FLOOD DAMAGE IN URBAN AREAS DOWNSTREAM 18
4.1 General Comments On the Structure of the Real Time Flood Model 18
4.2 Inclusion of the Real Time Flood Model (RTFM) in the *Operating Procedures* ... 19

5.0 RECOMMENDATIONS TO THE COMMISSION CONCERNING THE NEED TO UPGRADE OR REPLACE THE REAL TIME FLOOD MODEL AND REVISETHE OPERATIONAL PROCEDURES 21
5.1 The Need to Revise the Objective of the RFTM 21
5.2 The Need to Upgrade the Hydrodynamic Modelling Capability within the RTFM 21
5.3 Potential to Add an Optimising Module 21
5.4 Hydrological Modelling 22
5.5 Flood Operations Strategies 22
5.6 Retention of Existing Design Flood Levels until RTFM has been Upgraded 23

REFERENCES 24
FIGURES 25
ATTACHMENTS 26
EXHIBITS 30

1.0 BACKGROUND

1.1 Geographical Context

The Wivenhoe Dam on the Brisbane River above Lowood was constructed after the 1974 floods to provide 1,150,000 ML of water supply storage and up to 1,400,000 ML of temporary flood storage, the amounts and rates of storage utilised during a flood event being managed by the operation of flood gates (**Reference 1**).

The general location of the dam in the catchments of the Stanley and Upper Brisbane rivers, its location immediately upstream of the confluence of Lockyer Creek and, much further downstream, inflows from the extensive Bremer River catchment and from local creeks causing localised flooding in the Greater Brisbane area, may be seen by reference to **Figure 1.**

The relative locations and magnitudes of these storages, catchments, stream flow paths and floodplains are more readily identifiable by viewing the *Brisbane and Environs* 3–dimensional map, the copyright for which is held by Geo-Maps Company, 122 Castlereagh Street, Sydney 2000. This map has a 1:300,000 horizontal scale and a 1: 70,000 vertical scale. A copy of this map is proposed to be tendered for consideration during the Inquiry as **Exhibit 1** of this submission.

1.2 Background to this Submission

This submission is a more-detailed response to the request for submissions to the Queensland Floods Commission of Inquiry than that which was foreshadowed in an email to Counsel Assisting the Commission by the author, dated 15 February 2011, requesting further information which would enable a comprehensive submission to be prepared.

A copy of that email is included as **Attachment 1.**

It is considered that this present submission is now based upon sufficient evidence that it is suitable for a submission to the first part of the Inquiry in that it addresses issues which need to be considered for implementation prior to the 2011 – 12 wet season.

2.0 COMMUNITY EXPECTATIONS REGARDING THE FLOOD MITIGATION POTENTIAL OF WIVENHOE DAM

2.1 Expectations Prior to the Completion of Construction of Wivenhoe Dam

Being downstream of the Somerset Dam on the Stanley River catchment, the water supply and flood storage capacity of the Wivenhoe Dam have significantly augmented the total amount of water available for urban water supplies and the total volume of flood storage since its completion in 1985.

As a consequence, there has been an expectation in Brisbane and Ipswich that the flood storage in the dam can be managed to achieve lower flood levels in Brisbane than were experienced during the January 1974 flood event. This major flood has been estimated to have been the result of precipitation in the catchments of the Wivenhoe and Somerset Dams similar to that expected of a 40 - 50 year average recurrence interval (40 - 50 yr ARI) rainfall event.

This expectation was given some quantification in the information released as a series of pre-Wivenhoe flood maps in 1975 which showed the anticipated boundaries of inundation areas under a range of major rainfall events, together with an indication of how these might be compared with the post - Wivenhoe Dam scenarios. These maps were produced as the result of a report prepared as a response to the 1974 flood by the Snowy Mountains Engineering Corporation (**Reference 2**).

An extract from the flood map for the City reaches of the Brisbane River is included with this submission as **Figure 2.**

A copy of Sheet 4 of the Brisbane River Flood Plain Map can be provided as **Exhibit 2.**

Each of the 18 sheets comprising the Flood Map contains information on its reverse side. This information, including the pre-Wivenhoe river flood profiles for a range of flood flows past the Brisbane City Gauge (**Figure 3**), provide an overall perspective of the probable extent of flooding prior to the construction of Wivenhoe Dam.

In most cases, development planning is based around estimates of the 100 yr ARI flood event, with the hydrology used to generate the rainfall and runoff inflows being based on recognised statistical information and modelling, with the flows and water levels along the streams and floodplains being calculated by the use of hydraulic models.

While the hydrological and hydraulic analyses used to generate the profiles of **Figure 3** are unknown to the author at this stage, it is worth noting from **Figure 3** that the pre-Wivenhoe Dam peak water level at the Brisbane City Gauge for a 110 yr ARI flood was estimated to be RL 8.0 m AHD and that the peak flood flow in the river would have been 13,200 m^3/s.

If, as indicated on the reverse side of the Flood Map sheets, Wivenhoe Dam was expected to cause a 2 metre reduction in flood level during a lesser 1974 flood flow of 8650 m^3/s, it is indicated that the post- Wivenhoe 110 yr ARI flow would be reduced to a pre-dam 60 yr ARI flow of 10,150 m^3/s and the peak level reduced to RL 6.0m AHD

The notes on the reverse side of the Flood Map sheets also indicate that if peak flood levels could be reduced at the Brisbane City Gauge by two metres, the estimated reduction in flood damage during a 1974 type flood would be approximately $ 150 million dollars (in 1974 $A).

At the time of writing this submission, no information was available to the author to indicate the nature of the investigations adopted by the designers of Wivenhoe Dam which may have

led to the adoption of a temporary flood storage capacity significantly greater than that provided for water supply purposes. It can only be surmised that savings, for example, of up to $ 150 million in a 1 in 50 year flood and lesser amounts in more frequent floods, was a justifiable reason.

It might also be expected that the one metre 1974 flood level mitigation provided by the Somerset Dam could be significantly improved by providing a far greater amount of flood storage in a downstream dam which controlled the discharge from approximately 50 percent of the catchment above Brisbane's urban areas. For example, the flood storage capacity in Somerset Dam is 524,000 ML, whereas that in Wivenhoe Dam is 1,400,000 ML.

The author has sought to obtain further information on what flood levels might be expected in Brisbane post-Wivenhoe and found that there is a history of disagreement on what might be called "design flood levels" and that much of this goes back to how the *Manual of Operational Procedures for Flood Mitigation for Wivenhoe and Somerset Dam* (**Reference 3**) and measures of catchment hydrology may have been interpreted from time to time by Council and Queensland Government officers.

It is relevant in this regard that the initial estimates were identified in a March 2004 report by the Crime & Misconduct Commission into the Brisbane City Council's handling of flood study reports (**Reference 4**):

> *In 1984 a study was conducted to assist in the refinement of operational rules for the Wivenhoe Dam. This study assessed the Q100 flow at 6800 cubic metres per second (m^3/s) at the Port Office Gauge. The Q100 level at the Port Office Gauge estimated by this study was 3.8m AHD. The BCC later adopted development levels which reflected this estimate of the Q100.*

2.2 Expectations Post Completion of Wivenhoe Dam

It is apparent from the available reports that the *Operating Procedures,* as interpreted by the various stakeholders in Brisbane River management, have been a significant factor in establishing "design flood levels" in Brisbane and Ipswich and that there is no evidence of how the dams could be operated to optimise their flood mitigation potential under varying but significant rainfall and runoff events.

The only references appear to refer to differences in design flood flows and peak water levels, principally for the Q100 or 100 yr ARI design flood event.

Reference 4 states, relevant to the apparent disparity between flood levels generated by the various agencies involved in Brisbane River flood mitigation and floodplain planning which led to the CMC's inquiry:

> *In 1992 the DNRME released results of a study to apply the temporal rainfall distribution pattern suggested in the 1987 publication* Australian Rainfall and Runoff *(a guideline document published by the Institution of Engineers Australia). This study, which was undertaken for the South East Water Board and not specifically for a Q100 flood event in Brisbane, produced a Q100 estimate at the Port Office Gauge of 9380 m^3/s. This, in turn led to a re-examination by Council officers of the risk of the Brisbane River flooding and to a decision that a comprehensive flood review was necessary.*

It would appear that the DNRME study raised questions concerning dam safety responsibilities and how these might be addressed. As a result a lengthy review of the impact of dam management on Brisbane's 1984 design flood levels was undertaken.

This culminated in the production of a draft report by Council's City Design section in 1999 (**Reference 5**), which stated:

> *At the Port Office gauge the flood level corresponding to the calculated 1 in 100 year design flow of 8,600 m^3/s is estimated to be 5.0 m AHD. The current development design flood level, based on the 1984 study, is 3.8 m AHD, some 1.2 m lower than the level predicted in the study. From the two flood profiles plotted on Figure 3 it can be seen that the flood levels calculated in this study vary from about 1.0 m to almost 3.0 m higher than the current development design flood in Brisbane.*

This was viewed with some concern by Council who commissioned more flood modelling and, after lengthy discussions, DMRME carried out their own studies and provided the preliminary results of this study to Council on 27 June 2003.

Council then engaged an independent panel of experts to review the information.

The experts' report of 3 September 2003 (**Reference 6**) found as follows:

> *With respect to its Terms of Reference, the Panel:*
>
> *(i) have reviewed the methodology used by SKM to determine the Q100 river flow and level;*
> *(ii) believe that the appropriate technical processes have been followed in this study;*
> *(iii) based on the evidence available, is of the view that, for the Brisbane Port Office, the best current estimates for*
>
> - *the Q100 flow is 6000 m^3/s*
> - *the Q100 level is 3.3.m AHD*
>
> *There is an inevitable degree of uncertainty in any estimates of this kind. The Panel believes the possible range for flow to be 5000 to 7000 m^3/s; for the level to be 2.8 to 3.8 m AHD.*

Many of the differences concerning design flows and design water levels, as determined by the two reports, could be explained by differences in the hydrological modelling, by potential differences in how to interpret the operating rules of Wivenhoe Dam and by potential differences in how to apply the phasing of releases under the dam operating rules to the input to the hydraulic model used to determine design flood levels.

It is understood that the model commenced significantly downstream of the dam wall, at a locality where the outflows from Lockyer Creek discharge before entering a relatively confined valley downstream of Savages Crossing.

Council continued to adopt the 1984 design flood levels.

In 2007, Brisbane City Council's Taskforce on Suburban Flooding issued a report (**Reference 7**) which concluded as follows with respect to river flooding:

- *With regards to river flooding, the Taskforce notes that an Independent Expert Panel has recently reviewed flooding associated with the Brisbane River (2003, Review of*

Brisbane River Flood Study) and that development and redevelopment in areas below the Defined Flood Event (DFE) flood level have strict flood immunity requirements under the Brisbane City Plan. Such requirements are supported.

- *The Taskforce recognises the very low risk of dam failure flooding. It is noted that this risk is managed principally through dam safety audits that are a State Government responsibility.*

The extract from a recent Floodwise Property Report from Council's *Floodwise* system (**Attachment 2**), downloaded from the website for a property located near the Brisbane River Flood Gauge, 3 Edward Street and included with this submission as **Figure 4**, shows a 100 yr ARI flood level here to be RL 3.9m AHD, which is consistent with the independent panel's advice in 2003 and the earlier 1984 design flood level information.

It is understood that Council has subsequently carried out 2-dimensional hydrodynamic modelling of the Brisbane River to produce more-accurate floodplain planning and flood forecasting information than can be obtained from the 2003 report and from the Real Time Flood Model incorporated in SEQWater's *Operating Procedures.*

An example of the 2-dimensional flood mapping obtained from the Council website at the time of the January 2011 flood and included with this submission as **Figure 5**, shows the extent of the inundated area during a PMF (Probable Maximum Flood), for which the river flow appears to have been estimated to be 12,000 m^3/s.

It is obvious from the variability in the various assessments that the degree of inundation of Brisbane's flood prone areas is quite dependent upon the degree of flood mitigation which can be applied under the dam's current operating rules and the reliability of results obtained from the Real Time Flood Model during major flood events.

As a consequence of the above and for the reasons outlined later in this submission, the author has reached the following conclusions regarding the flood mitigation potential now available as a result of construction of the Wivenhoe Dam:

- If the *Operational Procedures* in place at the time of the January 2011 flood had been based upon the use of an updated and upgraded hydrodynamic model, rather than the current Real Time Flood Model, the operators should have been able to manage the releases from Wivenhoe Dam within the expectations of the *Expert Review*, such that the Q100 flood levels identified by Council should not have been exceeded in the apparently worst affected areas.

- The Real Time Flood Model should be upgraded or replaced and the *Operational Procedures* modified accordingly to incorporate best practice flood mitigation technologies.

- The design flood levels as shown by Council's current Floodwise Property Reports should be retained until the Real Time Flood Model and the *Operating Procedures* have been modified and the resultant model which incorporates these technologies is used in a floodplain planning mode to generate design flood levels that incorporate the improvements in flood mitigation likely to be found possible.

Argument supporting these conclusions is provided in the following sections of this submission.

3.0 OPERATING THE FLOOD GATES FOR OPTIMAL FLOOD MITIGATION

3.1 Overview of the Existing System

Because of the need to be able to manage flood storage during the rising and falling stages to less than the inflows into the dam, the five flood gates built into the Wivenhoe Dam were designed to be opened as required during a flood event and also to provide a means for significant environmental flows to be released downstream for ecological and water quality purposes.

The extent to which the gates should be opened under a range of dam inflow scenarios has been nominated in a series of manuals of operational procedures – the current Revision 7 of the *Manual of Operational Procedures for Flood Mitigation and Wivenhoe Dam and Somerset Dam* (November 2009) (**Reference 3**) being only available outside a nominated distribution list as a "redacted version".

This part of the submission relies on the limited amount of information made available in the redacted version of **Reference 3,** supplemented by material recently obtained from ANCOLD references concerning the design and operation of Wivenhoe Dam, the author's knowledge of Brisbane River flooding and a limited amount of data collected during and subsequent to the January 2011 flood event, including recorded flood levels in the Wivenhoe Dam and in the valleys of Lockyer Creek and the Brisbane and Bremer Rivers (**Attachment 3**).

3.2 Review of the Current Primary Objectives of the *Manual of Operational Procedures*

It is noted that the primary objectives of **Reference 3**, in order of importance, are:

- ensure the structural safety of the dams;
- optimum protection of urbanised areas from inundation; (author's emphasis)
- minimise disruption to rural life in the valleys of the Brisbane and Stanley Rivers;
- retain the storage at Full Supply Level at the conclusion of the flood event; (author's emphasis) and
- minimise impacts to riparian flora and fauna during the drain down phase of the Flood Event.

It is the author's opinion that only the first three objectives require to be considered during the rising stage of the Flood Event and that the structural safety of the Wivenhoe Dam has been shown to be quite adequate for dam inflows of greater than 10,000 year average recurrence interval (10,000 yr ARI) and should not be of concern during significantly lesser floods (**References 1, 8, 9,10, 13, 14**).

Thus, during lesser than extreme but during more frequent major floods, the provision for the optimum protection of urbanised areas from inundation should be the principal objective when using the current Real Time Flood Model and flood forecasting methodologies or, as is now proposed, when using a fully integrated hydrodynamic modelling system to manage dam releases to maximise flood protection of potentially inundated urban areas.

The provisions in the *Operational Procedures* for minimising disruption to rural life in the river valleys appear to be generally concerned with maintaining the trafficability and structural integrity of bridges and bridge approaches downstream of the dam.

As a result, it appears that too much weight can be given by the dam operator to these constraints when selecting releases during the rising stages of a flood.

This effectively constrains the time during which a higher release strategy can be developed to optimise the flood protection expected in urban areas further downstream while not allowing the dam water level to reach the fuse plug initiation level.

This factor significantly stresses the optimal application of the Real Time Flood Model and reduces the ability of the dam operator to test options that might minimise peak flood levels in the downstream urban areas.

It is considered that the lesser importance of maintaining the dam level at Full Supply Level at the conclusion of a flood event reflects the original dam design philosophy of providing a higher temporary flood storage capacity (1,400,000 ML) when compared with its full water storage capacity (1,150,000 ML).

