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10 Floodway design

10.1 Introduction

Section 4.1 of the Austroads Guide to Road Design – Part 5B is accepted for this section subject to the following amendments.

Addition(s)

1. Floodways are sections of roads which have been designed to be overtopped by floodwater. An example of a flood is shown in Figure 10.1.

Figure 10.1 – Little Annan River floodway

These overtopping floods usually have a 5% Annual Exceedance Probability (AEP) or higher (Average Recurrence Interval (ARI) 20-years or lower), but any crossing can be designed as a floodway. The Manual of Uniform Traffic Control Devices (QG 2019) describes floodways as sections of road over which water may flow for short periods in times of flood but the road remains trafficable with care.

Chapter 2 outlines many factors which should be considered before deciding on the design flood immunity for new road works.

10.2 Additional considerations

Section 4.2.1 of the Austroads Guide to Road Design – Part 5B is accepted for this section subject to the following amendments.
Addition(s)

1. Floodways may offer environmental advantages over culverts or bridges, since they will tend to spread flows more widely. This means that the risk of scour to waterway and surrounding land is generally reduced because flow is less concentrated.

### 10.3 Geometric and safety issues

Section 4.2.2 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section subject to the following amendments.

Addition(s)

1. Recent research shows that modern passenger vehicles become buoyant and susceptible to flood forces at much lower levels of roadway inundation than those used to describe closure criteria in previous publications of this manual (300 mm of total head). Additionally, the public safety campaign stating “If it's flooded, forget it” has been widely publicised and adopted as policy by Department of Transport and Main Roads (TMR). The closure criterion of 300 mm total head of water is therefore under review and needs to be confirmed on a project by project basis until further guidance is available.

2. Exceptions to the level grading in Queensland occur where bridges have been built significantly higher than the flooded approaches on both sides. The bridges have been built on the basis that the approaches will be raised sometime in the future.

3. For further geometric requirements of width, crossfall, vertical and horizontal alignment, refer to the relevant chapters of the department’s *Road Planning and Design Manual* (RPDM). Signage of the floodway is also important and designers are referred to the latest release of the *Manual of Uniform Traffic Control Devices* (QG 2019) for warrants/guidance.

### 10.4 Environmental factors

Section 4.2.3 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section.

### 10.5 Hydraulic design

#### 10.5.1 Floodway terminology

Section 4.2.4 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section.

#### 10.5.2 Flow over the road

Section 4.3.1 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section.

#### 10.5.3 Full floodway design calculations

Section 4.3.2 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section.

### 10.6 Time of submergence/closure

Section 4.4.1 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section.

Addition(s)

1. Due to the uncertainty about the appropriate closure criterion (refer Section 10.3), for the purposes of TMR projects, the focus of calculations should be on TOS and AATOS analysis.
The actual time of closure of a road typically includes a post-submergence clean up and inspection time. If these aspects are important, an estimate of these should be made and added to the Time of Submergence.

### 10.6.1 Time of submergence

Section 4.4.2 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section.

### 10.6.2 Time of closure

Section 4.4.3 of Austroads *Guide to Road Design* (AGRD) – Part 5B is no longer required or accepted.

For the purposes of TMR projects, the focus of calculations should be on TOS and AATOS analysis. It is noted that the actual time of closure of a road typically includes a post submergence clean up and inspection time. If these aspects are important to the analysis being carried out, an estimate of these should be made and added to the TOS to derive time of closure.

### 10.6.3 Issues related to times

Section 4.4.4 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section subject to the following amendments.

**Addition(s)**

1. The first paragraph of Section 4.4.4 of AGRD Part 5B shall be disregarded.
2. The final paragraph of Section 4.4.4 of AGRD Part 5B shall be disregarded.
3. Some roads become inundated for months at a time during the wet season and/or may be inundated by tides. Calculations of TOS for these cases is very difficult and should use either a stream gauge or continuous simulation techniques.
4. Average time of submergence or closure may be assessed for a range of selected grade levels and a plot of average time of submergence against level may be produced as in Figure 10.6.3.

