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Analysis of Wivenhoe Releases

What could have been done with the benefit of hindsight in the January 2011 Flood Event.

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This report is an analysis of the operation of the Wivenhoe and Somerset Dams during the January 2011 flood event, to determine whether a better outcome could have been achieved.

A separate analysis has also been conducted to determine what the level of flooding would have been if the second peak inflow had been equal to that predicted by BoM.

Release Scenarios Modelled

Several scenarios have been modelled, these include:

- **Actual Releases** – modelling of the reported releases from Wivenhoe for model verification purposes
- **Run 1** – discharging the maximum allowable flows (as specified by the Operations Manual for Wivenhoe) based on the recorded flow at Moggill Gauge (excluding Wivenhoe releases) in 24 hours time. The maximum allowable flow at Moggill Gauge was assumed to be 4000m^3/s.
- **Run 2** – as per Run 1 but with smoother transitions in release amounts and an allowing for the flow at Moggill Gauge to be greater than 4000m^3/s if it was not possible to maintain this level.
- **Run 3** – discharging the maximum allowable amount (i.e. 1900m^3/s under W1 and 4000m^3/s under W3) without consideration of the total flow at Moggill Gauge.

For Run 1 and Run 2 it was assumed that the dam operators would have perfect knowledge of what the flow at Moggill Gauge would be in 24 hours. A 24 hour time period was chosen as this is roughly the time that it takes for releases from Wivenhoe to reach the Moggill Gauge. Moggill Gauge is located near the confluence of the Brisbane and Bremer Rivers, and is also downstream of the Lockyer Creek catchment. In reality it would be extremely difficult for dam operators to know exactly what the flow would be at this point in 24 hours time as it would be dependent on accurate rainfall predictions and hydrologic models as well as having reliable rating curves available at critical locations in the catchment.

The main purpose of Run 1 was to determine whether it would have been possible to maintain flows at Moggill at less than 4000m^3/s, which is considered the point at which damage to urban areas occurs. For Run 1, once the critical level of 74.0 for W4 was reached in the dam the outflows were increased to an amount sufficient to avoid activation of the fuse plugs. In reality there would have been a more gradual increase to the flows (as modelled for Run 2) prior to W4 being activated, as it would not have been possible to limit the flow at Moggill to 4000m^3/s.

Run 2 would provide the best representation of the optimal operation of the Wivenhoe Dam as constrained by the release guidelines in the Operations Manual. However, it should be noted that this scenario uses the benefit of hindsight. Based on the information that the dam engineers had during the event, different release rates would be expected.

Run 3 assumes that the dam releases were the maximum amount as specified by each operating strategy, e.g. releasing 1900m^3/s when in W1 and 4000m^3/s when in W3. It should be noted that this scenario would not comply with the Operations Manual as it doesn't take into account the total flow at Moggill Gauge and Lowood. In most flood events it is likely that this release strategy would exacerbate flooding downstream.

Summary of Data

Flow at Moggill Gauge

The flow at Moggill Gauge from the Bremer, Lockyer and Lower Brisbane catchments was calculated by subtracting the reported release from Wivenhoe Dam from 24 hours previous. The rating curve at Moggill Gauge has recently been updated by SKM (refer Figure 5.4 of *Joint Calibration of a Hydrologic and Hydrodynamic Model of the Lower Brisbane River,* 24 June 2011) based on information attained during the January 2011 event. The original rating curve underestimated the flows at this point. The levels recorded at Moggill Gauge were taken from Figure 6.5.12 of the SEQWater report prepared in March 2011. The rating curve adopted for the analysis is shown in Table 1 below.

Table 1 Moggill Gauge Rating Curve

Level (mAHD)	Flow (m^3/s)
1.5	800
2.0	1200
2.5	1400
3.0	1600
3.5	1850
4.0	2060
4.5	2250
5.5	2625
6.5	3000
7.5	3500
8.5	4000
12.0	5900
14.0	7100
14.5	7420
15.5	8350
16.5	9230
17.0	9760
17.5	10400
17.7	10500

The flow at Moggill Gauge is critical to the operation of Wivenhoe Dam as it controls how much is allowed to be released during the W2 and W3 operating strategies. During the W1 operating strategy, the peak flow at Lowood in the main constraint. As there was insufficient data available to determine what this was, the flow at Moggill Gauge was used in its place. The SEQWater March 2011 report indicates that there were relatively minor differences in the peak flows at these two locations when W1 would have been in place.