The redacted version of the *Operational Procedures* appears to be relatively silent on how to optimise the protection of urban areas from inundation, a term which implies minimising flood levels in the urban areas of the downstream floodplains.

However the short section of the *Procedures* which deals with such inundation (Section 3) refers only to controlling dam release flows in a number of locations – none of which appear to be in potentially inundated urban areas.

3.3 Review of Strategies Included in the *Operational Procedures*

Section 8.4 of **Reference 3** describes the four strategies (W1 to W4) to be used during a flood event to achieve the stated objectives of the *Operating Procedures.*

These may be summarised by the following extract from Section 8.4 of **Reference 3:**

> *The strategy chosen at any point in time will depend on the actual levels in the dams and the following predictions, which are to be made using the best forecast rainfall and stream flow information available at the time:*
>
> - *maximum storage levels in Wivenhoe and Somerset Dams;*
> - *peak flow rate at the Lowood Gauge (excluding Wivenhoe Dam releases); and*
> - *peak flow rate at the Moggill Gauge (excluding Wivenhoe Dam releases).*

None of the above can be directly related to projected flood levels in the downstream urban areas which could be inundated if the release flows are excessive.

Section 8.4 recognises that release strategies are likely to change as forecasts and rainfall change in the catchments and, also, that it is unlikely the actual range of strategies to be used to manage flooding during a flood event can be predicted at the commencement of a flood event.

It also recognised that strategies may need to change during the course of an event in response to changing rainfall forecasts and stream flow conditions *..to maximise the flood mitigation benefits of the dams.*

A common need to change strategies is often created by the arrival of a second burst of rainfall in the catchments – as has often been found during major flood events.

Apart from the rather simplistic suggestion ....*when determining dam outflows within all strategies, peak outflow should generally not exceed peak inflow* ...reference is made to the use of the flowchart included as **Figure 6** of this submission ...*to select the appropriate strategy to use at any point in time.*

Figure 6 shows that these strategies relate firstly to the need to initiate release strategy (W1) if the dam water level is likely to exceed RL 68.5m, i.e after the inflows to the dam cause the predicted dam water level to rise by 1.5 metres above full supply level and after a quite significant amount of the dam's total flood storage capacity has been lost.

Reference to **Figure 7**, extracted from the Bureau of Meteorology web-site during the falling stages of the recent January 2011 flood event, shows that the dam water level was maintained at around RL 68.5m for a significant period (> 12 hours) prior to the start of the peak inflow into the dam.

This is an indicator that the flow release strategies of the *Operational Procedures* are not directly linked through the Real Time Flood Model to the goal of minimising the extent of flood damage in the urban areas downstream.

An estimate of the volume of flood storage which was lost through not releasing water as soon as the dam water level started to rise about Full Supply Level of RL 67.0m will be included as an addendum to this report, when more information concerning the time history of dam flood levels prior to reaching 68.5m are known and the results analysed with the aid of an approved version of the dam's stage –storage relationship (not included in the redacted version of the *Operating Procedures*).

There appears to be no obvious link between flood flows produced by the Real Time Flood Model to flood levels observed in the flood monitoring stations downstream of the Moggill gauging station and levels indicating the Major, Moderate and Minor flood classifications of the Bureau of Meteorology.

3.4 Demonstration of RTFM System Performance

Reference 15, a paper describing the real time flood management of Wivenhoe and Somerset Dams during the 1999 flood, provides summary descriptions of the *Operational Procedures*, the data collection system and the Real Time Flood Model.

It provides specific information of how the overall system was implemented and performed during the February 1999 flood event – claimed to be ...*about 80% of the magnitude of the disastrous 1974 event* .

With regard to the statistical rainfall experienced during this flood event, the paper states:

> *The February event was a significant flood event in the Brisbane River. This was especially so in the upper Brisbane River and Stanley River catchments. Rainfalls in the upper Brisbane catchments were typically greater than those associated with 2% AEP* (50 yr ARI) *events and at Devon Hills rainfalls were greater than the 0.5% AEP* (200 yr ARI) *event.*
>
> *The resultant flood in the upper Brisbane River was of a similar magnitude to the January 1974 event although the volume was not as large.*

Below Wivenhoe Dam there were only minor rainfalls and this only generated minor flows in Lockyer Creek and the Bremer River. This avoided any repeat of the January 1974 flood event type flooding.

The following extract from **Reference 15** provides a basis for comparison of how the system performed at that time :

Characteristic	Wivenhoe Dam	Somerset Dam
3-day total rainfall in catchment	263 – 306 mm	432 mm
Maximum inflow	6922 m^3/s	3778 m^3/s
Volume of inflow	1,198,000 ML	522,000 ML
Storage Deficit at start of event	297,000 ML	207,800 ML
Maximum outflow	1800 m^3/s	910 m^3/s
Volume of outflow	900,800 ML	324,200 ML
Peak Reservoir Level	EL 70.38 mAHD	EL 103.03 mAHD

Thus, while the actual and anticipated inflows were significant, the paper demonstrates that, at the start of the flood event, it was known that 43 mm of runoff would be required before the dam reached full supply level (67.0 mAHD) and that the flood gates might need to be opened. It was also estimated that 112 mm of total rainfall at an average rainfall intensity of 10 mm per hour would be required to get to this point – mainly because the Wivenhoe Dam was at 75% supply capacity at the start of the flood event and Somerset Dam was at 53% supply capacity.

Figure 8, from **Reference 15**, shows that, even though there were two distinct peaks in the rainfall rate and the later peak had the greater volume, the dam discharge was managed to avoid the peak outflow from the Lockyer Valley and that the peak discharge from the dam was limited to 1800 m^3/s by enabling this flow to extend over two days.

As a consequence, it was possible to limit the impact of the flood to the reaches downstream to Mt Crosby for a little longer than this period and to avoid exceeding a minor flood in Brisbane's urban areas.

The performance of the *Operational Procedures* during this flood event were thus not stretched into providing significant flood mitigation in Brisbane's flood-prone areas.

As the strategies described in the paper are quite similar to those which are included in the current *Operational Procedures*, it is of concern that apparently SEQ Water has not modified the procedures to take into account the disparity in design flood levels in Brisbane that were the subject of such public dispute that they were investigated by the Crime and Misconduct Commission.

3.5 Measures Taken in 2005 Upgrade to Protect the Structural Integrity of Wivenhoe Dam

3.5.1 General Observations

It is noted that protecting the structural integrity of both Wivenhoe and Somerset Dams is still the prime objective of the *Operating Rules* and is given more weight than to protecting urban areas from inundation.

It is considered that this weighting needs to be placed in context following the 2005 augmentation of Wivenhoe Dam, which should have removed most concerns about the integrity of the Wivenhoe and Somerset Dams from consideration when operating the flood gates for flood mitigation.

The author's conclusions in this regard are based upon consideration of several papers obtained from the Australian National Committee on Large Dams (ANCOLD) and referred to in this submission as **References 1, 8,9,10,13 & 14.**

These references show that, by upgrading Wivenhoe Dam by raising its crest level and including an auxiliary spillway, the dam's structural integrity should now be sufficient to withstand a Probable Maximum Flood – a quite unlikely event that needs to be taken account of in the maintenance of the completed structure rather than in mitigating floods.

The relevance of this upgrade in probability terms is best exemplified by the following extract from **Reference 13**, which describes the basis for the dam's flood security upgrade – an upgrade which was considered necessary to adapt to changes in the methodology used to predict Probable Maximum Precipitation in tropical areas and to changes in the *ANCOLD Risk Guidelines.*

It is stated as follows:

> *Upon completion of the Stage 1 works, the Dam Crest Level will be the 1 in 100,000 Annual Exceedance Probability (AEP) event (peak inflow of 43,000 m^3/s). The existing Dam Crest Flood (DCF) has an AEP of 1 in 22,000 (peak inflow of 25,700 m^3/s.*
>
> *By comparing the pre and post upgrade Dam Crest Floods it can be seen that the Stage 1 works provide a substantial reduction in flood risk and ensures the dam satisfies the ANCOLD societal risk criteria.*
>
> *Stage 2 will be constructed within a 15 to 20 year time frame and will increase the flood capacity to cater for the PMF (peak inflow of 49,000 m^3/s).*
>
> *Stage 1 is currently being constructed by the Alliance and is detailed in this paper.*

Reference 13 summarises the works which were proposed to comprise Stage 1 as follows. The author of this submission has assumed that these works have been constructed :

- *A new 164 m wide secondary spillway located through the right abutment of the dam controlled by three fuse plug embankments. The three fuse plugs proposed for Stage 1 result in the best compromise between delaying the triggering level of the fuse plugs ad optimising the width of the spillway.*
- *Raising the Maximum Flood Level by 3m to RL 80 (1m above the embankment crest level).*

- *Strengthening the existing spillway against overturning, protect the spillway gates, and modify the dam crest to minimise piping risk for the increased flood loads*

and states that the proposed future Stage 2 upgrade will comprise:

- *A new 100 m wide tertiary spillway located through Saddle Dam 2 controlled by a single fuse plug embankment.*

3.5.2 Consideration of Adequacy of Upgrade in January 2011 Flood

It is relevant to consideration of the manner in which flood storage was released during the January 2011 flood event, that **Reference 13** provides the following information concerning the current Stage 1 upgrade in Table 1 of that paper:

Maximum Flood Level (MFL)	*The adopted MFL for Stage 1 of the works is RL 80 m AHD*
Spillway Initiation	*The first fuse plug embankment initiates at a flood event with an AEP of 1 in 5000.*

Figure 9 of this submission shows Tables 2 – 4 of **Reference 13** which clearly indicate how the main spillway, fusible plugs and auxiliary spillways of the current dam have been designed to operate.

It shows (Table 2) that the main spillway crest level is RL 67 m AHD. It might be noted that the *Operating Procedures* for lake levels up to 68.25m AHD allow for a range of spillway discharges up to 1900 m^3/s to protect bridges if the lake level is likely to be less than 68.5 m AHD. However, it allows for switching to strategies W2 or W3 ...*if the level reaches EL 68.5m in Wivenhoe Dam.*

Reference 11 notes with regard to the potential flood mitigation of the dam and its upgrade:

- *Both Wivenhoe and Somerset Dams provide significant flood mitigation benefits for the design flood outflow peaks compared with the pre dam flood flows.*

- *The proposed works do not change estimated flood outflows for flood events up to the 1 in 500 AEP event, thereby preserving the flood mitigation benefits of Wivenhoe Dam for more frequent flood events.*

3.5.3 Apparent lack of recognition that hydrodynamics rather than hydrology provide a more reliable basis for selecting flood mitigation strategies

The following comments may be made concerning the apparent manner in which flood storage was released from Wivenhoe Dam during January 2011 in the context of the above information. These comments are made in the absence of the detailed rainfall and flow records held by the Bureau of Meteorology (BoM) and SEQ Water and of other than anecdotal evidence of the actual rates of release from Wivenhoe Dam.

The following brief explanation of hydrological and hydraulic modelling may assist the Commission in understanding the relevance of each type of computer program or model in assessing use of the RTFM in flood mitigation.

Hydrological models are used to generate the rate at which rainfall converts to runoff in the hydraulic model's catchments and sub-catchments and provide data to be input to the hydraulic model.

They may be real time, in which the hydrological model estimates inflows from actual rainfall intensities and patterns using recognised software or hypothetical, generating "design flood" inflows to a hydraulic model to generate the flows and water levels in the area covered by the hydraulic model. In this context they normally utilise data and methodologies provided in the most recent versions of "Australian Rainfall and Runoff" (**Reference 11**).

Hydraulic models, on the other hand, use the equations of motion to route the inflows from hydrological models from the upstream to the downstream boundaries of the area in which flood flows, water levels and velocities are required to be simulated for comparison with recognised criteria.

Hydraulic models may be either steady state or hydrodynamic. The former are normally used in relatively small models to investigate flows, velocities and water levels in structures where flood storage effects are relatively minimal. They are rarely used now in floodplain management.

Hydrodynamic models, by incorporating algorithms which solve the equations of conservation of mass, momentum and energy, can predict variations with time in flood flows, velocities and water levels at various points in a flow network (e.g. MIKE-11) or at numerous grid points in a two-dimensional network extending over the complete area of inundation (e.g. MIKE-21 and TUFLOW).

Because of the amount of computing power and speed required to solve the equations in a two-dimensional model, a network model representing the stream flows can be embedded in the two dimensional model representing flood plain and flood storage areas in software such as MIKE-FLOOD and later versions of TUFLOW.

Modelling linkages between flood flows and flood levels is a fundamental part of hydrodynamic modelling of floods in streams and floodplains and, if carried out two-dimensionally, can generate instantaneous plots of flood level, inundation depth and overland flow velocity in the floodplains and inundated riparian areas – the product of depth of inundation and velocity being an important indicator of potential flood damage and risks to life and property (**Reference 12**).

It is the author's opinion that indicators of catchment hydrology have been used as the drivers of the Real Time Flood Model and the *Operational Procedures*, whereas contemporary flood mitigation technologies would place more emphasis on basing flood gate operation upon the use of fast hydrodynamic modelling to test control strategies and demonstrate their potential performance in the flood affected areas upstream and downstream of the dams.

There are a number of indicators that the rainfalls in the catchment, their local amounts and their areal distribution, are such that the rainfall would have been less than that which would cause a Q100 flood event - that event being as described in the 2003 review of Brisbane flood levels undertaken by the expert panel (**Reference 6**).

The BoM dam water level record shown on **Figure 7** shows that a level of 68.5m was reached in the dam on Saturday 8 January 2011 and did not start to increase until mid-afternoon January 9.

Strategy 2 could have been implemented probably as early as midday, Saturday January 8 and would have allowed releases to cause the peak flow at Lowood to reach 3500 m^3/s at Lowood or 4000 m^3/s at Moggill.

Consideration of the BoM flood level data for these and other gauging stations, included with this submission as **Attachment 3,** show that the discharge from Lockyer Creek did not exceed minor flood proportions until late on Sunday night (January 9) while the cumulative effect of Lockyer Creek flows and Wivenhoe Dam releases did not reach moderate flood levels at Savages Crossing (downstream of the Lowood floodplain area) until mid-morning on Tuesday January 11.

At this time the flood level at the Moggill Gauge had not reached 10 metres – the indicator level of a minor flood.

Table 3 of **Figure 8** shows that the design flow out of the main spillway for a 1 in 200 year flood was 2,800 m^3/s, well below the 11,600 m^3/s capacity expected during a 1 in 10,000 year event.

Thus, as there was apparently considerable residual capacity in the existing spillway to cope with a flood inflow of 1 in 200 year proportions, it is questionable as to why it may have been found necessary to release water at more than 2800 m^3/s or even 4500 m^3/s, the 1 in 500 year design spillway flow or less than half of the spillway capacity.

From anecdotal evidence it is understood that this was necessary, at up to full spillway capacity, to prevent the fuse plugs from being initiated.

Table 4 of **Figure 8** summarises the situation which would arise after each of the three fuse plugs would have been initiated, with the relevant flood frequency being that which would "just initiate a fuse plug breach".

The following comments from **Reference 13** demonstrate that there should have been little risk to compromising the structural integrity of the dam during the January 2011 flood event and that opening the gates up to nearly full capacity may not have been necessary and, as a result, significant opportunities to mitigate flooding in Brisbane's urban areas were lost:

- *The capacity of each fuse plug bay increases incrementally with flood AEP.*
- *The first fuse plug breach increases downstream flows by about 1,600 m^3/s within about 20 to 30 minutes.*
- *The second fuse plug breach increases flows by 3300 m^3/s within about 30 to 40 minutes and the third by 4000 m^3/s in about the same time.*
- *The final fuse plug at Saddle Dam 2 increases downstream flows by 7400 m^3/s in about an hour.*

What is not obvious from the above is what the above levels and flows mean with regard to the rate of change in dam flood storage – the only indicators available to the author of this submission at this time being the BoM record of water levels in the Wivenhoe Dam (**Figure 7**) – the essential stage-storage volume relationship not being provided in the redacted version of **Reference 3.**

Figure 7 also shows the dam rose relatively quickly from the adverse starting level of 68.5 m AHD from Sunday evening until about 5pm on Monday afternoon, when the rate of increase was significantly reduced for about 14 hours, probably by increasing the rate of release.