*Figure 10.6.3 – Typical deck level/time of submergence relationship*

In many cases, the plot will reveal a particular grade level above which a relatively large increase in level will result in only a small decrease in time of submergence, and a small reduction in level results in a large increase in average time of submergence. Such a level may be selected as a starting point for economic analysis.
10.6.4 Calculation of time of submergence or closure

Section 4.4.5 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section subject to the following amendments.

1. A project considering revision of the procedures associated with calculations of Annual Average Time of Submergence with respect to new procedures set out in *The Australian Rainfall and Runoff: A guide to flood estimation* (ARR) 2019 is currently underway. Pending the outcome of that study, the following interim measures should be used:
   a. The time of submergence or closure for any particular AEP design event, among an ensemble of patterns for a given AEP, may be adopted from that pattern which provides a peak flow closest in magnitude to the mean flow of all events. However, care must be taken to ensure that the TOS is monotonically increasing with event magnitude (i.e. a 1% AEP TOS must be longer than a 2% AEP TOS). To achieve this, an alternative temporal pattern or event duration may need to be selected. The adopted temporal pattern and duration should be selected by applying sound engineering judgement.

10.6.5 Procedure for estimating AATOC/AATOS

Section 4.4.6 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section subject to the following amendments.

Addition(s)

1. A project considering revision of the procedures associated with calculations of Annual Average Time of Submergence with respect to new procedures set out in ARR2019 is currently underway. Pending the outcome of that study, the following interim measures should be used:
   a. The method is revised to consider AEP in place of ARI in general.
   b. The time of submergence or closure for any particular AEP design event, among an ensemble of patterns for a given AEP, may be adopted from that pattern which provides a peak flow closest in magnitude to the mean flow of all events. However, care must be taken to ensure that the TOS is monotonically increasing with event magnitude (i.e. a 1% AEP TOS must be longer than a 2% AEP TOS). To achieve this, an alternative temporal pattern or event duration may need to be selected. The adopted temporal pattern and duration should be selected by applying sound engineering judgement.
   c. The probability distribution should be: \( F_T(t) = 1 - \text{AEP} \), where AEP is the Annual Exceedance Probability expressed as a fraction.
   d. The probability density function (Equation 35) should be: \( f_T(t) = \frac{D F_T(t)}{D t} \).

2. Refer to Appendix 10A for an example AATOC/AATOS calculation.

10.7 Floodway protection

10.7.1 Types of protection

Section 4.5.1 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section.

10.7.2 Floodways with grassed batters

Section 4.5.2 of the Austroads *Guide to Road Design* – Part 5B is accepted for this section.
10.7.3 Floodways with other than grassed batters

Section 4.5.3 of the Austroads Guide to Road Design – Part 5B is accepted for this section.

10.8 Worked examples

Section 4.6 of the Austroads Guide to Road Design – Part 5B is accepted for this section.
10A Appendix: Worked examples

AATOS example and commentary

This worked example provides a step by step application of the interim procedure for estimating AATOS and sufficient commentary to relate the interim method to previous methods and outline approaches which are considered acceptable.

Step 1

Determine AEP of the threshold flow of the crossing (i.e. the AEP of a flood with peak flow at the point where the road is at the point of becoming untrafficable).

The threshold flow should be established using a suitable hydraulic model.

The AEP of the threshold flow can be estimated by interpolating a plot of peak flow vs. AEP.

This process can become complex in cases where immunity is very low (e.g. immunity less than the 63% AEP event). In these cases, either:

- further analysis must be carried out to estimate smaller events; or;
- a reasonable assumption must be made regarding flow conditions at the 100% AEP and the plot interpolated.

Figure 10A-1 below shows the example where it was assumed that 100% AEP implied a flow of 0.15m³/s based on gauge records at this site. For ephemeral streams it may be considered reasonable to adopt 0m³/s (i.e. at some point in every year the stream stops flowing).