Port Office Gauge

The resultant water levels at Brisbane Port Office were determined using the updated rating curve produced by WMA Water (refer Figure 8, *Flood Frequency Analysis*, September 2011). This curve predicts slightly higher water levels for the 2011 event than what was recorded.

Between Moggill Gauge and Brisbane Port Office there was a reduction in peak flow of around 10 percent reportedly due to the attenuation provided at the confluence of the Brisbane and Bremer Rivers. Therefore the peak flows calculated at Moggill were reduced by the same percentage to determine the peak flow at Brisbane Port Office, which was then used to calculate the peak water level.

Rainfall Predictions

The rainfall predictions for the Wivenhoe Dam catchment would have been used by the operators of the dam to help determine the appropriate release rates based on what inflows were likely to occur. Due to the historical inaccuracy of these predictions they are not solely relied upon to dictate the operation of the dam. In this analysis, as the actual flows at Moggill are known, it is the equivalent of having perfectly accurate rainfall predictions available. The 24 hour rainfall predictions provided to SEQWater on a twice daily basis are shown in the following image.

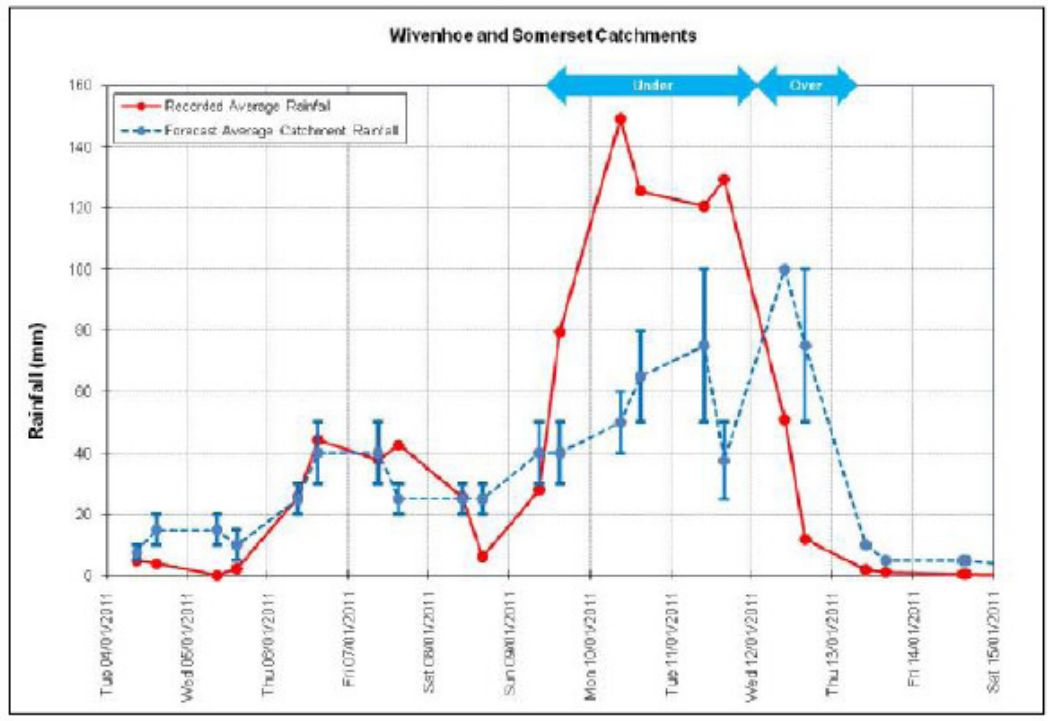


Image 1 **Predicted and Recorded Rainfall (EA Presentation by Terry Malone, November 2011)**

As evidenced by Image 1, at the start of the flood event the rainfall estimates matched fairly well to what was recorded. However, from late on the 9th until late on the 11th the rainfall estimates were significantly underestimated. From the 12th onwards the rainfall estimates were then overestimated. Based on this data it can be assumed that the operators of the dam were not expecting the amount of inflow into the dam that actually occurred. At the moment of the peak release from the dam, late on the 11th, the future rainfall that was to occur was predicted to be higher than all previous predictions.