The rate of water level increase in the dam then increased for about 10 hours to about 74.5m AHD before the rate of release was again increased to actually lower the dam water level and then stabilise it at less than 75m AHD.

This is generally consistent with anecdotal evidence that the dam peak water level reached to within 60 cm of fuse plug initiation.

A clear explanation of the construction and operation of the auxiliary spillway and its three fuse plugs is provided in **Reference 9** which describes these three components of the auxiliary spillway as follows:

> *The upstream face of the embankment consists of a riprap layer to protect against wave action. Consecutive layers consist of coarse rock followed by a coarse filter and then the impermeable clay core that are laid on a similar slope to the riprap. Downstream of the sloping clay core are more layers of filters that lie on compacted rock fill, which extends to the downstream slope of the embankment.*
>
> *The controlled erosion is initiated at a low point or pilot channel located in the embankment crest. A narrow vertical slot of coarse filter material is located immediately downstream of the pilot channel that extends to the downstream slope of the dam and replaces the compacted rock fill.*
>
> *As the water level in the lake rises above the pilot channel crest to a depth of about 0.15m, fast flowing water starts to erode the coarse filter in the vertical slot, which removes the material supporting the clay core, eventually causing it to collapse. The material adjacent to the slot is then exposed to the fast flowing water initiating lateral erosion.*

This and other references describe the extent to which the structural strength of the dam wall, the existing and auxiliary spillways were analysed and tested to demonstrate that this and the inbuilt hydraulic capacity of the auxiliary spillway and fuse plugs not only met ANCOLD's most recent guidelines but that the currently constructed Stage 1 of the upgrade has given these features of the dam the ability to pass the Probable Maximum Flood with a peak inflow of 49,000 m^3/s – an event of extreme improbability.

Reference 8 also discusses the impact of the preferred upgrade on the downstream river system using, firstly, an adapted SKM MIKE-11 model of the Brisbane River to provide inundation maps of the downstream area, estimate damages and provide approximate warning times.

In addition, the TUFLOW 2-dimensional software package was used to model flood levels and velocities in the floodplain area where the Lockyer Creek flows join the Brisbane River above Savages Crossing, with a view to identifying the localised impacts of spillway discharges from the various upgrade options.

While most of this modelling was concerned with extreme flood events, **Reference 8** reached the following conclusions with regard to the downstream performance of the now-upgraded dam:

- *The outflows from the dam are less than Wivenhoe inflows for all design flows investigated up to the initiation of the tertiary spillway at Saddle Dam 2.*

- *Outflows from the dam are always less than pre-Somerset or natural flows.*
- *Triggering of the fuse plugs on the Right Abutment spillway increases peak water levels by 0.7 m to 1.1 m at Savages Crossing (on top of a flood depth of 30m) and by 0.3 m to 0.5 m at Moggill Gauge, on the western outskirts of Brisbane (on top of a flood depth of 14 m).*
- *The rate of water level rise downstream of Savages Crossing is not significantly affected by the fuse plug breaches.*
- *The flood peak travel times from Wivenhoe Dam to Savages crossing (Fernvale) vary from 7 hours prior to the initiation of fuse plug 1 to 1.5 hrs following the initiation of fuse plug 4.*
- *The flood peak travel times from Wivenhoe Dam to Moggill Gauge vary from 23.5 hours to 15.5 hours following the triggering of fuse plug 4.*
- *The fuse plug flows do not significantly alter the flood peak travel times.*

Thus the maximum damage that could be caused in this instance was that the erosion of the first fuse plug would initiated and that the auxiliary spillway could be damaged – an event which had been taken into account in the upgrade's extensive value analysis on the basis that it would occur, on average, no more than once in 5000 years.

That this amount of damage was even commensurate with the flood damage in urban areas the apparently excessive releases from the dam are believed to have caused, is difficult to reconcile with the information made available at the time the dam was upgraded to meet ANCOLD specifications.

This suggests there is a need to examine why use of the Real Time Flood Model and the strategies defined in the *Operational Procedures* were quite inappropriate on this occasion.

4.0 EXAMINATION OF THE SUITABILITY OF THE REAL TIME FLOOD MODEL FOR MINIMISING FLOOD DAMAGE IN URBAN AREAS DOWNSTREAM

4.1 General Comments On the Structure of the Real Time Flood Model

It is stated in the *Operational Procedures* that:

> *The RTFM is a suite of hydrologic and hydraulic computer programs that utilise the real time data to assist in the operation of the dams during flood events.*

However the redacted version of the *Operational Procedures* provides little information on the technology employed in the development and progressive upgrading of what appears to be an out-dated Real Time Flood Model (RTFM) and one which does not integrate routing of the dam inflows through the dam flood gates and down the middle reaches of the Brisbane River, followed by the essential routing of those subsequent inflows through the urban areas of Brisbane and Ipswich City.

A clearer but by no means definitive summary of the RTFM may be gained from information provided in 1999 as part of an assessment of the performance of the use of the RTFM in operating the flood gates for flood mitigation during the February 1999 flood (**Reference 15**).

Reference 15 indicates that the RTFM was developed by the former DNR and that the February 1999 flood was the first time that the model had been used operationally. It was described as follows:

> *The system is divided into two principal modules, FLOODCOL and FLOODOPS.*
>
> *The FLOODCOLL data collector module is designed to:*
>
> - *Collect, filter and store incoming hydro-meteorological data in real time;*
> - *Enable viewing, editing, infilling and validation of the data;*
> - *Produce Intensity, Frequency Duration (IFD) curves for incoming rainfall;*
> - *Enable editing of sensor details and performance of all the necessary system housekeeping.*
>
> *The FLOODOPS operations module is designed to utilise the incoming data to set up operating scenarios in order to develop and run hydrologic and hydraulic models on which to base decisions for the operations of the dam during flood events. It is used to:*
>
> - *Generate data files (from the databases) suitable for the use in hydrologic routing, reservoir routing and hydraulic routing downstream of the dams (e.g. pluviograph patterns , subarea rainfall excesses, hydraulic boundary conditions);*
> - *Perform hydrologic routing and reservoir routing;*
> - *Perform hydraulic modelling downstream of the dams to predict flood levels;*

- *Allow the user to intervene at any stage and vary any of the model parameters, data sets or scenarios.*

The 1999 flood was not really very demanding of the RTFM compared with the January 2011 flood because of the large amount of unused flood storage available below Full Supply Level in both dams at the start of this flood .

Thus performance of the RTFM during this flood did not really demonstrate the extent to which the dam's storage might be used to optimise flood protection in the downstream urban areas in a "design flood" situation such as is required by Brisbane and Ipswich City Councils for floodplain planning.

Given that the January 2011 rainfall event caused design flood levels to be exceeded in most of Brisbane's flood-prone urban areas, it is useful to examine why this apparently occurred.

It is the author's opinion that the fundamental problem with the current RTFM lies in the FLOODOPS module rather than in the FLOODCOL module for reasons described below.

4.2 Inclusion of the Real Time Flood Model (RTFM) in the *Operating Procedures*

Section 5 of the *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam* (**Reference 3**) describes the Flood Monitoring and Forecasting System relied upon by SEQ Water to operate the flood gates of both dams.

In this context, upon receipt of projected and actual rainfall and river height data from the real time flood monitoring system operating in more than 100 field stations in the dam catchments. SEQ Water uses its RTFM to estimate dam inflows and evaluate a range of possible inflow scenarios.

It is claimed that the RTFM is then used *...to operate the dams in accordance with (the) Manual ....by optimising releases of water from the dams to minimise the impacts of flooding in accordance with the objectives and procedures contained in (the) Manual.*

Reference to **Figure 6**, from **Reference 3**, shows that the various strategies are initiated by expectations of the level to which the water in Wivenhoe Dam will rise.

These levels are linked only to flows downstream of the dam from the bridges near Lowood and Fernvale and to the flows in the river at the Moggill Flood Gauging Station.

As there is no direct or obvious linkage as to what flood levels may be expected in the urban areas downstream, it is understandable that the dam operator prioritises protection of the downstream structures above the level of protection that is or can be afforded to the urban areas where the benefits of flood mitigation are far greater in major flood events.

In addition, there is a quite wide range of possibilities concerning predicted dam water levels that have to be taken into account.

For example, only relatively minor releases of water are required under Strategies W1A – W1E, unless it is expected that the dam water level will exceed EL 68.5m, by which time a quite significant amount of flood storage could be lost.

Then there is the quite large range of possibilities that may be applied if it is expected that the dam water level could reach EL 74.0m - Strategy W2 only being a "Transition Strategy" from protecting the downstream structures to protecting urban areas from inundation. This still restricts the maximum outflow from the flood gates to 3,500 m^3/s, approximately one-third of the gates' full capacity.

The potential loss of flood storage during this Transition Stage, while unable to be quantified by the author at this stage, is probably of the order of 50 percent of the total amount of flood storage provided for in the construction of the dam. This is an unreasonable amount of flood mitigation potential to be left to the discretion of the Dam Operator and to the vagaries of the information likely to be provided to the Dam Operator by the Real Time Flood Model.

The point at which maximum releases from the dam can be increased beyond 3500 m^3/s is 4000 m^3/s total flow at Moggill, which then limits flows from the dam to 4000 m^3/s (40%) of the flood gate capacity. During this period Strategy W3 applies and "the primary consideration is protecting urban areas from inundation".

It is expected that other information likely to be provided to the Inquiry will confirm the author's opinion that limitation of the operation of the flood gates to approximately 40% of their capacity for such a very small window of opportunity, severely restricts the ability of the Dam Operator to provide any meaningful flood mitigation in the urban areas during a major flood if the dams are at or near Full Supply Level at the commencement of the flood event.

Application of an EL 74m criterion for the onset of Strategy W4, when .... *The Primary Consideration is Protecting the Structural Safety of the Dam* ... might also be seen to be another significant constraint to the amount of flood storage then available to reduce the inundation of urban areas downstream in a major flood - given the extent to which the risks to the structural safety of the dam have been reduced by the Stage 1 upgrade.

It might be noted that the water level at which the first fuse plug would be initiated is EL 75.5m.

Strategy W4A allows no limit on maximum release rate within this range but indicates that "lower level objectives are still considered when making decisions on water releases" if indications of the peak level are such that it would not reach the trigger level of the first bay of the fuse plug.

Even so, the amount of flood storage which might not otherwise be lost through early implementation of Strategy W4A is considerable and the impacts of releases beyond 4000 m^3/s upon flood damage in downstream urban areas can be shown to be quite significant.

Strategy W4B is responsible – the problem is how to avoid getting to this point without causing dam discharge rate to worsen potential flood damage downstream within the constrained window of opportunity offered by the structure of the *Operational Procedures* and the potential for a belated feedback of the results of such strategies to the Dam Operator.

The problem is compounded by reliance upon the FLOODCOL module of the RTFM and the hydrological components of the FLOODOPS module to give timely and reliable advice to the Dam Operator upon the level of water that can be expected in Wivenhoe Dam.

5.0 RECOMMENDATIONS TO THE COMMISSION CONCERNING THE NEED TO UPGRADE OR REPLACE THE REAL TIME FLOOD MODEL AND REVISE THE *OPERATIONAL PROCEDURES*

5.1 The Need to Revise the Objective of the RFTM

It is considered that the previous sections of this submission have provided ample demonstration that the RFTM did not allow the Dam Operator to manage the releases of water stored in Wivenhoe Dam during the January 2011 flood event to minimise flood damage in the urban areas downstream to the extent expected in previous flood studies.

It would appear that that the RFTM does not recognise that the flood gates are the only control mechanism available to minimise flood damage in the urban areas downstream and that the optimal performance of a control system is achieved when feedback from the objective of a control system is received and assessed in a timely manner and the controller is adjusted accordingly.

In this case it would appear that the "objective", as far as flood mitigation is concerned, is minimising flood flows at downstream structures initially and, in the later parts of a major flood, flood flows at the Moggill Flood Gauge. Downstream flows are only indicators of potential flood levels downstream, not the variable for which feedback to the flood gate controller is required.

The RFTM needs to be upgraded to better predict peak flood levels in the downstream urban areas rather than flows at Moggill.

5.2 The Need to Upgrade the Hydrodynamic Modelling Capability within the RTFM

It would appear that the hydrodynamic modelling capability of the FLOODOPS module is not capable of carrying this out to the extent that current hydrodynamic models can achieve, e.g. MIKE-11, or can be interfaced with those which are already in use for floodplain planning downstream of the dam, e.g. MIKE-11 and TUFLOW.

The author's experience of the technologies now available to model flood flows through catchments, streams, storages, structures, rivers and floodplains, suggests that the hydrodynamic model to replace or upgrade FLOODOPS should be extended upstream of the existing models to include the dam gates and regulators in the Wivenhoe and Somerset Dams and the flood routing through each of these storages of actual or anticipated inflows to these storages from the various dam sub-catchments.

This would enable the flood gate and flow regulator operations to be embedded in the model and so allow the model to compute the impact of proposed or actual changes to these release mechanisms as flood inundation levels downstream, allowing these to be directly correlated with projected amounts of flood damage.

The actual hydrodynamic software needs to be selected such that its modelling speed can match the speed required of advice to the flood gate controller, manual or automatic, to achieve the optimum result downstream. It is considered that there are a number of software systems in use in Australia which could be adapted for this purpose.

5.3 Potential to Add an Optimising Module

If the hydrodynamic module is upgraded to show how varying the release flows from Wivenhoe Dam impacts on a selected measure of flood inundation downstream, under real time conditions, then this information can be fed back into an optimising module.

The optimising module would then consider measured changes to the dam water level and send a signal to the flood gate controller if the release rate needs to be changed and would indicate the extent of the change which should be made to minimise any increase in flood levels in the downstream areas.

The optimising module could also be programmed to include constraints to the operation of the flood gates to provide for many of the issues addressed by the various strategies outlined in the *Operational Procedures.*

Optimisation through the use of dynamic systems modelling is not a new technology.

It is understood that a Brisbane-based company, DHI Water and Environment, has developed a Computer Aided River Management System, which is about to be implemented to manage the releases from a major irrigation dam such that the amount of water conserved in the dam is maximised by matching the variable demand from irrigators at a considerable distance downstream of the dam.

DHI Water and Environment are the Australian representatives of the Danish Hydraulic Institute, which is an internationally-recognised pioneer of hydraulic modelling of rivers and streams through the development of its MIKE-11, MIKE-21 and MIKE-FLOOD software.

It is recommended to the Inquiry that a submission should be requested of DHI Water and Environment to demonstrate how their Computer Aided River Management System might be adapted to optimise future releases of water from Wivenhoe Dam for flood mitigation in the urban areas downstream.

5.4 Hydrological Modelling

As the hydrodynamic and optimising modules can be operated either in real time or with inputs determined by another hydrological module, the author offers no comment upon the data collection, hydrological modelling and flood forecasting methodologies of the RTFM.

However, it is considered likely that these will need to be reviewed and modified where necessary if the RTFM is changed as recommended above.

5.5 Flood Operations Strategies

It is recommended that the provision of optimum protection of the urbanised areas from inundation should be the primary objective of the flood operations strategies in any revision of the current *Operational Procedures.*

The *Wivenhoe Flood Strategy Flow Chart*, as shown on **Figure 6**, should be changed to enable the window of opportunity for releases of between 1900 m^3/s and 4000 m^3/s to be accessible when there is a possibility that significant flood damage may be prevented in the urban areas by implementing such releases.

The *Flow Chart* should also be amended to raise the trigger level for Strategy W4 to at least EL 75.0m to further expand the above window of opportunity.

5.6 Retention of Existing Design Flood Levels until RTFM has been Upgraded

The design flood levels, as shown by Council's current Floodwise Property Reports, should be retained until the Real Time Flood Model and the *Operating Procedures* have been modified.