**Figure 10A-1 – Immunity Assessment Plot**

Therefore, for this example a threshold flow of 200m³/s implies 74% AEP.
Step 2

Determine the times of closure/submergence [TOS] \((t)\) for a series of floods with peaks greater than the threshold flow and the AEP of these.

Starting with the floods adopted as the design events is considered reasonable (i.e. the event with the peak flow closest in magnitude the mean of all events from the duration deemed to be critical). However, care must be taken to ensure that TOS is monotonically increasing with event magnitude.

Figure 10A-2 below shows an example plot of the design events. Table 10A-1 shows the extracted TOS from this plot.

*Figure 10A-2 – Design Flood Hydrographs*

![Design Flood Hydrographs](image)

**Table 10A-1 – TOS for design hydrographs**

<table>
<thead>
<tr>
<th>AEP (%)</th>
<th>TOS (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>63.2</td>
<td>24.2</td>
</tr>
<tr>
<td>50</td>
<td>31.2</td>
</tr>
<tr>
<td>20</td>
<td>26.0</td>
</tr>
<tr>
<td>10</td>
<td>29.8</td>
</tr>
<tr>
<td>5</td>
<td>32.5</td>
</tr>
<tr>
<td>2</td>
<td>35.0</td>
</tr>
<tr>
<td>1</td>
<td>36.7</td>
</tr>
</tbody>
</table>

Table 10A-1 shows that TOS decreases for the 20% AEP event by comparison to the 50% AEP. This invalidates the numerical approach to integrating the probability density function, therefore an effort must be made to select different hydrographs which ensure monotonic increase of TOS.
In this example, a monotonic increase in TOS was able to be achieved by selecting an alternate temporal pattern from the ensemble of ten patterns run for the 63% and 50% AEP events at the critical duration (Figure 10A-3 below shows the adopted flood hydrographs).

*Figure 10A-3 – Adopted Flood Hydrographs*

![Adopted Flood Hydrographs](image)

In some cases, it may be necessary to select a non-critical duration for some events. It should also be noted that the selection of initial loss parameters for the hydrologic model tends to affect the critical duration for more frequent events. Therefore, the effect of this parameter on the selection of critical hydrographs for very low immunity crossings should be considered early if AATOS is a key design criterion.

The probable maximum time of submergence (tmax) can be assessed directly if assessment of the probable maximum flood is included in the design analysis. Calculations of AATOS are relatively insensitive to the selection of this limit, therefore, it is considered reasonable to estimate tmax by extrapolating a plot of TOS vs. $\log_{10}(\text{AEP})$ as per Figure 10A-4 below.
Table 10A-2 below summarises the adopted series of TOS for the range of design events.

**Table 10A-2 – TOS for adopted hydrographs**

<table>
<thead>
<tr>
<th>AEP (%)</th>
<th>TOS (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>63.2</td>
<td>15.2</td>
</tr>
<tr>
<td>50</td>
<td>23.2</td>
</tr>
<tr>
<td>20</td>
<td>26.0</td>
</tr>
<tr>
<td>10</td>
<td>29.8</td>
</tr>
<tr>
<td>5</td>
<td>32.5</td>
</tr>
<tr>
<td>2</td>
<td>35.0</td>
</tr>
<tr>
<td>1</td>
<td>36.7</td>
</tr>
<tr>
<td>1 x 10^-6 (tmax)</td>
<td>65.0</td>
</tr>
</tbody>
</table>

Step 3 and 4

Calculate and draw the cumulative probability distribution:

\[ F_T(t) = 1 - AEP \]

Where:

AEP = the annual exceedance probability as a decimal

Figure 10A-5 below shows the cumulative probability distribution for the example.
Step 5

Determine and plot the probability density function:

\[ f_r(t) = \frac{\Delta F_r(t)}{\Delta t} \]

Figure 10A-6 below shows the probability density function.
Step 6

Determine AATOS using the following equation:

\[
AATOS = \sum_{t=0}^{t=max} \Delta p \times \bar{t}
\]

Where:

\(\Delta p\) = Area of rectangles under probability density function

And

\(\bar{t}\) = Centroidal distance of each rectangle from the y axis

A graphical example showing the first rectangle is shown in Figure 10A-7 below
Figure 10A-7 – Graphical interpretation for AATOS Integral

It should be noted that these calculations are typically tabulated using a spreadsheet of the form of Table 10A-3 below.

