Chapter 10
Floodway Design
Chapter 10 Amendments – Mar 2010

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10.1 Introduction

Floodways are sections of roads which have been designed to be overtopped by floodwater during relatively low average recurrence interval (ARI) floods. An example of a flood is shown in Figure 10.1.

Figure 10.1 - Little Annan River Floodway

In Queensland, these overtopping floods are usually in the ARI 10 to 20 year range although some roads may be overtopped by smaller flood events.

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

10.2 Additional Considerations

Further to the requirements discussed in Chapter 2, floodways may require costly batter protection and therefore a higher level road together with a larger culvert or bridge option may be more cost effective. Floodways also have smaller waterway (under road) requirements and may be more prone to blockage by debris. These cost related performance factors should be considered as well as trafficability and other requirements in the selection of final road level.

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.

It is also important that a floodway be designed so that it is not covered by water from ponding or backwater for any significant period of time after a flood event.

10.3 Geometric and Safety Issues

It is important that adequate approach sight distance be provided to allow drivers time to recognise water over the road and to stop. It is also important that the length of a floodway be limited at about 300 m so that drivers do not become disorientated when confronted with wide open stretches of water. Where a proposed floodway would be longer than 300 m, it is recommended that the proposed floodway be broken into shorter lengths by providing sections of road that are raised above the maximum flood level.

As a general principle, floodways should be designed so that the depth of water over the road should be as uniform as possible over the flooded section. Building a floodway on a level grade avoids the possibility of a driver unexpectedly encountering deeper water and possibly stalling or being swept downstream.
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.

Floodways should not be placed on horizontal curves as:

- there are problems in defining the edge of the pavement for motorists;
- any superelevation may change the normal flow distribution i.e. push more water to the non-superelevated sections of road; and
- the water depth will be deeper on one side of the road than the other in a superelevated section of road and there is the possibility of the high side being trafficable but not the other, thus creating a safety problem.

Floodways should also not be located on vertical curves to avoid variations in depths of flows.

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*. Signage of the floodway is also important and designers are referred to the latest release of the *Manual of Uniform Traffic Control Devices* for warrants / guidance.

### 10.4 Environmental Factors

For floodways that contain floodplain culverts (i.e. culverts located away from a watercourse channel) only terrestrial movement generally needs to be considered. However, if fish migration is expected to occur across the floodplain during times of flood, then a check should be done on allowable flow velocities.

The procedures outlined in Section 9.7 should be followed for fauna passage through culverts.

As noted above, floodways reduce the concentration of flow, compared to culverts or bridges, so the risk of scour damage to waterway and surrounding land is reduced.

#### 10.5 Hydraulic Design

##### 10.5.1 Floodway Terminology

A floodway consists not only of the roadway embankment to accommodate flow over the road but also waterway openings to provide for flow under the road. These openings may be required for one or more of the following functions:

- reduce the afflux or rise in water level upstream due to the obstruction (embankment);
- raise the tailwater level so that less batter protection is required on the downstream side e.g. grass instead of concrete; and/or
- act as anti-ponding structures for low flow stream conditions.

Flow over roadways may be:

- free flow; or
- submerged flow.

In the initial stages of overtopping a low tailwater usually exists and free flow occurs. Under these circumstances flow passes through critical depth over the road and the discharge is determined by flood levels upstream.
Free flow may be either:

- plunging flow which flows over the shoulder and down the downstream face of the embankment. The flow then penetrates the tailwater surface producing a submerged hydraulic jump on the downstream slope. Velocities are likely to be high and erosive; or
- surface flow which separates from the surface of the road embankment and rides over the surface of the tailwater. This flow will have less erosion potential downstream.

Submerged flow occurs when the discharge is controlled by the tailwater level as well as the headwater levels. This occurs when the depth of flow over the road is everywhere greater than the critical depth.

Typical velocities of flow over a floodway are shown on Figure 10.5.1 as sourced from *Waterway Design* (Austroads 1994) after Cameron and McNamara (1966).

![Figure 10.5.1 - Indicative Velocities of Flow over a Typical Floodway](image-url)
10.5.2 Flow Over the Road

The broad crested weir formula used for flow over a road is:

\[ Q = C_f L H^{1.5} \left( \frac{C_s}{C_f} \right) \]

Where:
- \( Q \) = discharge over floodway (m³/s);
- \( C_f \) = coefficient of discharge ‘free’ flow;
- \( C_s \) = coefficient of discharge flow with submergence;
- \( L \) = length of floodway (m); and
- \( H \) = specific head or specific energy (m).