The resultant hydrodynamic model which incorporates the above technologies may then be used in a floodplain planning mode to generate design flood levels that incorporate the improvements in flood mitigation likely to be found possible with the upgraded RTFM and *Operating Procedures.*

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4. Crime & Misconduct Commission, *Brisbane River Flood Levels – A CMC report on the Brisbane City Council's handling of flood study reports* (March 2004)

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11. Institution of Engineers Australia, *Australian Rainfall & Runoff: A Guide to Flood Estimation, 1997 edition*

12. NSW Government, *Floodplain Development Manual (2005)*

13. Gill, D. et al, *Wivenhoe Dam Flood Security Upgrade*, ANCOLD/NZSOLD Conference (2004)

14. Barton, M. & Rodd, R., *Wivenhoe Alliance – Investigation to Pursue Innovation*, paper obtained from ANCOLD publications list (2005)

15. Allen, P. et al, *Real Time Flood Management of the Brisbane River and Pine River Dams During the February 1999 Flood*, paper obtained from the ANCOLD publications list (1999)

FIGURES

1. The Brisbane and Bremer River Catchments
2. Extract from Sheet 4 of the Brisbane River Floodplain Map
3. 1975 Estimates of Pre-Wivenhoe Dam Brisbane River Flood Profiles
4. Extract from Floodwise Property Report for 3 Edward Street, Brisbane
5. Sample Flood Map from Brisbane City Council web-site
6. Wivenhoe Flood Strategy Flow Chart
7. Extract from BoM Web-site Showing Dam Water Levels
8. Extract from Ref.15 Showing 1999 Flood Mitigation
9. Tables 2 – 4 from Reference 13

DRAWING REFERENCE
GEOMAPS, *Brisbane and Environs* 3D Model.

Queensland Floods Commission of Inquiry

TITLE

The Brisbane and Bremer River Catchments

JOB	QFCI	**FIGURE 1**
JOB NO.	QFCI-11	DRAWING NUMBER
DATE	10/03/11	**QFCI-1**
SCALE		

mwa

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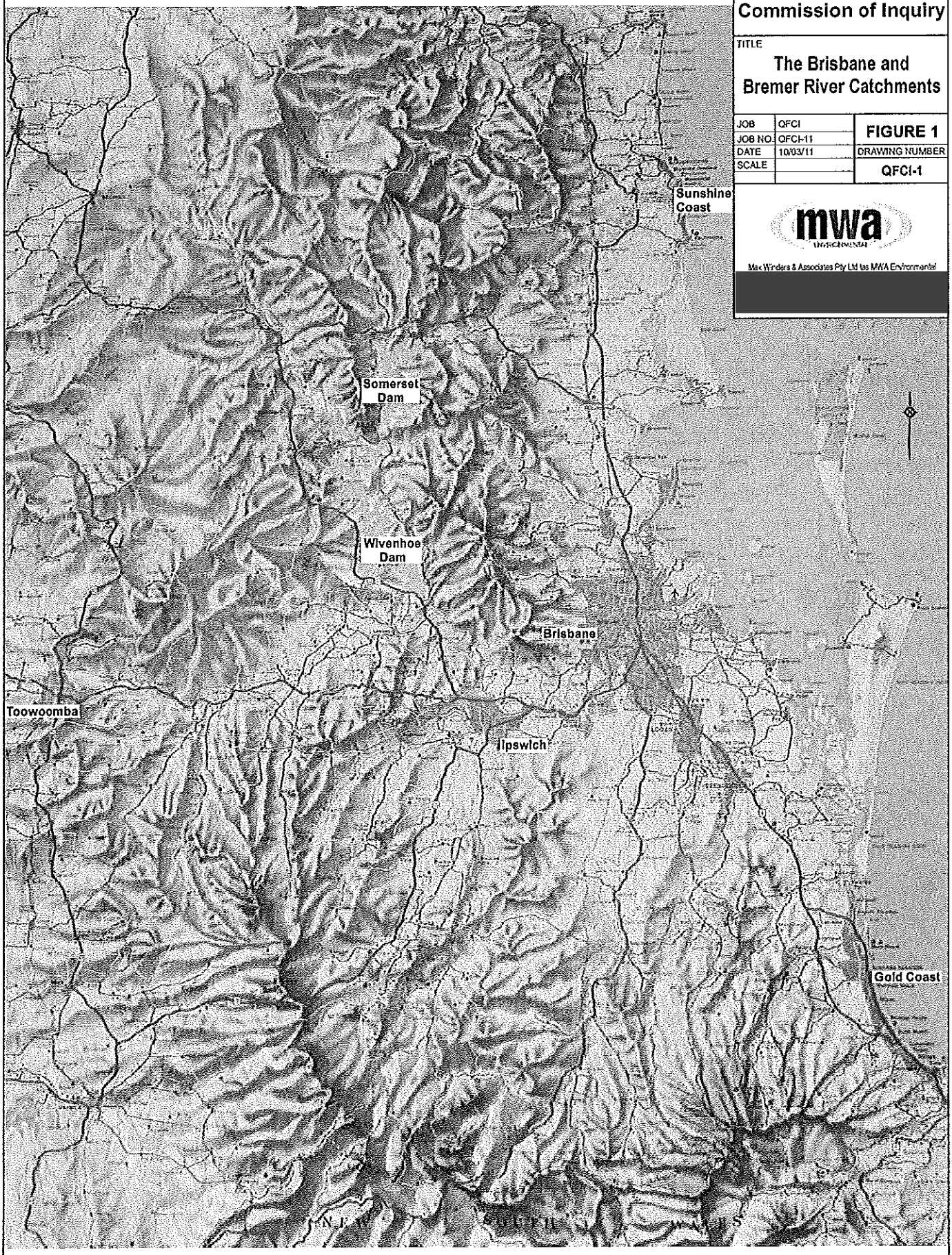

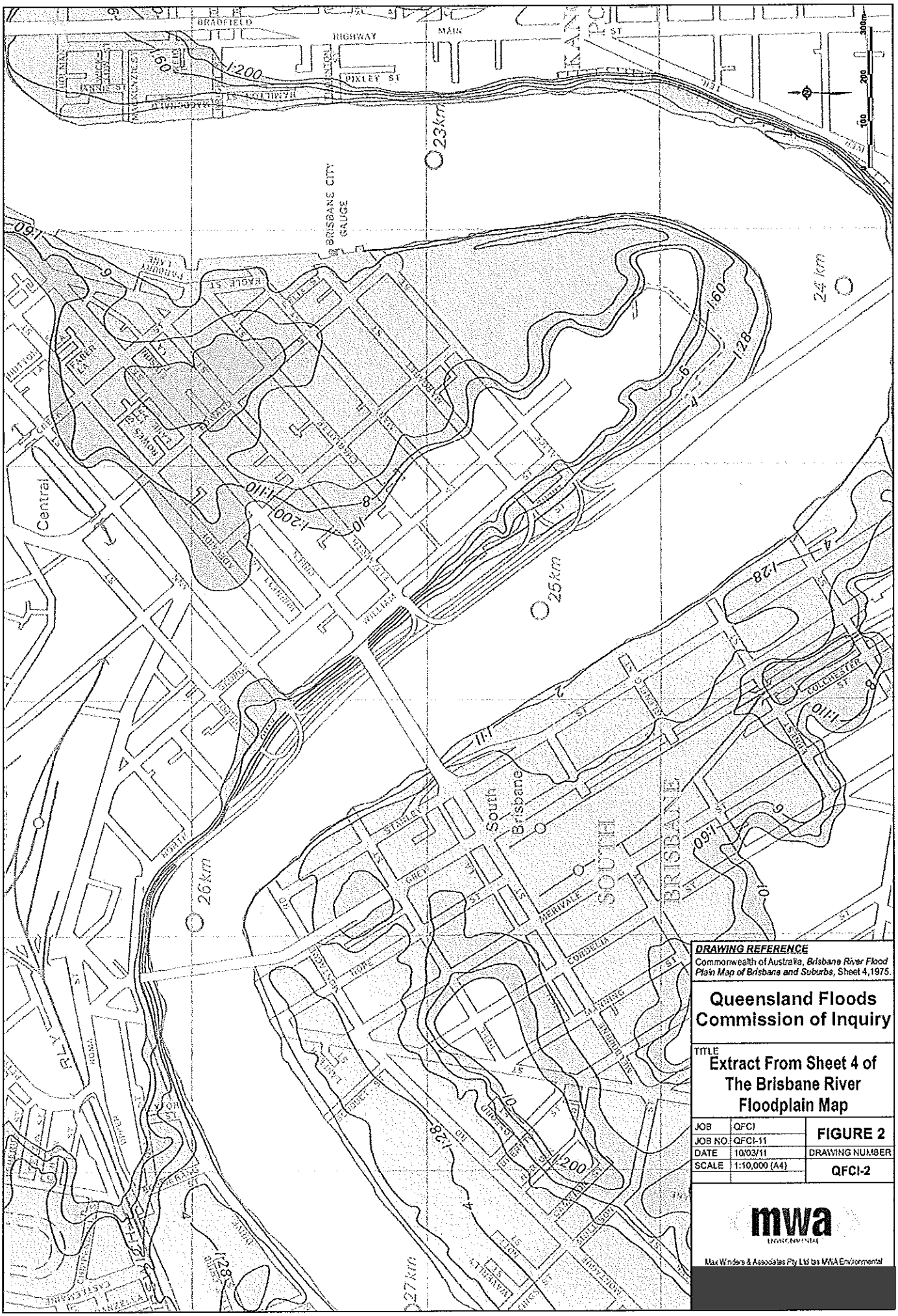

DRAWING REFERENCE

Commonwealth of Australia, Brisbane River Flood Plain Map of Brisbane and Suburbs, Sheet 4,1975.

Queensland Floods Commission of Inquiry

TITLE

Extract From Sheet 4 of The Brisbane River Floodplain Map

JOB	QFCI	**FIGURE 2**
JOB NO.	QFCI-11	
DATE	10/03/11	DRAWING NUMBER
SCALE	1:10,000 (A4)	**QFCI-2**

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DRAWING REFERENCE
Commonwealth of Australia, *Brisbane River Flood Plain Map of Brisbane and Suburbs*, Sheet 4,1975.
Notes on Flooding, *Figure 4 Brisbane River Flood Profiles*

Queensland Floods Commission of Inquiry

TITLE
1975 Estimates of Pre-Wivenhoe Dam Brisbane River Flood Profiles

JOB	QFCI	**FIGURE 3**
JOB NO.	QFCI-11	DRAWING NUMBER
DATE	10/03/11	**QFCI-3**
SCALE	Not to scale	

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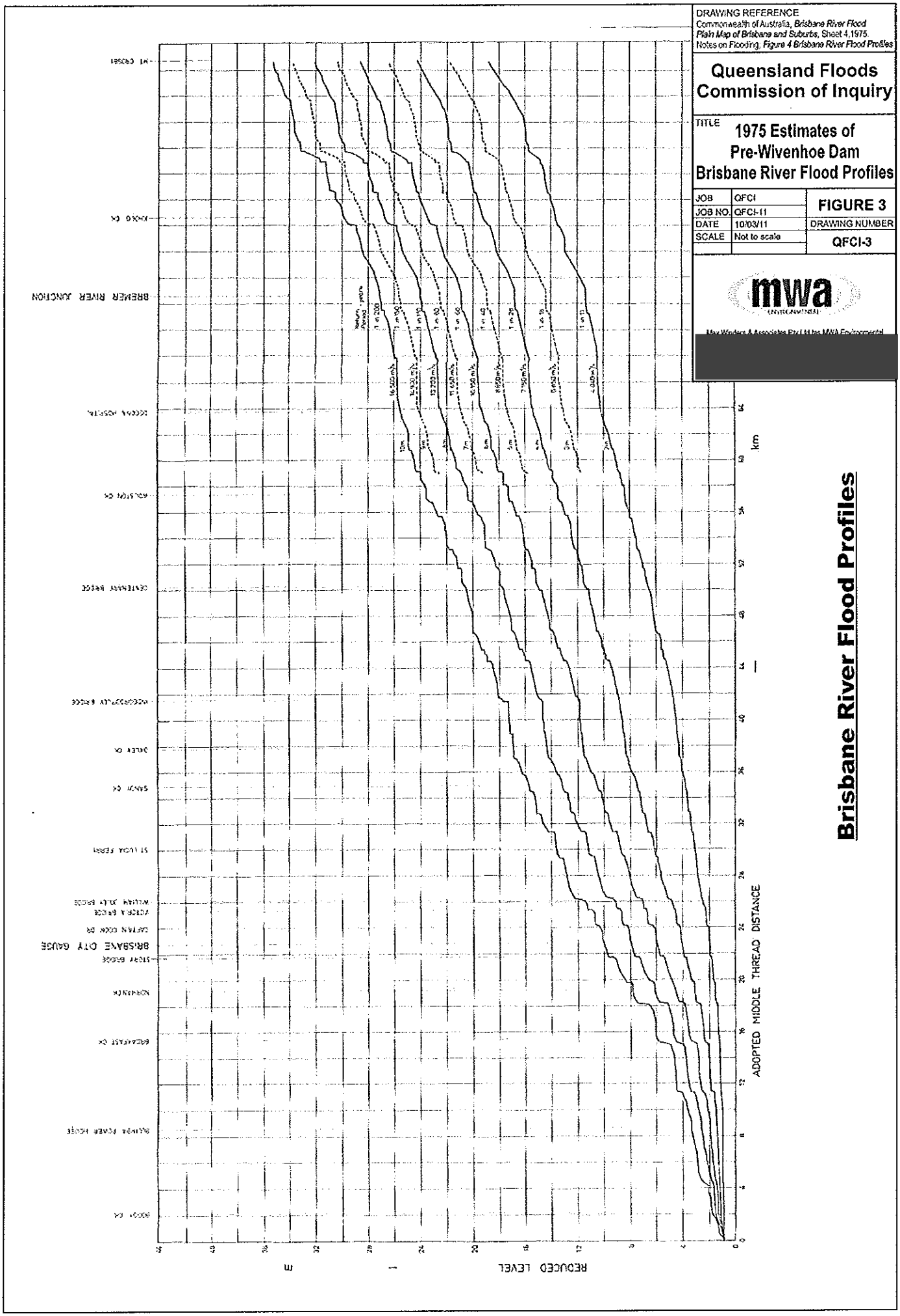


Brisbane City Council

FloodWise Property Report

Report Reference
1626238
10/03/2011 09:55:37

Dedicated to a better Brisbane

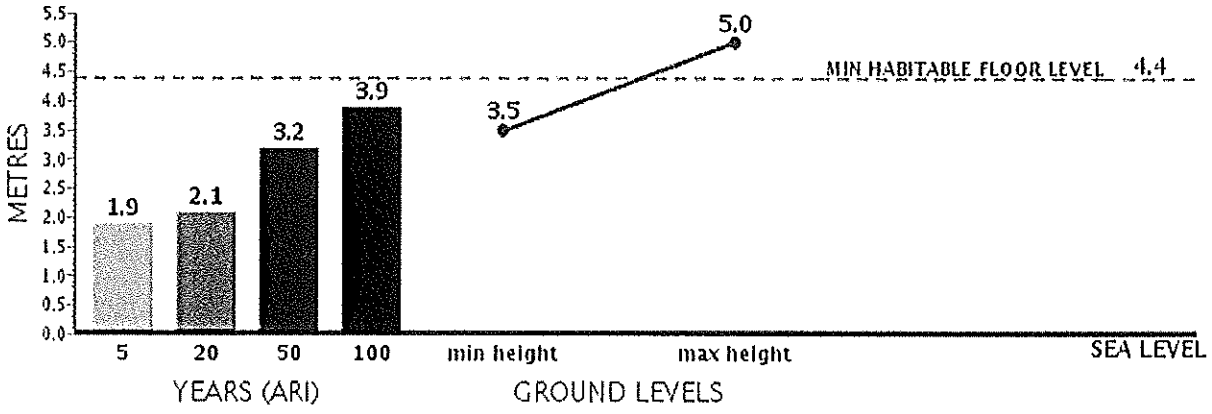
The FloodWise Property Report is a free report to inform Brisbane residents and professionals about flood risks for a specified lot or property so they may better prepare for flooding and to plan and build in accordance with Council requirements.

To find out more about how the contents of this report may affect your ability to build or renovate, as well as Council advice on how to protect your property and family by being FloodWise, visit www.brisbane.qld.gov.au, a Customer Service Centre or call (07) 3403 8888.

PROPERTY DETAILS:

Address: 3 EDWARD ST BRISBANE CITY QLD 4000
Lot Details: L.3/RP.129917

FLOOD LEVEL INFORMATION



Flood Levels
The blue bars in the graph above show the height of flooding estimated to occur on average once every 5, 20, 50 and 100 years at this address or lot.

