

Acceptable Flood Capacity Assessments of Rosewood and Marburg Detention Basins

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Abstract: *The purpose of an Acceptable Flood Capacity (AFC) assessment is to determine whether a dam can or cannot pass the AFC. If not, necessary upgrades and timing must be provided so the AFC is met. It was found that both the Rosewood and Marburg detention basins cannot pass the AFC. They require raising the embankment crest and the installation of a wave wall. In addition to raising the embankment, the Marburg basin needs investigation of various additional spillway configurations. The paper describes the background to dam safety practice in Australia (with particular reference to Queensland), the hydraulic design of these high hazard basins, the basis for determining the AFC of each basin and the way forward.*

Keywords: *Dam Safety, Flood Capacity, Detention Basin.*

1. INTRODUCTION

Most of the world's towns and cities evolved on river floodplains. Recent catastrophic flooding in the United Kingdom, the Continent and the United States of America is a consequence of that development, exacerbated by forest attrition and the expansion of impervious areas in catchments. Brisbane suffered disastrous flooding in 1974, after which Wivenhoe Dam was constructed with approximately 1.4 GL of flood storage above 1.2 GL of water supply capacity. 36000 people dwell within the failure inundation zone below the dam. At the local urban level, flood detention basins have become commonplace. The majority are small, pose no threat to human life and are not prescribed or regulated by any dam safety authority.

Parsons Brinckerhoff was engaged by Ipswich City Council to undertake Acceptable Flood Capacity assessments of Council's two detention basins that are classified as Regulated Dams. The basins are located at Rosewood and Marburg, which are regional townships approximately 20 km west of Ipswich City. Rosewood and Marburg have populations of about 2200 and 600, respectively (ABS, 2014).

In Australia, dam safety is a State or Territory matter. In Queensland, *The Water Supply (Safety and Reliability) Act (2008)* covers the administration of dam safety. The Director of Dam Safety in the Department of Energy and Water Supply exercises the authority to set design, operational and safety management criteria.

Ipswich City Council has an obligation to ensure that any of its dams that pose a potential threat to the community have adequate spillway capacity to provide appropriate immunity against overtopping of any embankment. It is in this regard that the Director of Dam Safety directed Ipswich City Council to prepare Acceptable Flood Capacity assessments for both of its Regulated Dams to determine if either requires an upgrade.

1.1. Basis of existing flood capacity

The criteria applied to dam characteristics are more onerous the larger the dam and the more likely it is that people downstream are placed at risk should the dam fail. A key instrument is the spillway design flood Annual Exceedance Probability (AEP). Guidelines provided by the department nominate the required AEP range corresponding to various levels of the consequences of dam failure. In Queensland the measure of failure consequences is population at risk (PAR), which is determined by undertaking a Failure Impact Assessment (FIA). An FIA involves a series of hydraulic analyses to

estimate the number of dwellings and other facilities inundated by a breach wave. Rosewood and Marburg Detention Basins have consequence categories that justify a spillway design flood equivalent to the Probable Maximum Flood (PMF).

At Marburg, the adoption of the PMF would have involved prohibitive cost because of the upstream impact on homesteads and an adjacent road, and accordingly, the detention basin would not have been constructed. In a guideline on risk assessment (ANCOLD, 2000a), a fallback approach is available, being a design flood capacity that makes the risk "as low as reasonably practicable" (ALARP). Under ALARP, a flood of 1 in 50,000 AEP was proposed and was accepted by the regulator. The basin was put to the test during a 1 in 100 AEP flood event in 2008 after which a State Emergency Service spokesperson asserted that, without the detention basin, lives would have been lost. This vindicated the ALARP concept. For Rosewood, the spillway design flood is the PMF that can be accommodated economically, there being no upstream impact of a large flood rise above spillway level.

1.2. Basis for Acceptable Flood Capacity

The Acceptable Flood Capacity is defined as:

The overall flood discharge capacity required of a dam determined in accordance with these guidelines including freeboard as relevant, which is required to pass the critical duration storm event without causing failure of the dam.

(DNRW, 2007)

Based on respective PAR of 140 and 173, the hazard category of Rosewood and Marburg basins is 'High A' according to DNRW (2007). The AFC for each basin is therefore the Probable Maximum Precipitation (PMP) design flood.

The Office of the Water Supply Regulator required an Acceptable Flood Capacity (AFC) assessment be prepared for the basins. The AFC reports must include an assessment of the identified current flood discharge capacity of the dam expressed as a percentage of the required AFC, of the form:

$$K (\%) = \frac{\text{Peak discharge for flood currently able to be safely passed}}{\text{Peak inflow for the critical duration AFC}} \quad (1)$$

Where the dam cannot pass the AFC, the report is to include preliminary proposals for the necessary work and timing required to upgrade the dam to the AFC.