With reference to Figure 10.5.2:
- \( h \) = level difference between the floodway crown and the upstream water surface (m);
- \( V \) = approach velocity of the stream (m/s); and
- \( l \) = top width of road formation (m).

The flow over the floodway may be calculated by means of the following design procedure:
- Calculate the stage-discharge curve (height versus discharge) for the unrestricted section, from open channel hydraulics (refer Chapter 8);
- Select a tailwater level and a headwater level (giving \( h \) and \( V \)) from the stage-discharge curve.
- Calculate \( \frac{H}{l} \)

Where:

\[ H = h + \frac{V^2}{2g} \]

On Figure 10.5.2;
- for \( H/l > 0.15 \) (usual case) Use curve B to obtain the free flow coefficient of discharge, \( C_f \).
- for \( H/l < 0.15 \) Use curve A to obtain value of \( C_f \).
- Calculate \( D/H \times 100 \) and use curve C to obtain the submergence factor \( C_s / C_f \).
- Calculate the discharge over the road using the broad crested weir formula.

10.5.3 Full Floodway Design Calculations

Floodways incorporating culverts and bridges will require calculations in addition to those above.

The basic principle is that the total flow over the road and through the waterway structures equals the flow downstream in the unrestricted channel.

Given the many combinations of headwater and tailwater possible, it is necessary to fix at least one of these parameters for each design calculation.

With flow over the road, the issue of whether or not road batter protection is needed becomes important as the calculations require the tailwater to be fixed when the flood is at the point of overtopping the road.
Figure 10.5.2 - Discharge Coefficients for Flow over Floodways
Guidelines relating to the need for protection are given in Section 10.7 with the tailwater level generally in the range 0.4m to 0.6m below the crown of the road when the road is about to be overtopped.

**Full floodway design** must satisfy Case A and Case B conditions.

**Case A: When the flood is at the point of overtopping the road:**

- Tailwater level is not below the level specified for the type of protection to be adopted; and
- Velocities through the bridges and/or culverts are acceptable. (Scouring velocities may be acceptable, if additional outlet protection or the formation of scour holes is acceptable).

The step by step design procedure for this case follows:

Figure 10.5.3 illustrates results of calculations performed using the steps (a) to (g) below for an actual floodway.

(a) Calculate the rating curve (height versus discharge) for the unrestricted channel.

(b) Fix the level of the road as a first trial. The initial level of the road may be based on trafficability eg for required trafficability in a ARI 20 year flood, the initial road level may be the level of the ARI 20 year flood level in the unrestricted channel. (This allows culverts to be designed for a maximum head of 300 mm with the tailwater at the crown level of the road. It will be found that a lower road level will give less fill in the embankment, but require more culverts under the road in the ARI 20 year flood.)

(c) Fix the headwater level at the crown of the road (or the highest edge if superelevated). Avoid the design of superelevated floodways, if possible, as these can result in depth variations laterally and surface debris on the floodway surface can compromise safety. Residual, silt and gravel on floodways after isolated rainfall events can provide hazards on their own, causing serious injury. Effective maintenance programs must be in place by relevant authorities and new designs of new floodways need to minimise risk.

(d) Find the velocity $V_x$ through a suitable major culvert / bridge with the headwater in (c) above and the tailwater adopted for the type of floodway protection to be adopted. Say this tailwater level is $RL_x$ on Figure 10.5.3 Case A, corresponding to a total discharge, $Q_x$ in the unrestricted channel.

(e) With this velocity $V_x$ find the total area of waterway required from Total Area Required = $Q_x / V_x$ and select other culverts to give this total.

(f) For the fixed headwater and the tailwater level, $RL_x$, calculate the actual flow through each culvert and bridge and total the discharges to give $Q_y$ which may or may not be equal to $Q_x$ because of the different size openings.

(g) Adjust the culvert and bridge areas so that with the fixed headwater and tailwater level, $RL_x$, the total flow equals $Q_x$. (With progressive adjustments the total discharge may be $Q_y$ or $Q_z$ so on.)
Note that the initial assumption of all the waterways having the same velocity is approximate only as different size and shape openings have different hydraulic efficiency. This is why the same head will give different velocities.

The structures giving $Q_x$ are to be considered minimum requirements for the floodway regardless of the requirements calculated for a peak flood above the roadway, as all overtopping floods pass through this stage.