Ground Levels (Min - Max)
The line above shows this property's lowest and highest ground levels. Confirm with a surveyor.

Minimum Habitable Floor Level
The dotted line in the graph above depicts the minimum height above sea level that habitable areas of development must be constructed to, i.e. lounge, kitchen or bedroom.

For a detailed summary of anticipated flood levels and flags see technical summary over page

HIGHEST SOURCE OF FLOODING

RIVER The highest source of flooding affecting this property originates from a river. For mor
flooding in your area you can view and download Council's Flood Flag Maps by visiting
www.brisbane.qld.gov.au/floodmap

Queensland Floods Commission of Inquiry

TITLE: Extract From BCC Flood Property Report for 3 Edward Street Brisbane.

JOB	QFCI	FIGURE 4
JOB NO.	QFCI-11	
DATE	10/03/11	DRAWING NUMBER
SCALE		QFCI-4

mwa

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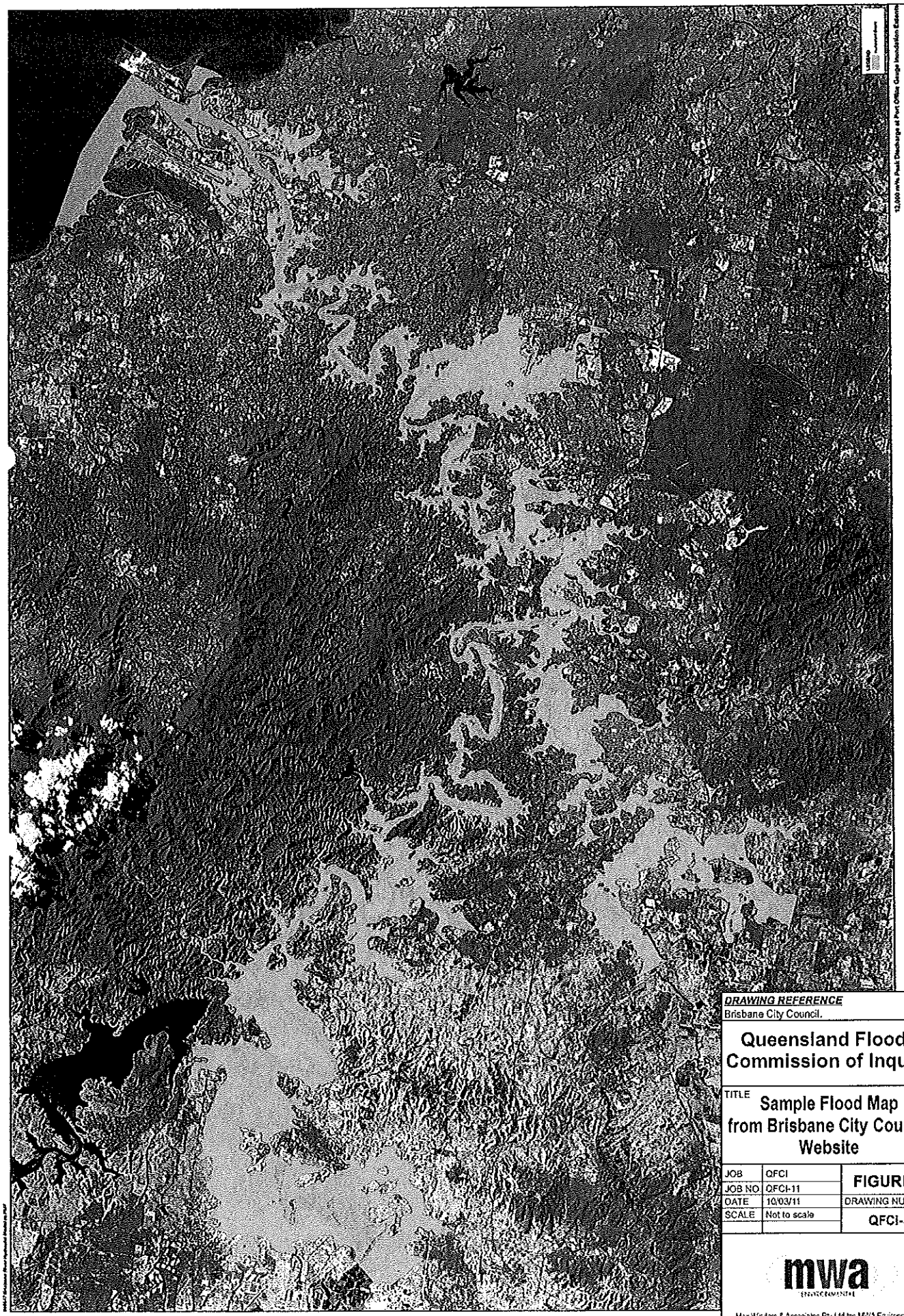

DRAWING REFERENCE
Brisbane City Council.

Queensland Floods Commission of Inquiry

TITLE
Sample Flood Map from Brisbane City Council Website

JOB	QFCI	**FIGURE 5**
JOB NO	QFCI-11	
DATE	10/03/11	DRAWING NUMBER
SCALE	Not to scale	**QFCI-5**

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ENVIRONMENTAL

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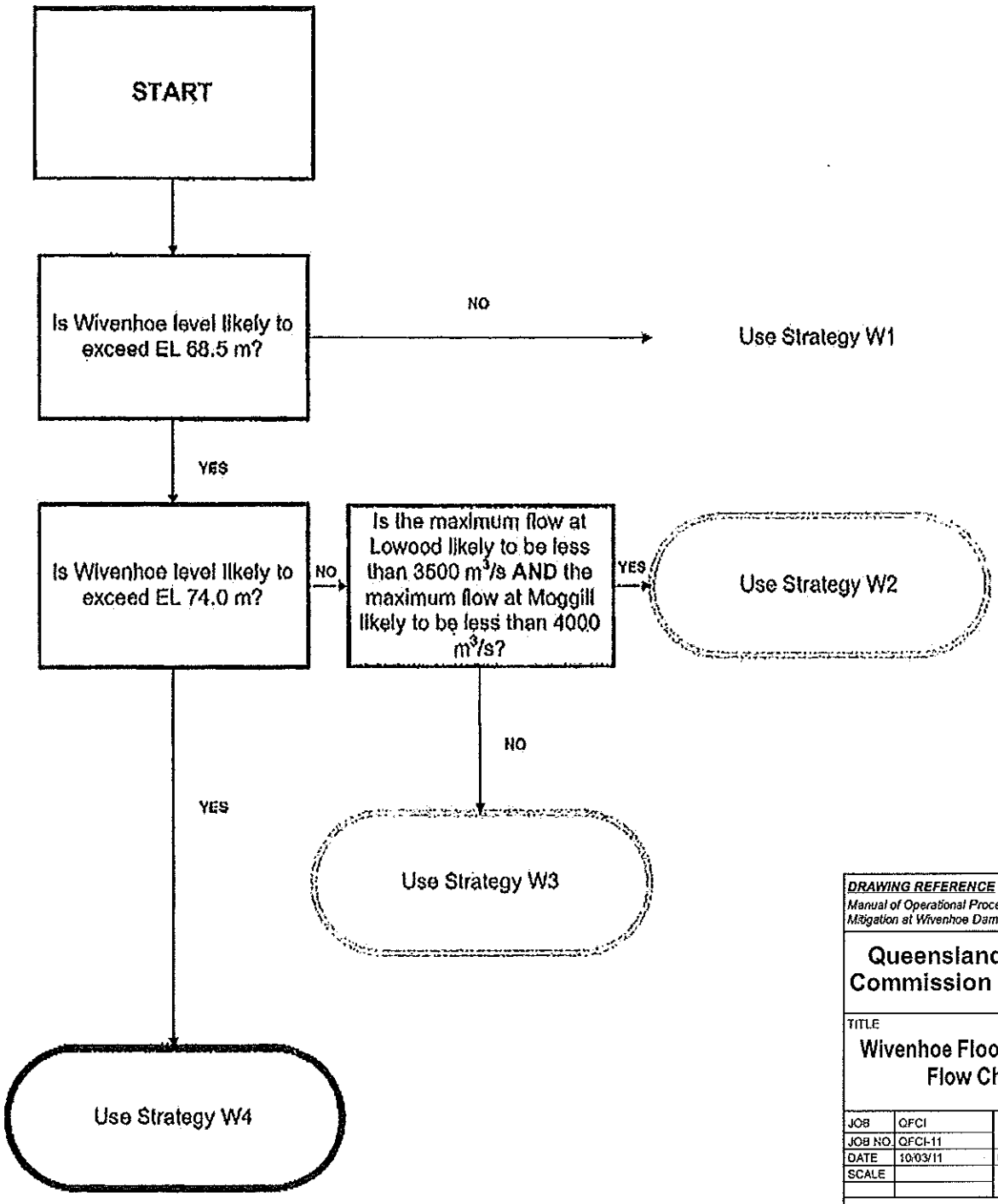
WIVENHOE FLOOD STRATEGY FLOW CHART



DRAWING REFERENCE	*Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*
Queensland Floods Commission of Inquiry	
TITLE	Wivenhoe Flood Strategy Flow Chart
JOB	QFCI
JOB NO	QFCI-11
DATE	10/03/11
SCALE	
FIGURE 6	
DRAWING NUMBER	QFCI-6

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IDQ65389

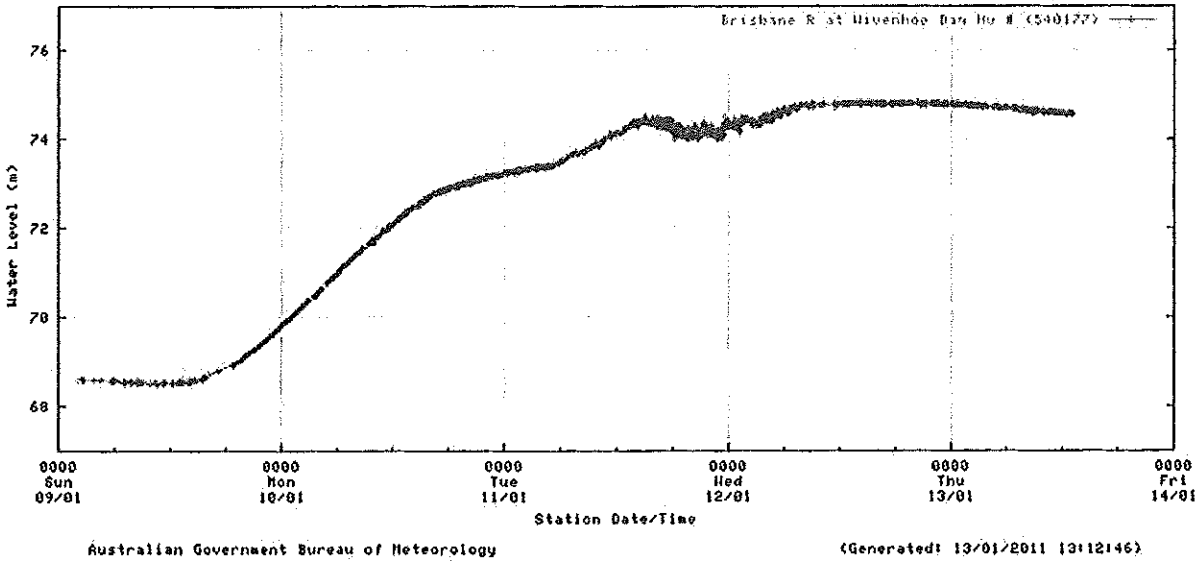
Latest River Heights for Brisbane R at Wivenhoe Dam Hw

Issued at 1:12 pm EST Thursday 13 January 2011

About river heights plots | About this Plot

Station details: Station Number: **540177** Name: **Brisbane R at Wivenhoe Dam Hw #** Owner: **SEQWCO:143822**

Data from the previous 4 days.



Data as Table | Previous Station | Next Station | Back to Bulletin

About this plot

1. The river height data is the latest available operational data provided for flood warning purposes and has not been quality controlled.
2. Stations marked with * or # indicate that the data is provided from automatic equipment.
3. Stations marked with * are Telephone Telemetry Devices and are nominally polled once a day and more often during floods.
4. Stations marked with # are ALERT Radio Telemetry and report every 3 hours and more often when the water level changes.
5. All river height reports are in metres and are shown in local time.
6. Heights or depths above/below roads, bridges, dam spillways and weirs are given as a guide only. For road open/closed information, see the RACQ website.
7. This product includes data made available to the Bureau by other agencies. Separate approval may be required to use the data for other purposes. Refer to Listing of Operating Agencies for Station Ownership.
8. Where data is supplied from a Department of Environment and Resource Management (DERM) Monitoring Site, please follow this link to get advice on data use and copyright.
9. For other Station details: Flood Classifications, Road Crossings, Survey/AHD Details, Maps

DRAWING REFERENCE	Australian Government, Bureau of Meteorology.
Queensland Floods Commission of Inquiry	
TITLE	**Extract from BOM Website Showing Dam Water Levels**
JOB	QFCI
JOB NO	QFCI-11
DATE	10/03/11
SCALE	
FIGURE 7	
DRAWING NUMBER	**QFCI-7**

mwa ENVIRONMENTAL
Mac Winders & Associates Pty Ltd t/as MWA Environmental

Queensland Floods Commission of Inquiry

TITLE
Extract from Reference 15 Showing 1999 Flood Mitigation

JOB	QFCI	FIGURE 8
JOB NO.	QFCI-11	
DATE	10/03/11	DRAWING NUMBER
SCALE		QFCI-8

mwa ENVIRONMENTAL

Mike Wookey & Associates Pty Ltd t/as MWA Environmental

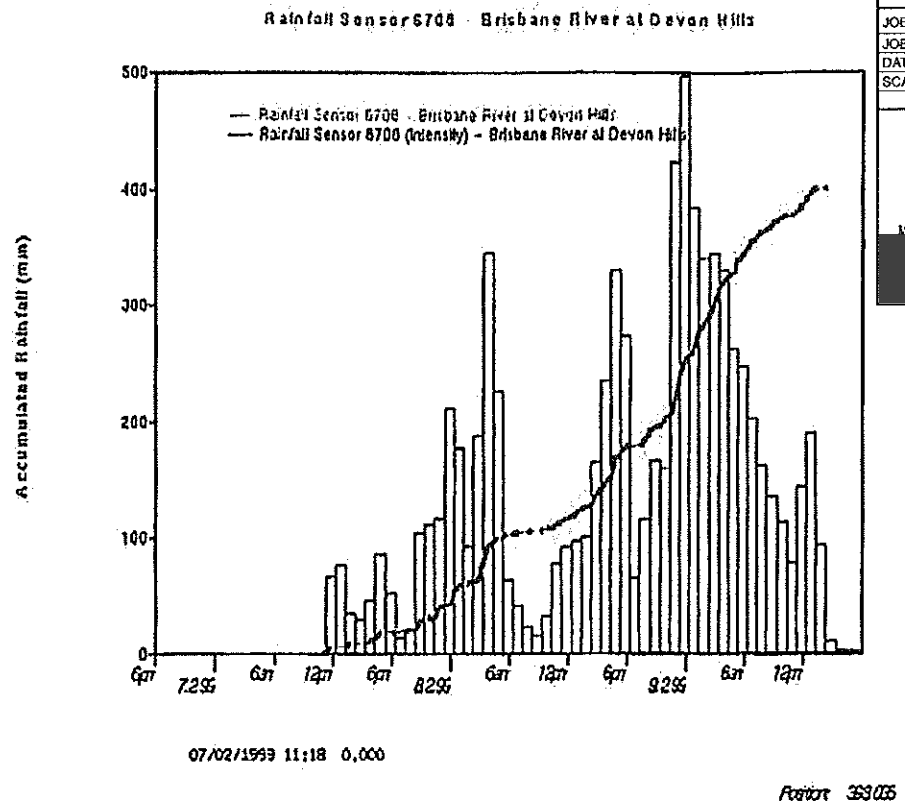


Figure 3 - Cumulative Rainfall - Brisbane River at Devon Hills (Upstream of Wivenhoe)