Dam Operation

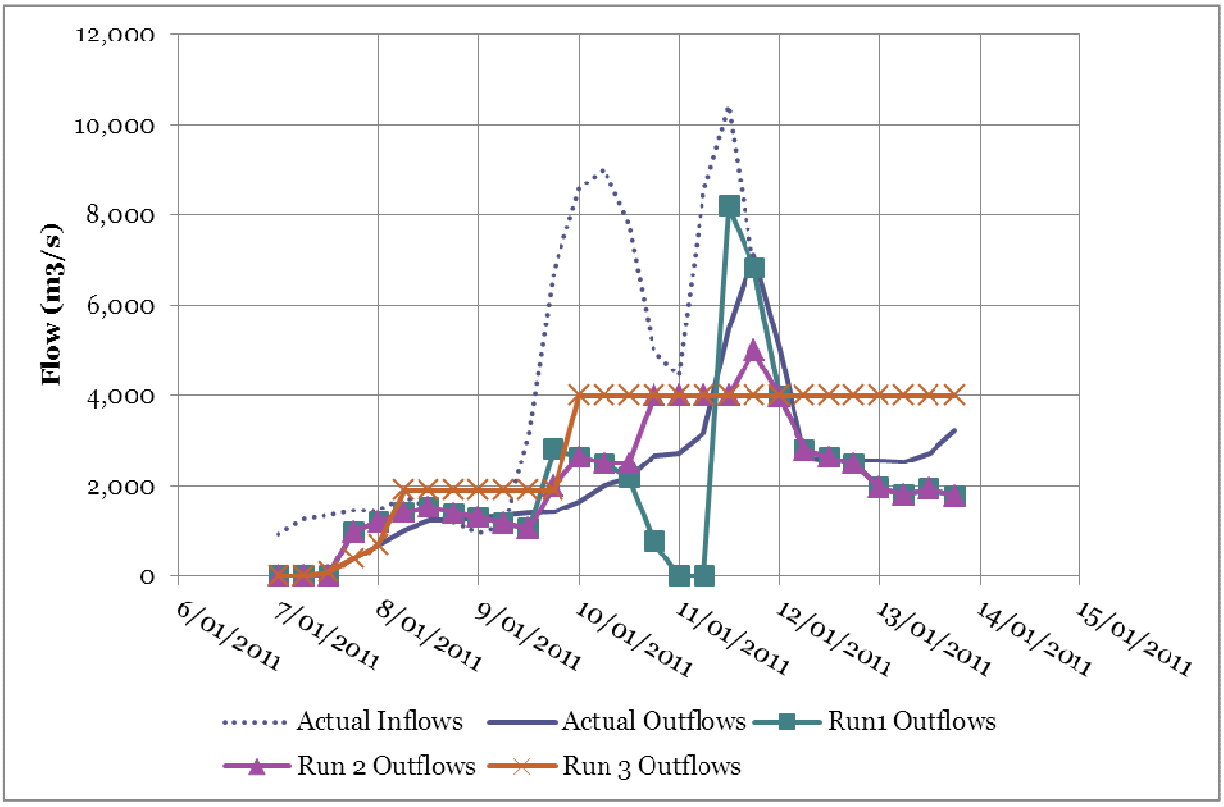
For the analysis it was assumed that the following rules were adhered to (with the exception of Run 3):

- Water Level < 67.5, maximum allowable flow 110 m^3/s at Lowood/Moggill
- Water Level < 67.75, maximum allowable flow 380 m^3/s at Lowood/Moggill
- Water Level < 68.0, maximum allowable flow 500 m^3/s at Lowood/Moggill
- Water Level < 68.5, maximum allowable flow 1900 m^3/s at Lowood/Moggill
- Water Level < 74.0, maximum allowable flow 4000 m^3/s at Moggill (it was assumed that the transition was directly from W1 to W3) unless it is not feasible to maintain the flow at Moggill at level. The maximum release allowed from Wivenhoe Dam is 4000 m^3/s
- Once 74.0 is reached the outflows are increased to a level sufficient to prevent the fuse plugs being activated and then reduced to equal the inflows into the dam.