**Note:** The design velocities through culverts are normally in the range 1.8 m/s to 3.0 m/s with 2.4 m/s commonly adopted, depending on the scour resistance of the surface material downstream. Higher and lower velocities have been adopted. Chapter 9 discusses the hydraulic design of culverts and Chapters 7 & 13 methods of erosion control.
Case B: At the peak of the flood above the floodway:

- Velocities through the waterway structures are acceptable; and
- Afflux caused by the floodway is acceptable.

The step by step design procedure for this case follows:

At the peak of the overtopping flood, allowance for flow over the road must be made and afflux calculated for the design flood (ARI 20 year in the example in Case A above).

The flow over the road is added to that through the culvert(s) and bridge(s) and the calculations initially include the structures from Case A. With reference to Figures 10.5.3 and Case A and Case B, the procedure is:

- Find the tailwater level corresponding to the design flood discharge from the rating curve for the unrestricted channel.
- Select a headwater level slightly above the tailwater level in (a), say 0.1 m above, and calculate the flow over the road and through each culvert and/or bridge with this headwater - tailwater combination. Add these flows together to obtain a total flow, say Q1.

Compare this flow with the design flood discharge. If Q1 is smaller, a greater head / afflux is required to ensure that the check flood is passed over the road and through the waterways.

Adopt a higher headwater and the same tailwater level and obtain the total Q2 for flow over the road and through the waterways. Similarly, Q3 etc may be obtained.

- Plot Q1, Q2, Q3 etc. against their respective headwater levels. Join these points to make the curve shown on Figure 10.5.3 Case B.
- From the curve, find the headwater which gives the required design flood discharge.
- If the afflux is acceptable, calculations are complete. If the afflux is too high, additional bridge or culvert waterways are required. Waterways from Case A are not to be reduced.

- Calculate the afflux for the check flood (usually of ARI 50 years).

Because of flow over the road, maximum velocities are obtained from Case B.

Both velocity and afflux requirements are to be met.

### 10.6 Time of Submergence / Closure

Some of the following text and diagrams have been taken from *Bridge Waterways Hydrology and Design* (NAASRA 1989) and *Waterway Design* (Austroads 1994).

Where a crossing is designed for overtopping, it is usually important that an estimate be made of the frequency and duration of the periods during which the crossing will be submerged as well as the times it is closed to traffic due to flooding. The time of submergence is of importance with respect to stability of embankments and pavements and consequent maintenance costs. The time of closure is of importance in consideration of acceptable delays to traffic.
10.6.1 Time of Submergence

Time Of Submergence (TOS) is defined as the period of time that the road is inundated by flood water, no matter the depth.

The time of submergence is expressed in one of two main ways. The first is the time of submergence during a major flood - for example, the number of hours of submergence during the flood with an average recurrence interval of 50 years. The second is as the Average Annual Time Of Submergence, abbreviated as AATOS. This is the average time per year that the road is submerged, expressed as hours per year.

Both expressions are an indication of the frequency and duration of submergence. For example a crossing that is submerged frequently for short periods of time may have a similar AATOS as one that is submerged less frequently for longer times. To understand the concept and to compare options, three parameters are needed, namely:

- Flood immunity;
- TOS for the ARI 50 year flood (or other large flood);
- AATOS.

The absolute value of the time of submergence is not particularly useful by itself for a crossing, but it is useful to compare several crossings or upgrading options.

10.6.2 Time of Closure

Time Of Closure (TOC) is similar to time of submergence. However this parameter takes account of the fact that some inundation of the road may not necessarily close the road, though there may be some hazard in travelling on the inundated road.

Different types of vehicles can travel on roads with different amounts of inundation with large and heavy vehicles capable of travelling in water that is deeper and flowing at a higher velocity than a light car.

Safety of vehicles in flood water is poorly understood and there has been considerable research on the topic.

There are different definitions of the flow conditions when the road is closed by flood waters. The normally adopted limit in the department is when the total head across the road exceeds 0.3 m. That is:

\[ H = d + \frac{v^2}{2g} \]

Where:

- \( d \) = depth of inundation
- \( v \) = flow velocity
- \( g \) = gravity (9.81 m/s\(^2\))

Similar to AATOS there is an Average Annual Time Of Closure, abbreviated as AATOC.

10.6.3 Issues Related to Times

The concept of time of closure, in association with the time of submergence, adds some additional information to the question of flood immunity.

Large and flat catchments will respond more slowly than small and steep catchments so the time of submergence for these catchments will generally be longer for an equivalent flood immunity.