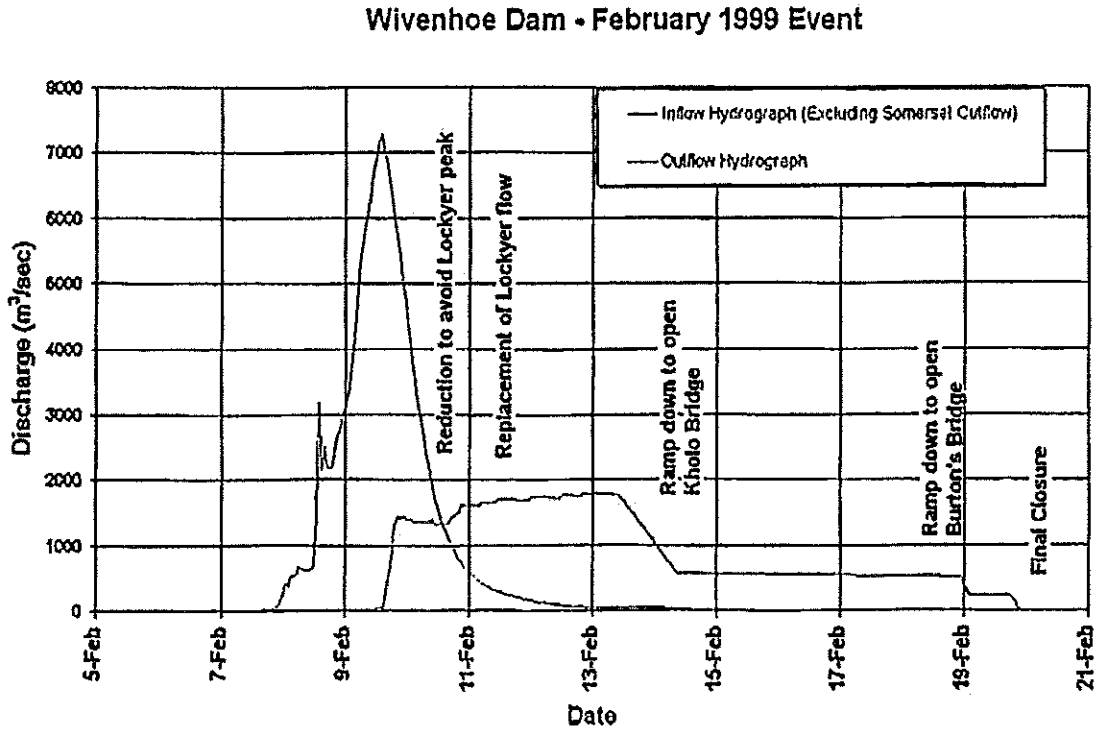


Table 2 Peak Outflows and Dam Water Levels at Fuse Plug Initiation Levels, Wivenhoe Dam

Auxiliary Spillway Location	Spillway Crest Control Type	Spillway Crest Width (m)	Spillway Crest Level (m AHD)	Peak Lake Level at Fuse Plug Initiation (m AHD)
Right Bank (Stage 1)				
Fuse plug 1	Ogee	34	67	75.7
Fuse plug 2	Ogee	64.5	67	76.25
Fuse plug 3	Ogee	65.5	67	77.2
Saddle Dam 2 (Stage 2)				
Fuse plug 4	Ogee	100	67	78.3

Table 3 Design Inflows and Outflows for Existing, Stage 1 and Stage 2 Upgrades, Wivenhoe Dam

Annual Exceedance Probability of Flood Event (1 in X)	Peak Inflow into Wivenhoe (m^3/s)	Peak Outflow (m^3/s)		
		Existing Spillway	Stage 1 Total Discharge	Stage 2 Total Discharge
200	8,300	2,800	2,800	2,800
500	10,500	4,500	4,500	4,500
1,000	12,100	6,200	7,200 [c]	7,200 [c]
2,000	14,000	8,700	9,700 [c]	9,700 [c]
5,000	17,200	9,700	11,300	11,300
10,000	20,800	11,600	16,500	16,500
22,000 [a]	25,700	12,300 [a]	18,000	18,000
50,000	34,900	- [b]	24,800	24,800
100,000	43,300	- [b]	28,200 [a]	35,000
PMF	49,000	- [b]	- [b]	37,400 [a]

[a] Dam Crest Flood [b] Overtops dam wall [c] Increases due to changes to flood operating procedures to remove the radial gates from the spillway flow prior to the initiation of the fuse plug spillway

Table 4 Peak Outflows and Maximum Lake Levels at Fuse Plug Initiation, Wivenhoe Dam

Fuse Plug No. Initiated	Approx. AEP (1 in X Years)	Peak Outflow (m^3/s)			Maximum Lake Water Level (m AHD)
		Gated Spillway	Right Abutment Spillway	Saddle Dam 2 Spillway	
1	5,000	9,700	1,600	0	75.7
2	8,500	11,000	4,900	0	76.25
3	25,000	12,200	8,900	0	77.2
4 (SD2)	52,000	13,000	12,100	7,400	78.3

Queensland Floods Commission of Inquiry

TITLE

Table 2 and Table 4 From Reference 13

JOB	QFCI	FIGURE 9
JOB NO.	QFCI-11	
DATE	10/03/11	DRAWING NUMBER
SCALE		QFCI-9

mwa

Max Winders & Associates Pty Ltd tas MWA Environmental

ATTACHMENTS

1. Email from M.F. Winders to Counsel Assisting the Commission, 15 February 2011
2. Floodwise Property Report for 3 Edward Street, Brisbane
3. Bureau of Meteorology flood level records at Relevant Flood Gauging Stations

ATTACHMENT 1

Max Winders

From: Max Winders
Sent: Tuesday, 15 February 2011 4:37 PM
To: 'info@floodcommission.qld.gov.au'
Subject: Request for further information required to compile a submission to the Inquiry

Attention: Counsel Assisting the Inquiry

Dear Counsel

As an engineer whose consulting practice has and is continuing to be involved in the analysis of actual and statistical flood scenarios in a large number of SE Queensland streams, I have followed the recent Queensland floods with some interest and spent a considerable amount of time over the period from Saturday 8 January 2011 until at least Thursday 13 January 2011 downloading from the Bureau of Meteorology website the water levels at a number of the Bureau's River Height Stations so that I might be able to predict the levels in areas of concern from the level traces and from the Bureau's rainfall intensity information.

On the afternoon of Tuesday 11 January 2011, my office was advised by our landlord, Investa Pty.Ltd., to vacate our leased premises on the 15th Floor of the Brisbane Club Tower because of the impending flooding – apparently with advice from the Premier and the Lord Mayor that it was going to be "worse than the 1974 flood". My BoM records show that the flood height at the City Gauge at high tide was 2.0m and at the onset of a "Moderate Flood".

At about 9am on Wednesday 12 January, I visited 241 Adelaide Street to find water levels in the basements of our and adjoining buildings rising to levels within a few metres of street level and continuing to rise. The level at the City Gauge, from my records was then about 3.2m and rising. The river then continued to rise to about 4.5m at the City Gauge about two tide cycles later.

During this period I travelled over the Gardens Point Bridge to the Kangaroo Point cliffs to view the flooding and paid particular attention to the eddy downstream on the bridge pier nearest the CBD to see if it was visually comparable with what I had viewed in that location when stream gauging in a boat on the Brisbane River after the peak of the 1974 flood. It is my recollection that there was a "whirlpool" there in 1974, approximately 15m diameter and 1.5m deep. On 12 January 2011 there was no evidence of a whirlpool – only a series of much smaller eddies streaming downstream from the bridge pier.

This strengthened my earlier assessment that the 2011 flood flows were not as high in the Brisbane CBD reaches as they were during the 1974 flood.

It was also shown at the time that the Bremer River, a quite significant source of flood flows through Brisbane, did not reach the same levels in Ipswich as they did in 1974.

This led me to the proposition that the peak flow of the Brisbane River past Brisbane's flooded urban areas should have been significantly lower than that which occurred during 1974 and that the actual flows may have been higher than expected due to an untimely and excessive release of floodwaters from the Wivenhoe Dam coinciding somewhat with the Bremer and Lockyer inflows and high tides.

To investigate the extent to which the timing and extent of the dam releases may have been inappropriate, it is necessary to resort to hydrodynamic modelling of the actual flood to reproduce the flood level traces identified by the BoM for various gauging stations in the flood flow network. These models are constructed from the geometry and hydraulic roughness characteristics of the river basin's flow channels and floodplains and the structures such as dams, weirs, bridges and levees which affect flood flows and flood levels.

The input to such models comprises runoff and precipitation inflows into the various parts of the model network, principally the upstream ends of the major tributaries, and tidal and storm surge water level variations at the downstream end.

Hydrological models are used to generate the rates at which rainfall converts to runoff and enters the model at its upstream boundaries. They may be actual and "real time" or hypothetical, using accepted statistically-based hydrological data to generate "design floods".

It would be expected that the Commission will be able to access the rainfall intensity data and the output from reliable hydrological modelling of the January 2011 flood event which might be used as the input to the hydrodynamic modelling which, in my opinion, is necessary to the understanding of the impacts of that flood event throughout the Brisbane River catchment. Your advice as to the availability of this information at some stage during the inquiry would be appreciated as access to this would improve the credibility of my submission.

There are numerous versions of hydrodynamic modelling software suitable for flood modelling and these have been available for many years. Because they solve the equations of conservation of mass, momentum and energy over discrete elements of the flood flow path over short periods of time, they are capable of producing output which can be compared with the time-varying level traces of the BoM at significant parts of the flow network, as well as flood velocities and flows. In other words they can show the potential delay in the flood peak from an upstream monitoring station as well as an estimate of the flood level, flow and velocity at various points at that time.

It is understood that MIKE-11, network hydrodynamic modelling and TUFLOW, two-dimensional hydrodynamic modelling has been carried out for Brisbane and Ipswich City Councils but that these models do not include the hydrodynamics of the Wivenhoe and Somerset Dams nor of the manner in which operation of the flood gates and auxiliary spillways may impact on the outflows from the Wivenhoe Dam.

Thus they have characteristically been run with hypothetical hydrological input data – probably with some assumptions concerning the water level in the Wivenhoe Dam at the start of a flood and the rate at which water might be released from the Dam thereafter. There were examples of the results of such modelling on the Brisbane City Council web-site during the early part of the flood which I was able to download at the time - but these no longer appear to be accessible. They appear to be of a Probable Maximum Flood of 12000 cumecs at the Port Gauge – approximately double the flow considered by the 2003 report to Council to be a Q100 flood flow at this point.

It is thus difficult for me to be able to identify what information might have had available to it when issuing flood warnings and when planning flood management and mitigation strategies.

Your advice as to the availability of the Council information developed from such modelling would be of further assistance in developing my proposed submission as it would indicate the extent to which this could be readily incorporated into an overall system model prior to the next La Nina period – the prime purpose of my submission.

Of equal significance is the potential availability of the stream gauging and level records of the Australian Government's Bureau of Meteorology for this flood. The Bureau operates a flood warning system "for the Brisbane River below Wivenhoe Dam to Brisbane City. The Bureau also provides indicators of flood risk and whether a flood has reached minor, moderate or major flood precautions.

The Bureau's description of the above flood warning system refers to a flood forecasting capability as follows:

> *The Bureau of Meteorology, in association with the South East Queensland Water Corporation (SEQWater) and the City Councils of Brisbane and Ipswich, operates a flood warning system for the Brisbane River Basin using rainfall and river height network shown on the map. The network is made up of manual and river height observers as well as automated telemetry equipment.*
>
> *The flood warning system has been upgraded in recent years by the Bureau, SEQWater, BCC and ICC with the installation of many ALERT flood warning stations. These provide early warning of heavy rainfalls and river rises throughout the catchment and enable more accurate and timely response to impending river and creek flooding throughout the Brisbane Valley.*

My enquiries to date suggest that this is basically a hydrological model which determines river flows at points downstream of Wivenhoe Dam and, from the river flows, flood levels at these gauging stations. As will be show below this is seen to be a major shortcoming in the flood warning system in that it is only a partial and incomplete model and is matter which needs to be examined by the Commission. Your advice as to the availability of a description of the current flood forecasting methodology would be appreciated.

The need for the Commission to focus on the systems and methodologies employed in forecasting Brisbane River flooding and so more-effectively managing the releases from Wivenhoe Dam is heightened by the Table of Agency Requirements in Section 6.2, p.7 of the "redacted version" of the *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam* which shows the chain of communication of SEQWater's actual and projected discharges from Wivenhoe and Somerset Dam in which SEQWater's Flood Operations Centre firstly pass this information on to DERM for "review of flood operations and discretionary powers" and to the Bureau of Meteorology for the "issue of flood warnings for the Brisbane River Basin, leaving the Bureau to pass this information on to Brisbane and Ipswich City Council to provide flood level information in the relevant city's flood-prone areas.

Section 5 of the SEQWater manual describes its "flood monitoring and forecasting system", referring to a Real Time Flood Model (RTFM) and it is believed that the results of this model, "a suite of hydrologic and hydraulic computer programs" are used as a basis for operating the dams during flood events.

I am concerned that the output from this model may be estimates of the flood flow in the Brisbane River at the Moggill flood gauge and that its inputs and outputs may not be consistent with the data that has been input to Council modelling.

Thus there could be quite significant delays in working out the impacts of various Wivenhoe gate opening strategies on those downstream urban areas where the need to minimise flood damage is maximum.

I would be grateful to receive advice as to the potential availability of a description of the RFTM and how it has been upgraded and operated during the January 2011 flood as this should confirm my belief that RFTM is inappropriate to use in its current context and should be discarded in favour of an upgraded hydrodynamic model of the whole river basin – including Wivenhoe and Somerset dams.

It is proposed that my submission would identify the systemic problems of managing the dam outflows using the current modelling technologies and forecasting methods.

To do so it would be much more credible if I could access a non-redacted version of the *SEQWater Manual*, as it contains quite basic information concerning the dams in the Appendices – all of which have been blacked out. I would appreciate advice upon the potential availability of controlled access to a non-redacted version of the *Manual* and other information describing the dams' stage-storage relationships such that I could better explain the systemic problems with the current flood management systems.

A subsequent submission is being considered to show how contemporary hydrological and hydrodynamic modelling techniques can be tailored to provide a real time flood forecasting system in which the operation of the Wivenhoe and Somerset Dams can be embedded to provide a more-effective means of minimising flood damage than has recently been demonstrated .

I would be pleased to meet with counsel assisting the Commission to discuss the above at your earliest convenience.

Yours sincerely

M.F. Winders BE(Hons) FIEAust RPEQ

Max Winders
Managing Director

Max Winders & Associates Pty Ltd tas
MWA Environmental

ATTACHMENT 2

Brisbane City Council

FloodWise Property Report

Report Reference
1626238

10/03/2011 09:55:37

Dedicated to a better Brisbane

The FloodWise Property Report is a free report to inform Brisbane residents and professionals about flood risks for a specified lot or property so they may better prepare for flooding and to plan and build in accordance with Council requirements.

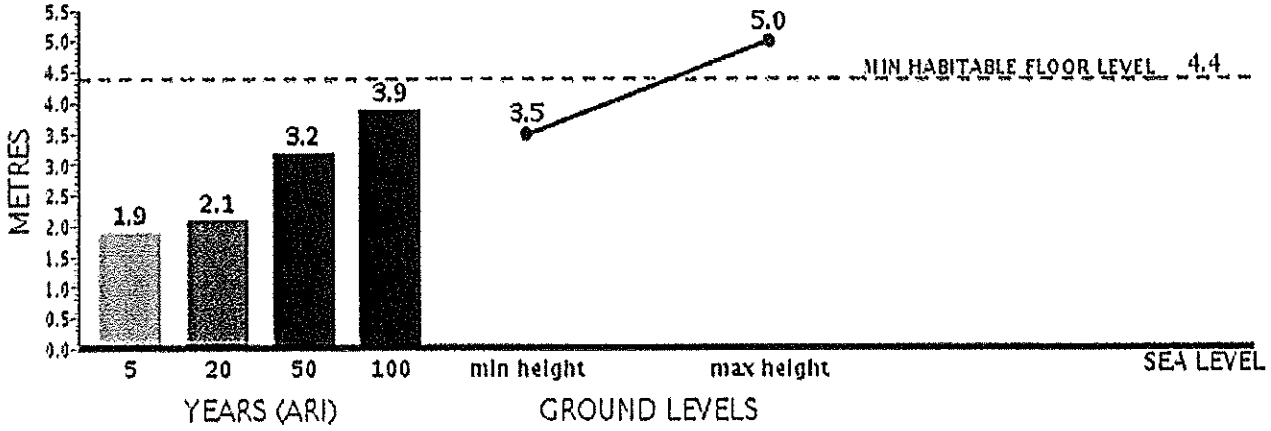
To find out more about how the contents of this report may affect your ability to build or renovate, as well as Council advice on how to protect your property and family by being FloodWise, visit www.brisbane.qld.gov.au, a Customer Service Centre or call (07) 3403 8888.