Table 10A-3 – AATOS Tabulated Calculation

<table>
<thead>
<tr>
<th>AEP (%)</th>
<th>TOS (hours) [t]</th>
<th>$F_t(t)$</th>
<th>$f_t(t)$</th>
<th>$i$</th>
<th>$\Delta p$</th>
<th>$\Delta p \times i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>74</td>
<td>0</td>
<td>0.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63.2</td>
<td>15.2</td>
<td>0.37</td>
<td>0.007</td>
<td>7.58</td>
<td>0.108</td>
<td>0.818</td>
</tr>
<tr>
<td>50</td>
<td>23.2</td>
<td>0.50</td>
<td>0.017</td>
<td>19.17</td>
<td>0.132</td>
<td>2.532</td>
</tr>
<tr>
<td>20</td>
<td>26.0</td>
<td>0.80</td>
<td>0.106</td>
<td>24.58</td>
<td>0.300</td>
<td>7.375</td>
</tr>
<tr>
<td>10</td>
<td>29.8</td>
<td>0.90</td>
<td>0.026</td>
<td>27.92</td>
<td>0.100</td>
<td>2.792</td>
</tr>
<tr>
<td>5</td>
<td>32.5</td>
<td>0.95</td>
<td>0.019</td>
<td>31.17</td>
<td>0.050</td>
<td>1.558</td>
</tr>
<tr>
<td>2</td>
<td>35.0</td>
<td>0.98</td>
<td>0.012</td>
<td>33.75</td>
<td>0.030</td>
<td>1.013</td>
</tr>
<tr>
<td>1</td>
<td>36.7</td>
<td>0.99</td>
<td>0.006</td>
<td>35.83</td>
<td>0.010</td>
<td>0.358</td>
</tr>
<tr>
<td>1 x 10^{-6} (tmax)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$AATOS = \sum_{i=0}^{tmax} \Delta p \times \bar{i}$ (hours per year) 17.0

Applying the fundamental theorem of calculus, this tabulated calculation can be further simplified using the below equation. Table 10A-4 below presents a simplified table which is considered an acceptable proof of calculation.

$$\Delta p \times \bar{i} = \left(\frac{i_i - i_{i-1}}{2}\right) \times \left(F_t(i) - F_t(i - 1)\right)$$
Table 10A-4 – AATOS Simplified Tabulated Calculation

<table>
<thead>
<tr>
<th>AEP (%)</th>
<th>TOS (hours) [t]</th>
<th>F_{T}(t)</th>
<th>Δp × t</th>
</tr>
</thead>
<tbody>
<tr>
<td>74</td>
<td>0</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>63.2</td>
<td>15.2</td>
<td>0.37</td>
<td>0.818</td>
</tr>
<tr>
<td>50</td>
<td>23.2</td>
<td>0.50</td>
<td>2.532</td>
</tr>
<tr>
<td>20</td>
<td>26.0</td>
<td>0.80</td>
<td>7.375</td>
</tr>
<tr>
<td>10</td>
<td>29.8</td>
<td>0.90</td>
<td>2.792</td>
</tr>
<tr>
<td>5</td>
<td>32.5</td>
<td>0.95</td>
<td>1.558</td>
</tr>
<tr>
<td>2</td>
<td>35.0</td>
<td>0.98</td>
<td>1.013</td>
</tr>
<tr>
<td>1</td>
<td>36.7</td>
<td>0.99</td>
<td>0.358</td>
</tr>
<tr>
<td>1 x 10^{-6} (t_{max})</td>
<td>65.0</td>
<td>1.00</td>
<td>0.508</td>
</tr>
</tbody>
</table>

\[ AATOS = \sum_{i=0}^{t_{max}} \Delta p \times \bar{t} \text{ (hours per year)} \]  

17.0

End of example