The assessment is to be undertaken according to the Guidelines on Acceptable Flood Capacity for Dams (DNRW, 2007). For the Marburg basin, this guideline supersedes the ALARP approach that was adopted for the basin's design. The guideline presents three methods for assessing AFC: the Small Dams Standard, the Fall-back Option and the comprehensive Risk Assessment Procedure. The Fall-back option is intended for larger dams where the cost of undertaking a full risk assessment is not warranted when weighed against the potential benefits, and is used for the Rosewood and Marburg basins. The guideline includes a schedule of dam safety upgrades, reproduced in Appendix A.

2. BACKGROUND INFORMATION

The crest of a dam wall is set at a level sufficiently higher than the spillway crest as to contain the maximum pond water level during the design flood without overtopping. For a dam impounding water, the inclusion of a net freeboard between maximum pond level and the dam crest is customary. This freeboard allows for wind induced wave action and, for major dams, seismic activity and possibly reservoir landslides.

For small flood detention basins with minimal or no impounded water, wave action can be ignored because the storage would be at peak flood level for only a limited time and the consequences of dam failure are negligible. For larger basins with PAR downstream, the regulatory position is not as clear.

The Australian National Committee on Large Dams (ANCOLD) is the peer technical association of dam owners, safety regulators and consultants, contractors and academics involved in the dams industry. A guideline being developed currently by an ANCOLD sub-committee will cover flood detention basins. The sub-committee chair indicated to one author that a wave freeboard requirement had not previously been considered but may be warranted for basins with PAR.

For a detention basin, blockage of the outlet works is considered a greater risk than crest damage from wave action, which involves no continuous flow and would be of short duration. Accordingly, the authors argued that a freeboard allowance, if required, should be applied not to any intermediate upgrade, but only to the non-overflow crest behind which the peak storage level rise corresponding to Acceptable Flood Capacity is fully contained. As explained below, the Regulator accepted this proposition.

3. CHARACTERISTICS OF ROSEWOOD AND MARBURG DETENTION BASINS

The catchment, embankment, outlet structures and storage information of Rosewood and Marburg Detention Basins are listed in Table 1.

Table 1 Characteristics of Rosewood and Marburg Detention Basins

Item	Rosewood Detention Basin	Marburg Detention Basin
Catchment area, land use and hydrology	1.36 km ² , rural, steep, rough terrain, narrow catchment	16.04 km ² , rural, gently sloping, grassed, wide catchment flanked by hills
Embankment type	Homogenous compacted earth-fill	Homogenous compacted earth-fill
Maximum population at risk	> 140	173
Crest level of spillway	RL 79.90	RL 86.70
Crest level of embankment	RL 81.70	RL 89.20
Embankment height	9.70 m	10.70 m
Spillway crest length	28.00 m	45.00 m
Embankment crest length	388 m	725 m
Storage capacity (to spillway crest)	117 ML	1145 ML
Storage capacity (to embankment crest)	211 ML	2650 ML
Pipe outlets (diameter pipe)	1 x 1050 mm, 1 x 900 mm	4 x 1800 mm

Figures 1 and 2 show aerial views of the features of the two detention basins.



Figure 1 - Aerial photo and feature locations of the Rosewood Detention Basin



Figure 2 - Aerial photo and feature locations of the Marburg Detention Basin

4. ACCEPTABLE FLOOD CAPACITY ASSESSMENT OF ROSEWOOD DETENTION BASIN

4.1. Background

Rosewood Detention Basin, completed in January 2002, is situated on an unnamed tributary of Western Creek, a tributary of the Bremer River.

The purpose of the basin is to attenuate peak flows to protect the township of Rosewood during large storms. The basin is designed such that the spillway is not overtopped for all storms up to the 1 in 100 AEP event.

The Rosewood Detention Basin is classified as a Hazard Category 2 structure under the *Water Act 2000* and the Queensland Dam Safety Management Guidelines (DNRM, 2002). This Category applies for an embankment breach where more than 100 persons are at risk.

4.2. Flood estimation

4.2.1. Flood estimation scenarios

Three cases were analysed during the course of the investigation:

- (i) The inflows and outflows from Rosewood Detention Basin for the critical storm duration for the range of events from the 1 in 50 AEP event to the Probable Maximum Precipitation (PMP) event.
- (ii) The critical storm duration of the AEP event that just reaches the Dam Crest without wind, being the Dam Crest Flood (DCF).