Results

Releases from Wivenhoe Dam

The releases from Wivenhoe Dam for each scenario are shown Graph 1. The inflows into the dam are also presented in this graph.



Graph 1 Inflows and Outflows from Wivenhoe Dam

The actual releases match fairly well with Runs 1 and 2 between the period from the 7th to the afternoon of the 9th of January, indicating that they were complying well with the optimum releases allowed from the dam. Although Run 3 shows higher releases during this period, this would not have been in compliance with the Operating Manual. The inflows into the dam were relatively low during this period. It is considered that increasing releases to levels higher than the inflow would not have been a viable strategy at this stage, as this could have resulted in an unnecessary exacerbation of downstream flooding.

On the start of 10th of January the releases were less than would have been optimal. It is considered that the reason for this could have been because the dam operators were also considering lower priority targets. Based on predicted rainfall available at this time it is likely that this strategy could have been maintained. Around midday on the 10th, the optimal release amounts had again been reached. Around midnight on the 10th the releases were less than optimal. It is considered that the reason for this would have been that they were attempting not to coincide with the peaks from Bremer and Lockyer catchments (as was

required by the dramatic reduction in releases evidenced by Run1) in order to minimise the peak flows at Moggill. As the predicted rainfall was less than recorded at this point, it is also likely that there was thought to be sufficient volume available within the dam to continue with this strategy.

By mid-morning on the 11th the releases were again at optimal levels prior to W4 being implemented.

The peak releases (averaged over a 6 hour period) from each of these scenarios is:

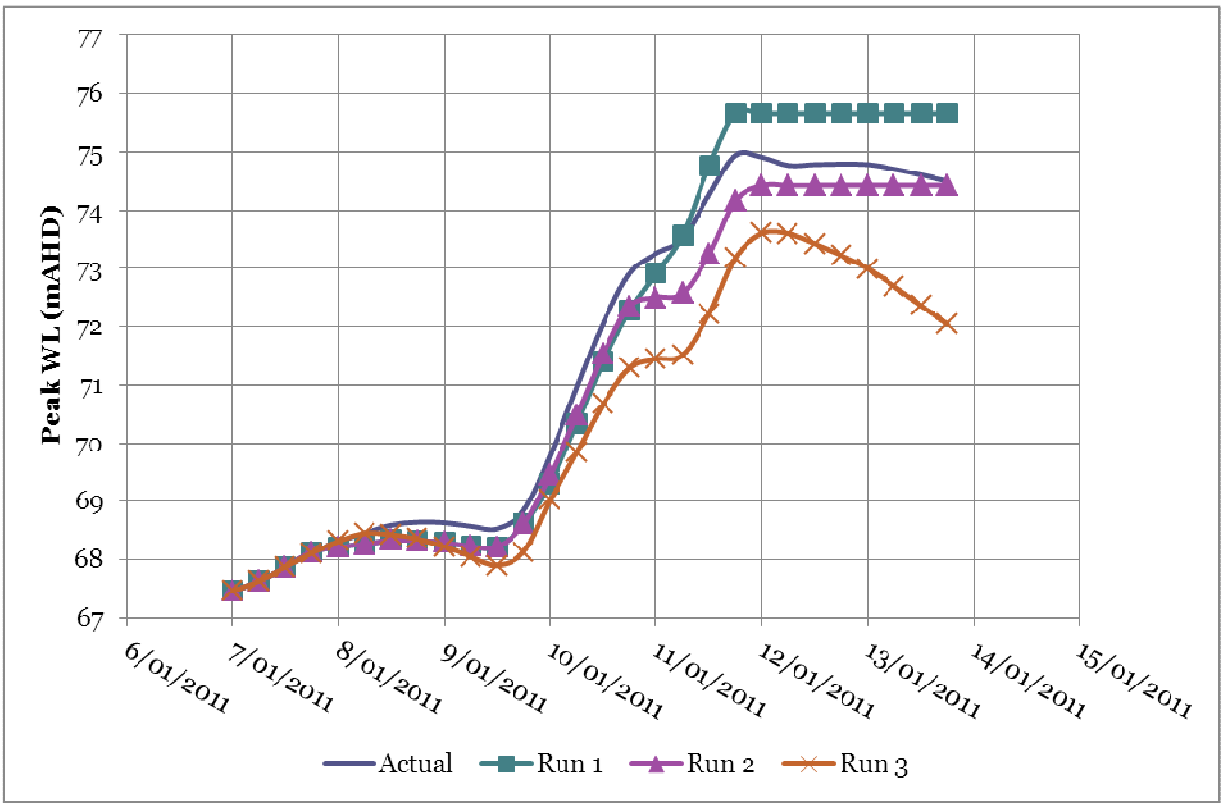
- Actual – 7,120 m^3/s
- Run 1 – 8,200 m^3/s
- Run 2 – 5,000 m^3/s
- Run 4 – 4,000 m^3/s