In small steep catchments, where the response time is short, the time of submergence will be low, even for a crossing with low flood immunity.
In small steep catchments, and also for urban catchments where the response time is short, floods may occur and then recede very quickly. In this case the disruption to traffic may be short. Similarly in small catchments, the depth of inundation may be low even if the flood immunity is low. In this situation, the time of submergence may be short so the cost of disruption may be very low and the additional cost of providing for a higher level of flood immunity may not be justified.

On the other hand, large catchments that have a long response time may inundate the road for extended periods of time. In this case the cost of disruption may be very high and a higher level of flood immunity may be more easily justified.

There are occasions where the road crosses a tributary close to the junction with a major stream. If the road is inundated by both the local catchment runoff and backwater from the major stream, the time of submergence may be quite different for the two flood mechanisms. The local catchment runoff, from a small catchment, may have a short time of submergence, while the larger catchment may inundate the road for longer periods of time. Local residents can often identify these two sources of closure and they may be quite distinct.

When calculating the time of submergence or closure in these situations, the calculation must consider both sources of inundation as well as the risk that the inundation is independent, in which case the times must be added together.

When the flood immunity is very low, the time of closure may not be represented accurately by the flood event hydrographs. In this case, long term records may need to be analysed, but this situation would be unusual for state controlled roads in Queensland though it does occur on interstate main roads and on more minor roads.

These situations can occur where the road is inundated for months at a time during the wet season or even sometimes the road may be inundated by tides. The calculation in this case is very difficult and should use either a stream gauge or calculated continuous discharge records.

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](image)

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

There are two approaches to calculating TOS / TOC of a road by flooding. The first approach is for the situation where there is a stream gauge located at the bridge site, which is not a common occurrence. The second approach is based on analysis of flood hydrographs, and is the method that is most commonly adopted.

Analysis with stream flow records is the most reliable approach and is recommended if there is a nearby station. However since this is often not the case, the theoretical approach is more commonly necessary.

If there is a stream gauge located on the stream at or very near the bridge, this gauge can be used to analyse the TOS / TOC. Whilst this does not occur commonly, it is the most accurate method for calculating the TOS / TOC. Use of a stream gauge is also useful since calculated hydrographs are prepared considering the maximum discharge and the length of the hydrograph may often vary and longer duration floods with a lower peak discharge may be more critical in consideration of time of submergence or closure than the actual peak discharge.

If there is no stream gauge located close to the crossing, it is possible to calculate a continuous record of discharge from a hydrologic model and to use this sequence of flows in the calculation of TOS / TOC in exactly the same way as a stream flow record would be used.

The procedure for applying the stream gauge records is as follows:

- Calculate the discharge that will just inundate the road (for time of submergence) or close the road (for time of closure).
- Calculate the total period of time where the road is submerged (or closed) from the complete record of the stream gauge.
- Calculate the average duration per year that the road is submerged (or closed). This is the AATOS (or AATOC).
- This procedure does not provide the duration of submergence (or closure) for a particular flood event.

As with all hydrologic analysis, it is important that the stream flow record is sufficiently long to provide a representative sample of flow at the bridge. If the period of record is too short, or the period of record is not representative, the result from the calculation may not be reliable.

It is hard to define the period of record that would be adequate for this analysis, since it depends on the variability at the site as well as other conditions. However it is likely that if there is less than 20 years of record at the site, the result may not be reliable.

If there is only a short record, careful analysis can be used to assess the best means of extracting data from the record, and useful information can be extracted.

It is much more likely that there will not no stream gauge located near the bridge, and the theoretical method discussed here must be used.

The first step in this process is to calculate design flood hydrographs for the crossing site. This can be done with a catchment hydrologic model, such as RORB or RAFTSTM. It is noted that the Rational Method calculates only the flood peak discharge so is not suitable for application
of time of submergence or time of closure calculations.

It is also noted that the actual time of inundation of the road depends on the flood levels and not necessarily the discharge so in some cases, especially on large flat floodplains, the hydrographs of water levels may not be exactly the same as the hydrographs of flood discharges so this issue may need to be considered at times.

However the normal procedure is to calculate flood hydrographs of discharge with a catchment model and use these directly for the calculation.

To calculate the time of submergence or time of closure the following is required:

- A hydrograph of the flood, which may be obtained from actual measurements at the stream crossing, or for ungauged streams, by the use of a runoff routing method or synthetic hydrograph method. (An experienced hydraulic engineer is required to undertake these analyses.)
- Flow capacity of the crossing at the point of submergence or closure.
- The time of submergence or closure may then be calculated by drawing a horizontal line on the hydrograph at the flow capacity level and measuring the time for which the flow is above this level.