- (iii) The critical storm duration of the PMP design flood, without wind, behind an embankment high enough to avoid overtopping.

Note: Critical storm duration is that which results in the maximum flood rise in the storage.

From analysis of the scenarios, it was found that the AEP of the DCF is between the 1 in 1,000,000 AEP event and the 1 in 1,355,000 AEP event. The basin has a discharge capacity during the DCF of 124.1 m³/s (spillway) and 11.6 m³/s (pipe outlets), totalling 135.7 m³/s. The PMP has an AEP of 1 in 1,355,000 and a peak inflow of 150.7 m³/s.

4.2.2. Spillway adequacy assessment

The PMP design flood results in a peak storage elevation of RL 81.71, so the dam crest (RL 81.70) would be overflowing. To contain the discharge in the spillway without this overflow, the embankment crest would have to be higher than a storage level of RL 81.74 at which the spillway discharge would be 132.8 m³/s. This value, together with the corresponding outlet discharge of 11.7 m³/s, is the Acceptable Flood Capacity discharge, totalling 144.5 m³/s.

The corresponding PMF (required AFC event) inflow is 150.7 m³/s. The existing Dam Crest Flood capacity totals 135.7 m³/s (spillway and outlet).

According to *equation (1)*, the proportion of the Acceptable Flood Capacity discharged during the existing Dam Crest Flood for the Rosewood Detention Basin is:

$$\begin{aligned} K (\%) &= 135.7/150.7 \\ &= 90\% \end{aligned}$$

Based on the calculations, the required minimum flood discharge capacity is within Tranche 4 of the upgrade schedule in Appendix A and as such the acceptable flood capacity is to be achieved by 1 October 2035.

4.2.3. Freeboard allowances

At maximum flood level the effective fetch is 234 m. The 1 in 100 AEP design mean wind speed is 30 m/s, which corresponds to a wind gust critical duration of 5.7 minutes and produces a significant wave height of 0.36 m and a wind tide of 0.01 m.

To accommodate wave action, a simple wall deflects waves with no run-up. The wind tide is accounted for by a small increase in the design crest level of the upgraded embankment.

4.2.4. Upgrade proposals

Rosewood detention basin was designed to pass the PMF without overtopping the embankment. The intended freeboard between the spillway and embankment crests was 2.0 m. The as-built survey disclosed that the spillway crest is 200 mm higher than the design level. Since the design, revised methods have revealed the PMF has increased and the basin cannot pass it without overtopping. The AFC study revealed that the AEP of the Dam Crest Flood without wave and wind tide allowances is between the 1 in 1,000,000 AEP and 1 in 1,355,000 AEP event.

To upgrade the flood capacity involves:

- (i) raising the embankment crest by at least 50 mm, comprising 40 mm flood rise and 10 mm wind tide; and
- (ii) constructing a wave wall to 0.5 m higher than the final embankment crest, which is higher than the 1 in 100 AEP significant wave height

In accordance with the AFC Guidelines, these works would be constructed at a time deemed suitable by Council but be completed no later than 1 October 2035.

In a preliminary analysis, the wave freeboard allowance was deducted from the available freeboard of 1.8 m. This resulted in a current K value of 45% and would have meant that upgrades to achieve the AFC had to be in place by 1 October 2015. During subsequent discussion with the Regulator of a proposal to defer providing for wave freeboard, it was determined that the upgrade components could be undertaken over a period of 20 years.

5. ACCEPTABLE FLOOD CAPACITY ASSESSMENT OF MARBURG DETENTION BASIN

5.1. Background

The Marburg Detention Basin, constructed in 2003/2004, is located on Black Snake Creek upstream of Rosewood–Marburg Road in the township of Marburg.

The Marburg Detention Basin is intended to attenuate the 1 in 100 AEP flood to improve flood protection of the township. The basin is also classified as a Hazard Category 2 structure, with a PAR greater than 100.

5.2. Flood estimation

5.2.1. Flood estimation scenarios

From analysis of the scenarios, it was found that the AEP of the DCF is the 1 in 1,000,000 AEP event with a discharge capacity of 365 m³/s (spillway) and 89 m³/s (outlets), totalling 454 m³/s. The PMP has an AEP of 1 in 10,000,000 and a peak inflow of 648 m³/s.

5.2.2. Spillway adequacy assessment

As the PMP results in a peak storage elevation of RL 89.51, the dam crest (RL 89.20) would be overflowing. To contain the discharge in the spillway without this overflow, the embankment crest would have to be higher than a storage level of RL 89.83, at which the spillway flow would be 498 m³/s. This value, together with the corresponding outlet discharge of 110 m³/s is the Acceptable Flood Capacity discharge, totalling 608 m³/s. The corresponding PMF inflow is 648 m³/s. The existing Dam Crest Flood capacity is 454 m³/s (spillway and outlet).