Based on the actual releases it would have been possible to reduce the peak amount released by around 500 m^3/s and still avoid activating the fuse plugs. However, it should be noted that at the time of this peak release that intense rainfall was predicted to occur, which did not eventuate. Given this, the peak amount release is considered to be reasonable.

Without the second peak in inflows the release strategy adopted would have resulted in a better outcome downstream than all the modelled scenarios, as it is likely than W4 would still have been activated in Run 1.

Water Levels at Wivenhoe Dam

The graph below shows the peak water level reached at Wivenhoe Dam for each of the scenarios modelled.



Graph 2 Peak Water Levels in Wivenhoe Dam

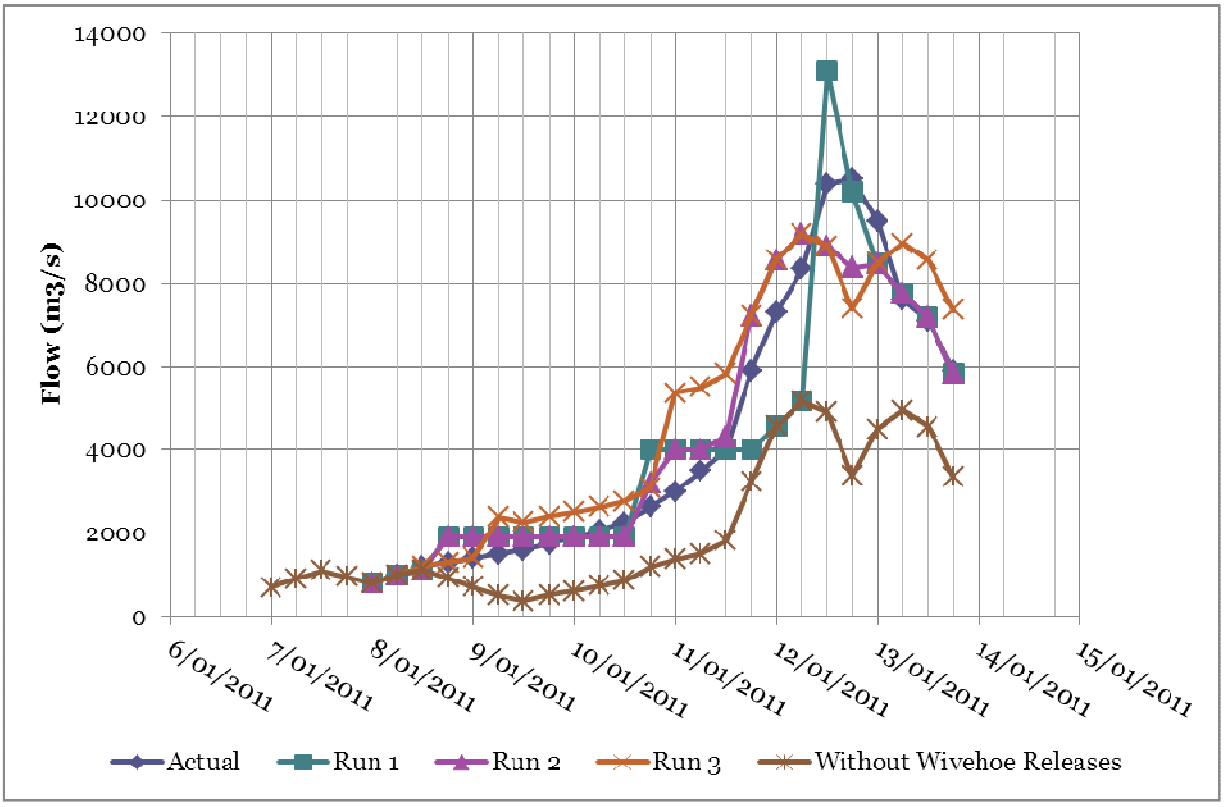
For Runs 1 and 2 the critical level of 74.0 mAHD, when W4 is implemented is reached. Run 3 is the only scenario that does not have to implement W4. However, it should be noted that Run 3 would not have been in compliance with the Operating Manual.