10.6.5 Procedure for Estimating AATOC / AATOS

The procedure for calculating the average annual time of closure (AATOC) is as follows:

**Step 1.**
Determine the ARI of the flood for which the stream crossing is trafficable, i.e. floodway with or without culvert or bridge.

**Step 2.**
Determine the times of closure $t_y$ for a series of floods greater than the trafficable capacity flood, and the ARI’s of each of these floods.

Estimate $t_{\text{max}}$ by extrapolating a graph of time of closure versus ARI or by estimating the probable maximum flood for the catchment. It should be noted that the probable maximum time of closure cannot be disregarded in the calculation of the AATOC.

**Step 3.**
Calculate the probability $F_T(t)$ of the road being closed for each ARI $y$ year flood:

$$F_T(t) = 1 - 1/y$$

**Step 4.**
Using the times of closure, $t_y$ and the probability, $F_T(t)$ of the road being closed for each ARI $y$ year flood, draw the cumulative probability distribution.

This distribution gives the probability of the road being closed in any year for less than $t$ hours.

**Step 5.**
Determine the probability density function:

$$f_T(t) = \frac{\Delta F_T(t)}{\Delta t}$$

This is the slope of the line connecting each point on the cumulative probability distribution.

**Step 6.**
Determine AATOC as:

$$AATOC = \sum \Delta p \times \bar{t}$$
Where:

- \( \Delta p \) = area of each rectangle in the probability density function; and
- \( \bar{t} \) = centroidal distance of each rectangle from the \( f_T(t) \) axis of the probability density function.

The same procedure is used for AATOS except a lower flow is used to derive critical flood level.

**10.7 Floodway Protection**

### 10.7.1 Types of Protection

Selection of the form of protection of floodways against scour is governed by:

- Whether flow across the floodway is free or submerged; and
- Under free flow conditions, whether plunging or surface flow occurs downstream from the floodway.

The tailwater level when the flood is at the point of overtopping the road usually controls the degree of protection required for a particular floodway. Therefore, the cost of providing adequate bridge and/or culvert waterways to raise the tailwater to a high enough level to require minimum protection becomes a prime consideration as well as the cost of the protection itself.

Floodway protection is considered in two categories:

- Minimum protection such as grassed batters; and
- Other than grassed batters.

The tailwater level for floodways with grassed batters is usually not more than 300 mm below the downstream edge of the road formation when overtopping first occurs.

The tailwater level for floodways with other than grassed batters is usually more than 300 mm and up to 600 mm or even 700 mm below the downstream edge of the road formation when overtopping first occurs.

Overtopping flows of long duration and at frequent intervals may cause pavement failures, and softening of the embankment, aggravating any tendency to scour. Even with a high tailwater when the flood is at the point of overtopping the road, the time of submergence may indicate the need for more elaborate protection other than natural grass.

### 10.7.2 Floodways with Grassed Batters

Grass in this type of floodway is defined as turf or seeded grass. Reinforced grass is discussed in the Chapter 8.

Because the physical properties of grass such as species, stiffness, cover density and rooting pattern varies with soil type and climate, only general guidelines based on constructed floodways in Queensland are possible.

Floodways with grassed batters should have the following features:

- Bitumen seal or asphalt pavements with concrete or other rigid margins / shoulders (stone pitching, cement stabilised gravel etc.) containing the bitumen in place;
- As an alternative to (a) above, concrete blocks / nib walls along the top edges of the formation with bitumen seal or asphalt pavement between them may be constructed. These containing blocks may be as simple as 10% by volume cement stabilised gravel strips 600 mm wide at the top by 180 mm deep;
- Culverts under the floodway section should raise the tailwater to not more than 300 mm below the downstream edge of the road formation when overtopping first occurs;

- Overtopping should occur for a period of less than 12 hours in a 50 year average recurrence interval flood. However, the type of material in the embankment and its saturated strength may require reduction of this allowable time of submergence.

Conversely there are some low floodways that can withstand submergence for much longer.

For this type of protection, it is desirable to have good grass cover when the overtopping flood occurs and this in turn requires an ability to maintain grass cover during the dry season.

Concrete pavements if used instead of bituminous types will, of course, cover the full width of the formation and not require grass batter protection.