The proportion of the Acceptable Flood Capacity, as per *equation (1)*, is:

$$\begin{aligned} K (\%) &= 454/648 \\ &= 70\% \end{aligned}$$

As per the Schedule for Dam Safety Upgrades (see Appendix A), the current flood discharge capacity falls within Tranche 3 and accordingly the date by which the minimum flood capacity (75% of AFC) is to be achieved is 1 October 2025. The target for Acceptable Flood Capacity (Tranche 4) is 1 October 2035.

5.2.3. Freeboard allowances

At maximum flood level the effective fetch is 763 m. The 1 in 100 AEP design mean wind speed is 32 m/s, which corresponds to a wind gust critical duration of 12.2 minutes and produces a significant wave height of 0.70 m and a wind tide of 0.03 m.

To accommodate wave action, a simple wall deflects waves with no run-up. The wind tide is accounted for by a small increase in the design crest level of the upgraded embankment.

5.2.4. Upgrade proposals

At the time when the basin design was in progress and a failure impact assessment undertaken, the 1 in 50,000 AEP flood event was proposed as the ALARP fall back. A higher embankment would have resulted in the inundation of upstream property whilst a longer spillway crest would have rendered the project unaffordable. The then NRM accepted this position.

The basin performed satisfactorily during the 2008 floods, despite serious blockage of the pipe inlets due to collapsed perimeter fencing and prodigious inflow of debris. The partial blockage resulted in a 600 mm storage rise above spillway crest level during an estimated 1 in 100 AEP flood. The basin performed without inlet blockage during the 2012 floods.

To upgrade the flood capacity, the following options require evaluation:

- (a) raising the embankment by approximately 0.5m
- (b) raising the embankment by approximately 0.7m
- (c) providing a second spillway immediately east of the existing spillway and at the same crest level
- (d) a secondary spillway as for (c) but at a crest level up to 0.5m higher
- (e) combinations of the above, and
- (f) wave wall constructed to 1 m higher than the final embankment crest level.

Table 2 shows tentative combinations and associated timescales to achieve required flood capacities.

Table 2 Tentative combinations and associated timescales to achieve required flood capacities

Option	By 1 October 2025	By 1 October 2035
a	✓	
b		✓
a + (c or d)		✓
f		✓

A preliminary analysis in which the available freeboard of 2.5 m was reduced by the wave freeboard allowance resulted in a *K* value of 32%. This would have required a costly and major upgrade before 1 October 2015. The Regulator agreed that the provision of wave freeboard could be postponed until 2035, so that the upgrades could be staged and undertaken over a 20 year period as shown in Table 2.

6. CONCLUSION

Dam failures caused by inadequate spillway capacity account for only one third of all failures. Most upgrades of major dams in Australia have been driven by increases in PMP estimates. Careful design and diligent construction supervision are vital in preventing failures from other causes.

Inevitably, the criteria for spillway capacity will be somewhat arbitrary, and whilst the ALARP principle allowed for negotiation with the Regulator, the AFC guideline appears to close off this option in the case of a new detention basin. The concentration of residents downstream of these detention basins leaves no case to argue against the requirements of the Dam Safety Regulator's guideline. This study has been a useful 'road test' of the new guideline.

The current spillway capacities of Rosewood and Marburg Detention Basins are not acceptable in terms of the guidelines published since they were constructed. The upgrade of the Rosewood basin involves only minimal works and is not required until 2035. By contrast, the upgrading of the Marburg flood capacity requires major works to be completed in two stages by 2025 and 2035. Because the

regulator accepted that the wave freeboard need not be included in the assessment of current flood capacity relative to AFC, large immediate expenditure by Council has been avoided.

Part of each final upgrade would involve the installation of a wave wall. If the ANCOLD guideline currently in preparation for detention basins waives the need for wave freeboard, then these walls need not be installed.

7. ACKNOWLEDGMENTS

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9. APPENDIX A

Tranche	Required minimum flood discharge capacity	Date by which the required minimum flood capacity is to be in place for existing dams
1	25% of AFC or 1:500 AEP flood event (whichever is the bigger flood)	These dams must be upgraded as soon as possible
2	50% of AFC or 1:2000 AEP flood event (whichever is the bigger flood)	1 October 2015
3	75% of AFC	1 October 2025
4	100% of AFC	1 October 2035