The peak levels reached in Wivenhoe Dam are:

- Actual – 74.95 mAHD
- Run 1 – 75.66 mAHD
- Run 2 – 74.42 mAHD
- Run 3 – 73.60 mAHD

Resultant Flows at Moggill

The resultant peak flows at Moggill are shown in Graph 3. The flow at Moggill assuming no releases from Wivenhoe Dam is also presented, to provide an indication of the total flow from the Bremer, Lockyer and Upper Brisbane catchments alone.



Graph 3 Flows at Moggill Gauge

As shown in Graph 3 it is not possible in any of the scenarios modelled to ensure that major flooding will not occur. The minimum flow at which urban damage occurs is 4000m³/s at Moggill. Even without any flows from Wivenhoe Dam the maximum flow at Moggill is 5,177 m³/s. The peak flows at Moggill (averaged over a 6 hour period) for each of the scenarios are:

- Actual – 10,500 m³/s
- Run 1 – 13,105 m³/s
- Run 2 – 9,177 m³/s
- Run 3 – 9,177 m³/s

For Runs 2 and 3, although the peak release from Wivenhoe Dam is significantly lower, the earlier release would have coincided with the natural peak at Moggill. The earlier release from Run 1 also coincides with the natural peak at Moggill, so even though the peak release was only 1,080 m³/s higher than the actual release, the total peak flow at Moggill is 2,605 m³/s higher. The actual peak in releases was able to coincide with the timing of the dip at Moggill between the two peaks.

For the Run 3 scenario the 4000 m^3/s flow at Moggill is exceeded around 15 hours prior to the actual case. The 1900 m^3/s limit at which local bridges become untrafficable is also reached 30 hours prior to the actual case. The rate of increase in peak flows is more rapid for all run scenarios. It should be considered what impact this would have had on emergency evacuation measures. If there was less time to implement sufficient warnings it would have been more likely that people would have taken unnecessary risks crossing flooded roads, and there would have been less time to evacuate those most at risk, and people would have been more likely to be caught in isolated locations. It is considered that there are greater risks regarding loss of life for each of the run scenarios when compared to the actual case.

Peak Water Levels at Port Office

The resultant peak water levels at Port Office were then determined. As discussed previously, due to attenuation around Moggill the peak flows at Port Office are around 10% less than those at Moggill. The resultant peak water levels for each of the run scenarios, based on the updated rating curve provided by MWA Water are:

- Actual – 4.60 mAHD
- Run 1 – 6.06 mAHD
- Run 2 – 4.00 mAHD
- Run 3 – 4.00 mAHD

The level of major flooding at Port Office is 3.5 mAHD. This demonstrates that even with the benefit of hindsight that the releases required would have resulted in a major flood event occurring. Although the flood levels could have been reduced by around 600 mm at Port Office it would have required the exact knowledge of actual and future flows throughout the catchment. Given that the rainfall predictions available did not provide accurate representation of what fell in the catchment it is considered that it would not have been possible to operate at the optimum strategy throughout the course of the event. Based on the information that the dam operators had available at the time of the event it is considered that they achieved close to an optimal result and followed the requirements of the Operations Manual.