PROPERTY DETAILS:

Address: 3 EDWARD ST BRISBANE CITY QLD 4000

Lot Details: L.3/RP.129917

FLOOD LEVEL INFORMATION



Flood Levels

The blue bars in the graph above show the height of flooding estimated to occur on average once every 5, 20, 50 and 100 years at this address or lot.

Ground Levels (Min - Max)

The line above shows this property's lowest and highest ground levels. Confirm with a surveyor.

Minimum Habitable Floor Level

The dotted line in the graph above depicts the minimum height above sea level that habitable areas of development must be constructed to, i.e. lounge, kitchen or bedroom.

For a detailed summary of anticipated flood levels and flags see technical summary over page.

HIGHEST SOURCE OF FLOODING

RIVER The highest source of flooding affecting this property originates from a river. For more information about flooding in your area you can view and download Council's Flood Flag Maps by visiting www.brisbane.qld.gov.au/floodmap

Technical Summary

Use this summary to supply information about this property to surveyors, builders, certifiers, architects and engineers who may request this FloodWise Property Report. This summary has been designed to be easily read if scanned or faxed.

Property Details

Address: **3 EDWARD ST BRISBANE CITY QLD 4000**

Lot Details: **L.3/RP.129917**

Flooding Information

Minimum Ground Level (AHD)	3.5 m
Maximum Ground Level (AHD)	5.0 m
Highest Defined Flood Level (DFL)	3.9 m
Highest Flooding Source	RIVER
Minimum Habitable Floor Level (AHD)	4.4 m
Flooding may also occur from:	STORM TIDE

Predicted Peak Flooding Levels (ARI)

Years	Level (AHD)	Source
5	1.9 m	STORM TIDE
20	2.1 m	STORM TIDE
50	3.2 m	RIVER
100 or DFL	3.9 m	RIVER

Disclaimer

1 Defined flood levels are determined from the information available to Council at the date of issue. The defined flood level for a particular property may change if more detailed information becomes available, or changes are made in the method of calculating flood levels.

2 For these reasons, Council makes no warranty or representation regarding the accuracy or completeness of a FloodWise Property Report. Council disclaims any responsibility or liability in relation to the use or reliance by any person on a FloodWise Property Report.

Useful Definitions

Australian Height Datum (AHD) – The reference level for defining ground levels in Australia. The level of 0.0m AHD is approximately mean sea level.

Average Recurrence Interval (ARI) – The probability of experiencing a flood of a particular magnitude. ARI can be interpreted in terms of years (frequency). ARI levels quoted in this report are measured in height above sea level (AHD).

Defined Flood Level (DFL) – The flood level associated with a defined flood event. Commonly, the standard used is the 100 year ARI. For further information refer to the House Code in Brisbane City Plan 2000, specifically Table 1: House Flood Immunity Levels for residential property.

Maximum and Minimum Ground Level – Highest and lowest ground levels on the property based on available ground level information. A Registered Surveyor can confirm exact ground levels.

Minimum Habitable Floor Level – The minimum level above sea level at which habitable areas of development (generally including bedrooms, living rooms, kitchen, study, family and rumpus rooms) must be constructed.

City Plan 2000 – City Plan 2000 sets out what you can build and where new development should go. Council assesses proposed new development against the City Plan 2000.

Find Out More

Whether you are building, buying, renting or preparing your property for flooding, obtaining a FloodWise Property Report is the first step in determining your property's flood risk. Council's 'Be FloodWise' series of publications can assist you to plan ahead, respond to and recover from flooding. They are available online at: http://www.brisbane.qld.gov.au/floodwise or by phoning Brisbane City Council on (07) 3403 8888.

The 'Be FloodWise' publications include:

Preparing for Flooding

Assess your flood risk, prepare for and respond to, flood events.

Be FloodWise - A guide for residents

Buying / Renting

Assess the flood risk of a property before making a decision to rent or buy.

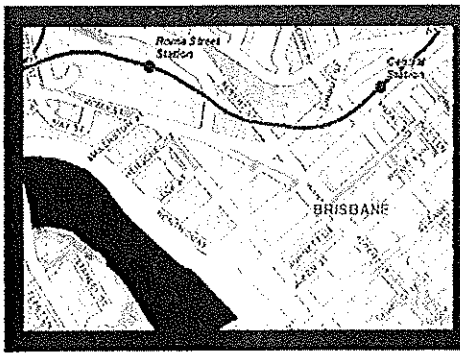
Buying and renting fact sheet

Building or Renovating

Renovations around your home or business can impact on your flooding exposure. Ensure your house meets City Plan 2000 flood immunity

Building and renovating fact sheet

If you are planning to renovate or build, Council recommends you engage a Registered Professional Engineer of Queensland to undertake a thorough assessment of all flood risks specific to the property.



Get a Free Flood Flag Map

Find out more about predicted flooding in your suburb or area by downloading a free Flood Flag Map. The map shows overland flow paths and where flooding may occur from creeks, rivers and storm tides on a suburb scale.

For more information visit **www.brisbane.qld.gov.au/floodmap** or visit a Council Customer Service Centre

ATTACHMENT 3

IDQ65389

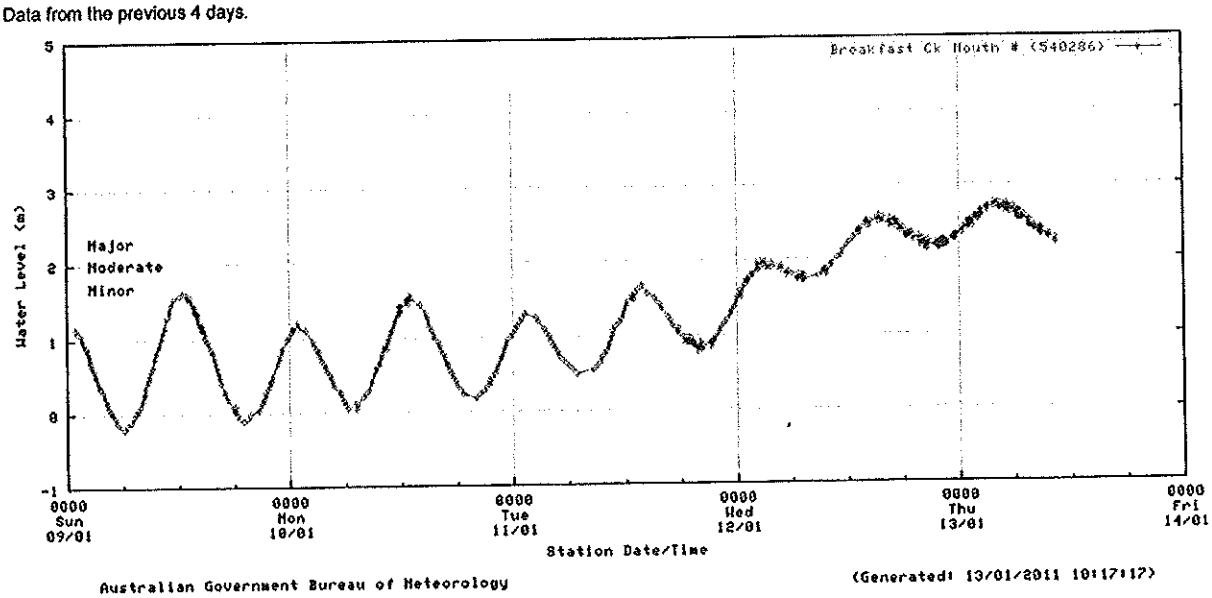
Latest River Heights for Breakfast Ck Mouth

Issued at 10:17 am EST Thursday 13 January 2011

About river heights plots | About this Plot

Station details: Station Number: **540286** Name: **Breakfast Ck Mouth #** Owner: **BCC:143877**
Flood levels: Minor: **1.70** Moderate: **2.00** Major: **2.30**

Data from the previous 4 days.



Data as Table | Previous Station | Next Station | Back to Bulletin

About this plot

1. The river height data is the latest available operational data provided for flood warning purposes and has not been quality controlled.
2. Stations marked with * or # indicate that the data is provided from automatic equipment.
3. Stations marked with * are Telephone Telemetry Devices and are nominally polled once a day and more often during floods.
4. Stations marked with # are ALERT Radio Telemetry and report every 3 hours and more often when the water level changes.
5. All river height reports are in metres and are shown in local time.
6. Heights or depths above/below roads, bridges, dam spillways and weirs are given as a guide only. For road open/closed information, see the RACQ website.
7. This product includes data made available to the Bureau by other agencies. Separate approval may be required to use the data for other purposes. Refer to Listing of Operating Agencies for Station Ownership.
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9. For other Station details: Flood Classifications, Road Crossings, Survey/AHD Details, Maps

IDQ65389

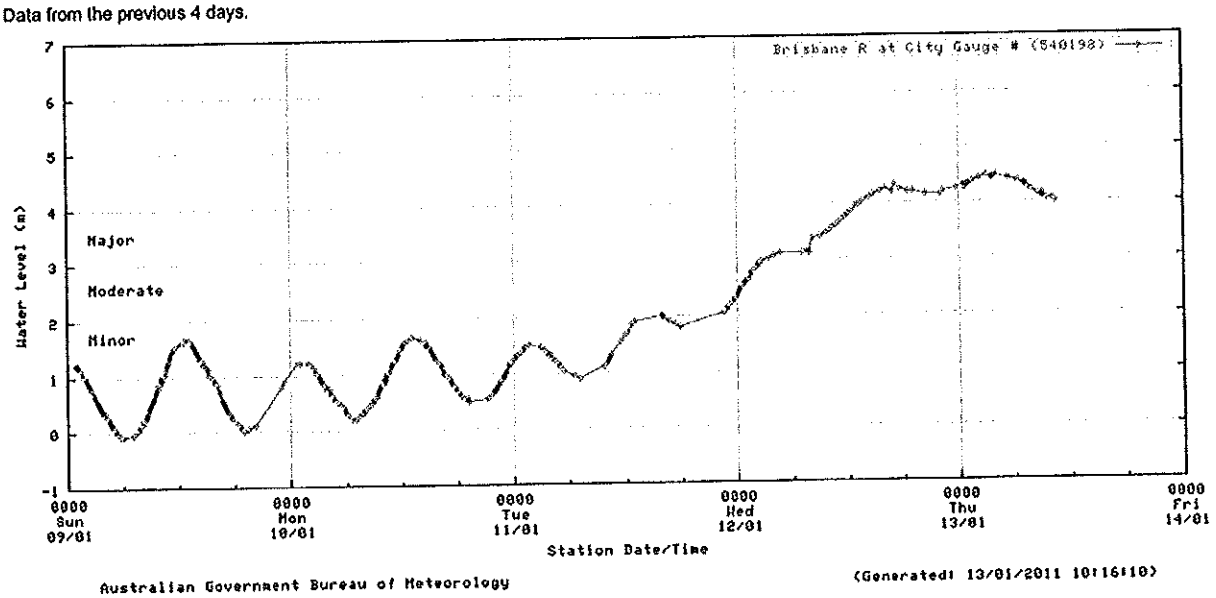
Latest River Heights for Brisbane R at City Gauge

Issued at 10:16 am EST Thursday 13 January 2011

About river heights plots | About this Plot

Station details: Station Number: **540198** Name: **Brisbane R at City Gauge #** Owner: **SEQWCO:143838**
Flood levels: Minor: **1.70** Moderate: **2.60** Major: **3.60**

Data from the previous 4 days.



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9. For other Station details: Flood Classifications, Road Crossings, Survey/AHD Details, Maps

IDQ65389

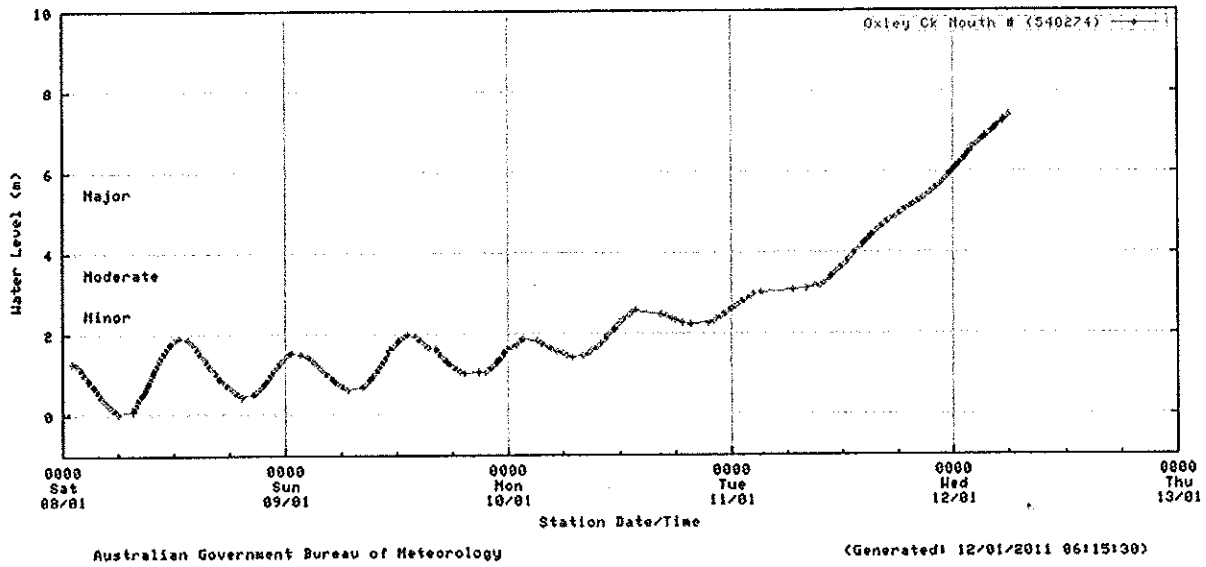
Latest River Heights for Oxley Ck Mouth

Issued at 6:15 am EST Wednesday 12 January 2011

About river heights plots | About this Plot

Station details: Station Number: **540274** Name: **Oxley Ck Mouth #** Owner: **BCC:143872**
Flood levels: Minor: **2.50** Moderate: **3.50** Major: **5.50**

Data from the previous 4 days.



Data as Table | Previous Station | Next Station | Back to Bulletin

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IDQ65389

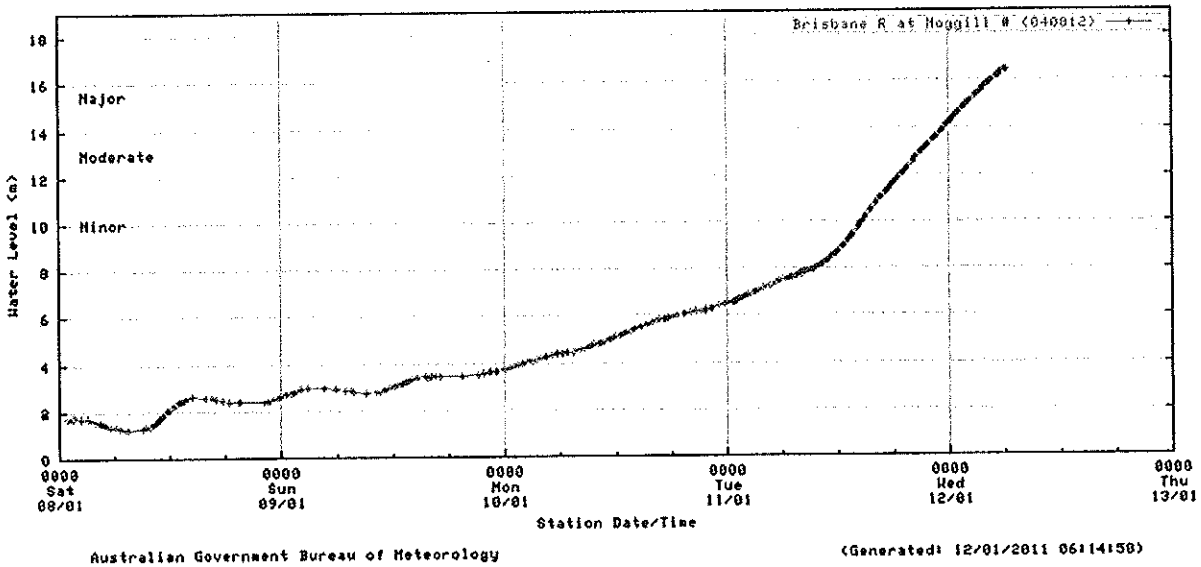
Latest River Heights for Brisbane R at Moggill

Issued at 6:14 am EST Wednesday 12 January 2011

About river heights plots | About this Plot

Station details: Station Number: **040812** Name: **Brisbane R at Moggill #** Owner: **CBM:143951**
Flood levels: Minor: **10.00** Moderate: **13.00** Major: **15.50**

Data from the previous 4 days.