10.7.3 Floodways with Other than Grassed Batters

There have been many types of floodways successfully constructed in Queensland with other than grassed batters. Recommended types of protection are described and illustrated in this section and the selection of the type of protection would be based on a cost comparison of recommended types considered suitable to that locality.

Most failure of floodways with downstream batter protection in the past commenced by scouring at the downstream aprons and/or the downstream edge of the road formation and savings in these areas should not be considered.

Five types of floodway which have performed satisfactorily are described in this section with their associated limitations specified. All these types of floodways should have the following general features:

- Culverts to raise the tailwater to not more than 600 mm below the downstream edge of the road formation when overtopping first occurs (actual range 300 - 700 mm). It is important to note that this afflux may not be acceptable in some areas and non-standard additional outlet protection at culverts may also be necessary;

- Full protection of the top surface of the road formation, as for floodways with grassed batters;

- Protection of at least the downstream batter. Although not clearly defined, it appears that protection of the upstream batters may only be required in floodways of low flood immunity in major streams. As a precaution where only downstream protection is adopted, protection for a distance of about 3 metres on each side of major culverts on the upstream side may be placed to offset possible scour due to turbulence from the mixing of longitudinal and direct flows at the culvert inlets;

- Adequate downstream aprons. For height of road embankment, \( H \), equal or more than 2.0 m, the downstream apron should extend at least 1.5\( H \) metres away from the toe of the embankment. For \( H \) less than 2.0 m, the downstream apron
should extend at least $H$ away from the toe of the embankment unless other specified; and

- Weepholes in the downstream rigid protection to relieve hydrostatic pressure. These weepholes are normally about 90 mm diameter at 1.8 m (maximum) centres with 300 x 300 x 150 no-fines concrete blocks behind the weepholes. The weepholes should be placed about 300 mm above the apron level or just above long standing water level if higher. The more porous types of protection such as rock on filter cloths or layers and some cement stabilised gravels, depending on the grading, do not require weepholes.

A brief description of the five successful types of floodway protection follows and sectional details of these types are shown in Figures 10.7.3(a) and 10.7.3(b). These types are not in any order of preference and comparative cost comparisons should be made where more than one suitable protection is considered.

A brief mention of reinforced grass, or a type of geotextile protection as it is also known in the USA, is given in Other Types. Although it appears to have been successful in some stream channels, little is known about its performance in floods overtopping embankments.

**Type 1 Floodway**

This type of reinforced concrete floodway has been constructed in many areas of the State, particularly in the west. The reinforcement selected should not only satisfy strength requirements, but also prevent temperature and shrinkage cracks.

Where cut-off walls have been used without the downstream apron, failures have occurred.

With a suitable width of downstream apron and weepholes, the Type 1 Floodway is recommended as suitable for all crossings where other than grass protection is required, cost permitting.

**Type 2 Floodway**

This is an example of a reinforced concrete floodway where the tailwater depth is uncertain but probably quite low (perhaps 700 mm or more below the downstream edge of the formation when the flood begins to overtop the road). No adverse reports are known. Costs are higher than Type 1 floodways.

**Type 3 Floodway**

This previously used type is no longer recommended.

**Type 4 Floodway**

This is considered by some to be an improvement on Type 3. The increased use of stone mattresses and gabions has given confidence to this type of construction.
Most common type.  Widely Used.

TYPE 1 – Concrete Protection

Type performs well, but need to justify cost. Requires specialist design.

TYPE 2 – Concrete Protection

An improvement over previous Type 3. Mattresses must be pinned / anchored. Consider a cutoff wall. Cut off walls may not be necessary as mattresses, usually achieve their optimum position with a little scour by dropping into a scour proof position

TYPE 4 – Rock Mattress Protection

Figure 10.7.3(a) - Downstream Floodway Protection (Types 1, 2 & 4)

Type 5 Floodway

This type of protection incorporating a bituminous seal is probably the lowest cost of the types shown, but its use is limited.

It should only be used only where:

- Fill height is not higher than 900 mm;
- Tailwater at overtopping is not more than 300 mm below the crown of the road; and

- Time of submergence is small (hours).

Rock fill with size 70 - 100 mm and median diameter 85 mm would be adequate for most uses.

Type 6 Floodway

This previously used type is no longer recommended.
Type 7 Floodway

This floodway was designed for use in Western Australia and is described in *Waterways Design* (Aust roads 1994).

As the riprap consists of rock with grading requirements, it may have limited application in Queensland where supplies of such rock are scarce where floodways are constructed.

Further details of the required grading and riprap thickness may be obtained from the reference.