If the peak release had been reduced by 500 m^3/s (which is the amount that would have avoided activation of the fuse plug), then the peak water level at Port Office would only have been around 220 mm lower.

Reduction in Second Peak

During the flood event there were two peaks in the inflows into the dam, both significantly greater than was estimated by BoM. An analysis was conducted to determine the expected level of flooding if the second peak on the 11th of January had only been as large as predicted by BoM. The flows from the other catchments were assumed to be unchanged.

The rainfall predictions from BoM were an average of 57.5mm for the 11th of January. An average of 125mm was recorded in the catchment, which was 117% more than the predicted rainfall.

Based on the actual release rates, if the inflow on the 11th had only been as high as predicted by BoM then it would have been possible to limit the peak release from Wivenhoe Dam to approximately 3000 m^3/s and the peak flow at Moggill would have been

around 8000 m^3/s. This would have resulted in a peak water level at Port Office of 3.5 mAHD, which is equal to the major flood level at this point.

If earlier releases of the maximum allowable amount (Run 2 and 3) had been implemented, then this would have coincided with the first peak from Lockyer and Bremer catchments and the peak flow at Moggill would have been $9177m^3/s$. The resultant peak water level at Port Office would have been 4.00 mAHD. If it was assumed that dam releases were reduced from 6am on the 11th of January then the peak at Moggill would still have been $8574m^3/s$ (3.75 mAHD at Port Office) as the earlier releases would still have coincided with the start of the first peak.

This highlights the fact that releasing the maximum amount early would have been a risky strategy to take as it could have worsened flooding downstream. It would have required the operators to assume future inflows much greater than those predicted by BoM in order to justify their actions. If the rainfall had only been as intense as predicted they would have been in clear breach of the manual. The manual's definition of W3 which clearly states that *"the intent of Strategy W3 is to limit the flow in the Brisbane River at Moggill to less than $4000m^3/s$…….depending on natural flows from Lockyer and Bremer catchments, it may not be possible to limit the flow to $4000m^3/s$. In these instances the flow at Moggill should be kept as low as possible"*.

It is only with the benefit of hindsight, with exact future flows known (which were much greater than predicted during the event) that an early peak release strategy could have been warranted, as early releases could also have resulted in an unnecessary worsening of flooding downstream.

CONCLUSIONS

Based on the benefit of hindsight the following conclusions can be made:

- Even with the benefit of hindsight major flooding of Brisbane was unavoidable based on the requirements of the Operations Manual.
- For the majority of the flood event close to optimal releases were being made as required by the Operations Manual.
- The release strategy adopted provided the least risk to human life.
- The peak release did not coincide with the peak from the remainder of the catchment, which reduced the severity of flooding downstream.
- Available rainfall predictions did not accurately predict the rainfall event.
- If the second peak had only been as extreme as predicted by BoM then the releases could have been limited to $3000m^3/s$ and the release strategy adopted would have resulted in a flood level of 3.5 mAHD at Port Office. Earlier releases of the maximum release amount (Run 2 and 3) would have resulted in higher total flows downstream and would have worsened flooding by around 250 to 500 mm at Port Office.
- Earlier releases of the peak amount possible would not have been in compliance with the Operations Manual. It would also have been necessary for the operators to assume future inflows would be much greater than those predicted by BoM to justify this course of action.

About the Author

Nadia Guterres is a Water Engineer and hydrologist with over 7 years of experience in the consulting industry in Brisbane. She has experience in 2D and 1D flood modeling for rural and urban areas, detention basin design, flood risk assessments and urban drainage design. She has not been commissioned by any party involved in the Flood Inquiry and completed this assessment to satisfy her own curiosity.