Data as Table | Previous Station | Next Station | Back to Bulletin

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9. For other Station details: Flood Classifications, Road Crossings, Survey/AHD Details, Maps

IDQ65389

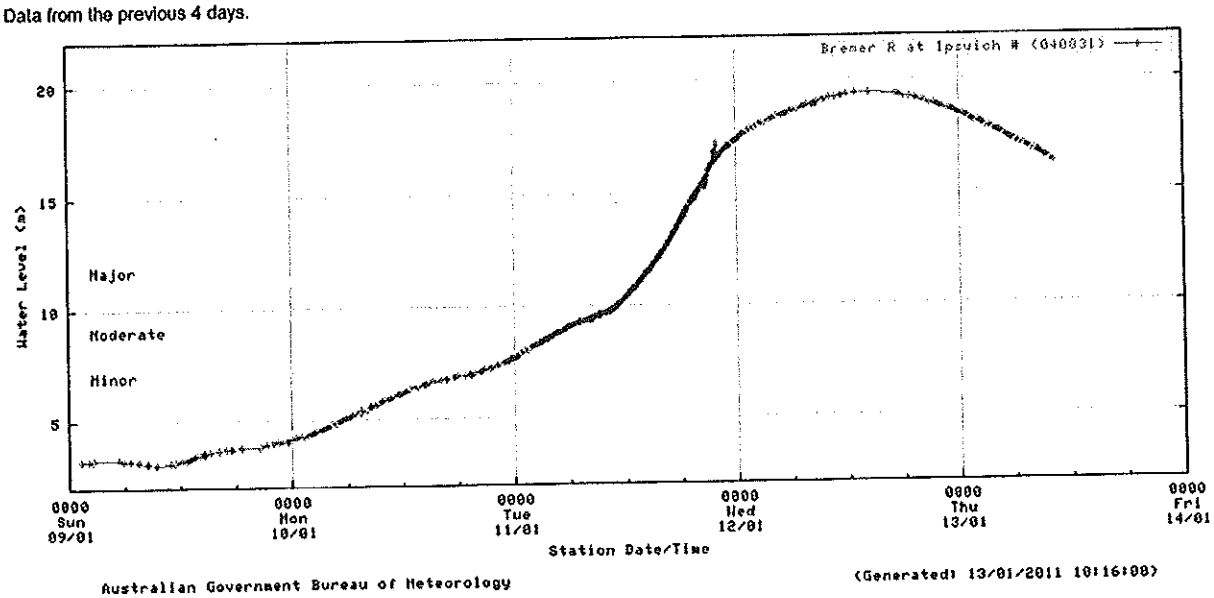
Latest River Heights for Bremer R at Ipswich

Issued at 10:16 am EST Thursday 13 January 2011

About river heights plots | About this Plot

Station details: Station Number: 040831 Name: Bremer R at Ipswich # Owner: CBM/ICC:143954
Flood levels: Minor: 7.00 Moderate: 9.00 Major: 11.70

Data from the previous 4 days.



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7. This product includes data made available to the Bureau by other agencies. Separate approval may be required to use the data for other purposes. Refer to Listing of Operating Agencies for Station Ownership.
8. Where data is supplied from a Department of Environment and Resource Management (DERM) Monitoring Site, please follow this link to get advice on data use and copyright.
9. For other Station details: Flood Classifications, Road Crossings, Survey/AHD Details, Maps

IDQ65389

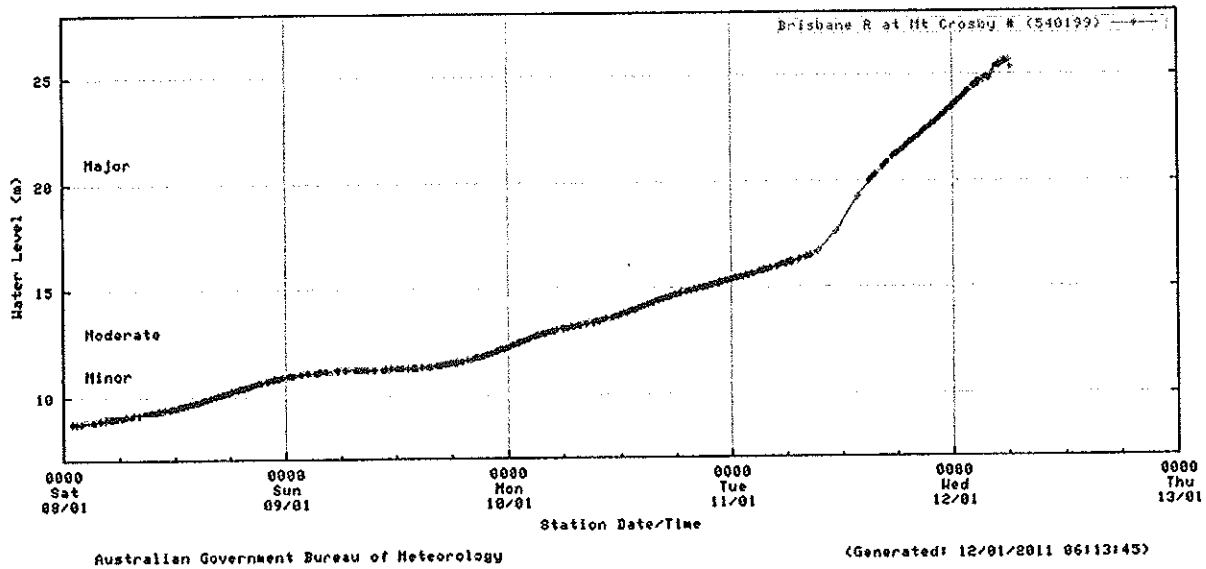
Latest River Heights for Brisbane R at Mt Crosby

Issued at 6:13 am EST Wednesday 12 January 2011

About river heights plots | About this Plot

Station details: Station Number: **540199** Name: **Brisbane R at Mt Crosby #** Owner: **SEQWCO:143839**
Flood levels: Minor: **11.00** Moderate: **13.00** Major: **21.00**

Data from the previous 4 days.



Data as Table | Previous Station | Next Station | Back to Bulletin

About this plot

1. The river height data is the latest available operational data provided for flood warning purposes and has not been quality controlled.
2. Stations marked with * or # indicate that the data is provided from automatic equipment.
3. Stations marked with * are Telephone Telemetry Devices and are nominally polled once a day and more often during floods.
4. Stations marked with # are ALERT Radio Telemetry and report every 3 hours and more often when the water level changes.
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IDQ65389

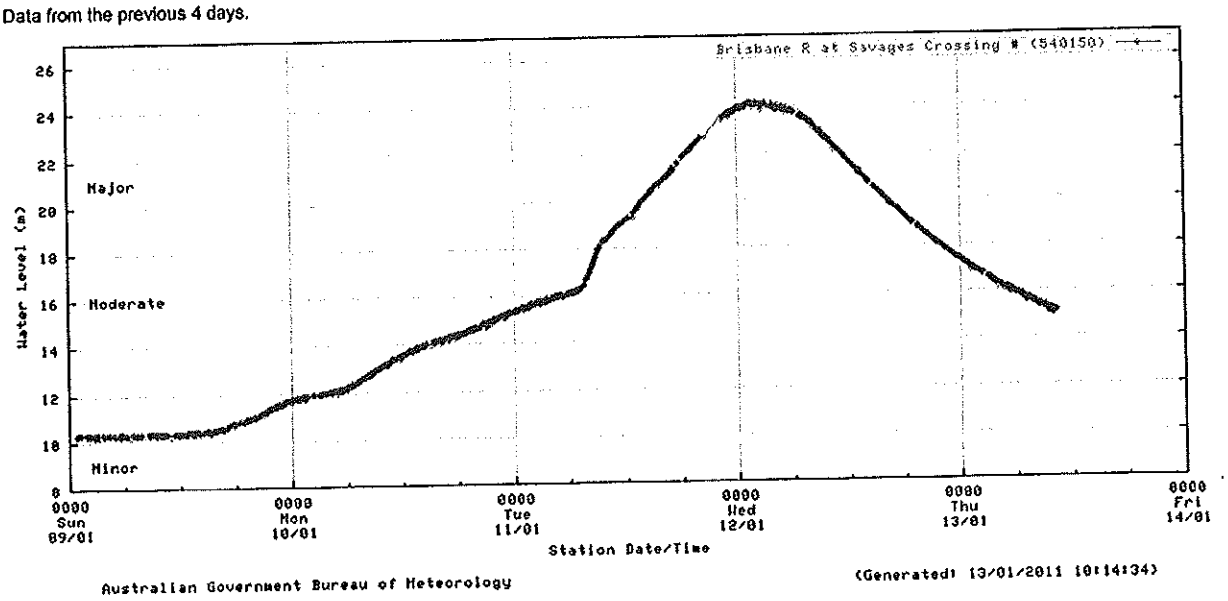
Latest River Heights for Brisbane R at Savages Crossing

Issued at 10:14 am EST Thursday 13 January 2011

About river heights plots | About this Plot

Station details: Station Number: **640150** Name: **Brisbane R at Savages Crossing #** Owner: **SEQWCO:143808**
Flood levels: Minor: **9.00** Moderate: **16.00** Major: **21.00**

Data from the previous 4 days.



Data as Table | Previous Station | Next Station | Back to Bulletin

About this plot

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IDQ65389

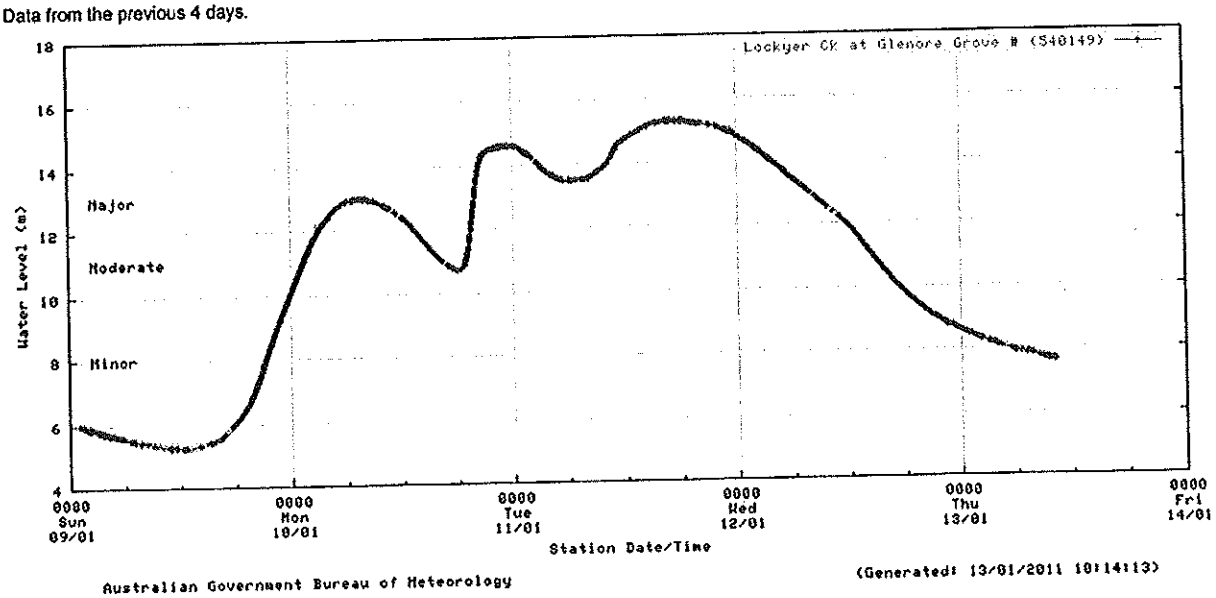
Latest River Heights for Lockyer Ck at Glenore Grove

Issued at 10:14 am EST Thursday 13 January 2011

About river heights plots | About this Plot

Station details: Station Number: 540149 Name: Lockyer Ck at Glenore Grove # Owner: CBM/SEQWCO:143807
Flood levels: Minor: 8.00 Moderate: 11.00 Major: 13.00

Data from the previous 4 days.



Data as Table | Previous Station | Next Station | Back to Bulletin

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IDQ65389

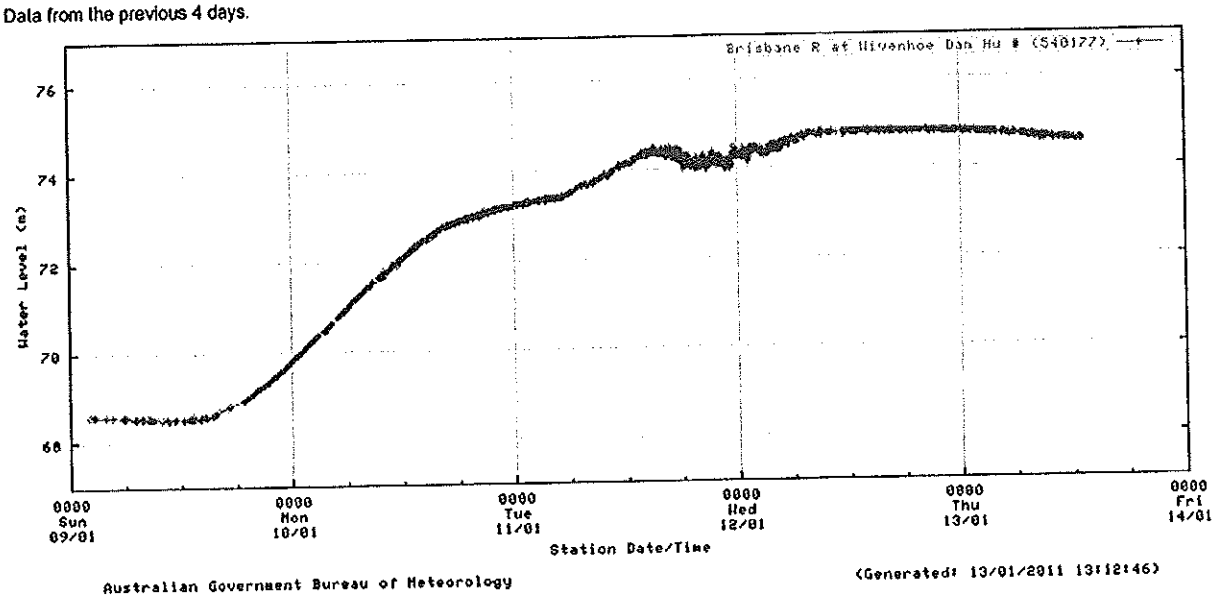
Latest River Heights for Brisbane R at Wivenhoe Dam Hw

Issued at 1:12 pm EST Thursday 13 January 2011

About river heights plots | About this Plot

Station details: Station Number: **540177** Name: **Brisbane R at Wivenhoe Dam Hw #** Owner: **SEQWCO:143822**

Data from the previous 4 days.



Data as Table | Previous Station | Next Station | Back to Bulletin

About this plot

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EXHIBITS

1. Three-dimensional map of the Brisbane and Bremer River Catchments
2. Sheet 4 of the Brisbane River Flood Plain Map