Flood function

Flood risk management guideline FB02

Department of Planning and Environment

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1. Introduction

Floodplains have the natural hydraulic functions of conveying and storing water. The flood function categories of floodway areas, flood storage areas and flood fringe are defined in the *Flood risk management manual: the policy and manual for the management of flood liable land* (the manual; DPE 2023) as follows:

- **floodways** are generally areas which convey a significant portion of water during floods and are particularly sensitive to changes that impact flow conveyance. They often align with naturally defined channels
- **flood storage areas**, which are areas outside of floodways, are generally areas that store a significant proportion of the volume of water and where flood behaviour is sensitive to changes that impact on the storage of water during a flood
- **flood fringe areas** are areas within the extent of flooding for the event but which are outside floodways and flood storage areas. Flood fringe areas are not sensitive to changes in either flow conveyance or storage.

The areas performing these functions vary in an event and between events of different scales. Identifying them is important as it enables any changes to these areas to be managed so they can continue to perform these functions, which can limit impacts on flood behaviour and the community.

While the concept of flood function is relatively simple, identifying these floodways and flood storage areas can be challenging. A performance-based approach should be used that considers acceptable limits for impacts.

To support the identification of flood function areas this guideline provides:

- advice on the use of flood function information (Section 2)
- advice on acceptable limits (Section 3)
- an overview of the different techniques for identifying flood function areas and their limitations and strengths (Section 4)
- advice on aspects to consider when selecting a technique for identifying flood function areas and modelling options (Section 5)
- an example of how the conveyance technique can be used to define floodways (Appendix A).

1.1 Relationship to the manual and guidelines

This guideline builds on the advice provided in the manual. It supports councils in their role in delivery of the *NSW Flood prone land policy* (the policy) through the flood risk management (FRM) framework and process outlined in the manual. It replaces the FRM guideline on floodway definition (DECC 2007).

This guideline refers to the manual, policy and other FRM tools and guidelines, relevant state agencies and legislation. Details on these are provided in *Administrative arrangements: flood risk management guideline AG01* (FRM guideline AG01). Links to flood risk management guidelines and relevant websites can be found in the 'More information' section below.

For more information on terms used in this guideline refer to the manual and FRM guideline AG01.

1.2 Audience

This guideline is written to support local council staff, state agencies and their consultants in defining flood function and use information on flood function in understanding and managing flood risk to local communities.

2. Uses of flood function information

Effective FRM requires an understanding of flood function and how it varies in floods and between floods of different scales up to and including the probable maximum flood (PMF). It can support:

- **understanding flood risk**. It is important to understand flood function as changes in topography, development, land use and vegetation in floodways and flood storage areas can significantly impact flood behaviour. This can change the flood impacts on and risks to the community. See *Understanding and managing flood risk FRM guideline FB01*
- **management of flood risk** (see FRM guideline FB01). Understanding flood function and how it varies is important as outlined below:
    - **FRM measures** can impact on flood behaviour. Understanding flood function provides us with an indication of where flood mitigation works are likely to affect flood behaviour. For example, placing or upgrading flood mitigation works (whether permanent or temporary) in floodway areas may alter flood behaviour, with adverse impacts on the community
    - **flood emergency management (EM)**. Understanding flood function can indicate the variation in flood behaviour. Floodways are generally areas with significant water and often debris movement. This can impede evacuation and may influence decisions on the suitability of evacuation routes. See *Support for emergency management planning FRM guideline EM01*
    - **land-use planning**. Flood function is an important constraint to consider in the use and development of land. Filling and development in floodways and flood storage areas can impact on flood behaviour to the detriment of the existing community. Information on their location can inform strategic land-use directions setting for a community, and development and implementation of environmental planning instruments, policies and development controls
- **flood-dependent ecosystem management**. Understanding flood function can inform decisions that may impact on the ecological health of flood-dependent ecosystems, particularly on large rural floodplains, such as those in the Murray–Darling Basin. In some circumstances even minor changes in hydraulic connectivity to flood-dependent ecosystems can cause adverse ecological impacts
- **flood-dependent Aboriginal values**. Understanding flood function can inform decisions that may impact on flood-dependent Aboriginal values. Aboriginal values can include sites, objects, landscapes, resources and beliefs that are important to Aboriginal people as part of their continuing culture, as well as cultural flows. Cultural flows are being integrated into water planning and management as part of the National Cultural Flows Research Project (reports from this project are available on the Murray Lower Darling Rivers Indigenous Nations website, see the ‘More information’ section of this guideline). Floodplain management should consider the variety of ways Aboriginal values can be connected to floodwater and maintain the function of the floodplain.

3. Acceptable limits

The identification of floodways and flood storage areas requires a performance-based approach to enable identification of these areas based on their function during a flood and the potential impact of changes in these areas. This involves a combination of qualitative assessment based on the characteristics of the areas, and quantitative assessment relating to the degree of change to flood behaviour and impacts to the community that are acceptable.

Identifying limits on the degree of change to flood behaviour that would be considered acceptable for a study area is important in defining floodways and flood storage areas. Setting these limits needs to consider the consequences of changes in flood impacts on the community. This is generally then quantified and managed in terms of changes to flood levels, flood flows and flow distribution.

Acceptable limits depend on factors including the:

- scale and intent of the study. For strategic or broad studies, such as those funded under the Floodplain Management Program, the acceptable limits should consider the cumulative impacts of multiple development areas within the floodplain and use acceptable limits developed for this purpose. This can involve the use of future scenarios as discussed in FRM guideline FB01. The limits used in project-specific or site-specific assessments (flood impact and risk assessments, FIRA, see *Flood impact and risk assessment FRM guideline LU01*), should be significantly lower than those set for cumulative impact assessments
- morphology and flood behaviour in the area. This may influence the scale of impact and the area affected by a change. It may also influence the level of impact that would be considered acceptable. For example, for the same degree of change, the area affected by the change is likely to be significantly smaller in areas where flood gradients are steeper compared to flatter areas where water ponds, such as upstream of waterway structures
- exposure of the community to flooding, and how sensitive to change the consequences of flooding on the community are. For example, a densely populated urban area with a high vulnerability to flooding will generally have a lower tolerance for change than a sparsely populated rural area.

Given all these factors it is not possible to provide explicit quantitative criteria for acceptable limits.

Advice on setting acceptable limits for cumulative impacts is provided in FRM guideline FB01.

Acceptable limits for FIRAs for specific development projects or sites are generally set by councils. Advice on FIRAs is provided in Section 5.2.1 of this guideline and in FRM guideline LU01.

4. Techniques for identifying flood function areas

The identification of flood function areas is generally an iterative process requiring judgement by experienced practitioners. The end results of any technique need to be carefully reviewed to consider if they are reasonable and fit for purpose.

This section provides advice on a range of techniques available for defining floodways and flood storage areas, however, there may be advances in these techniques and different techniques may emerge subsequent to this guideline that also need consideration. When identifying flood function areas, the first step is to define floodway areas (Section 4.1), then flood storage areas (Section 4.2). The remaining area of the flood event extents is defined as flood fringe.

4.1 Identifying floodways

The key requirements of a floodway are that it should be connected, continuous (not intermittent) and hydraulically logical. The results of any assessment need to be tested against these requirements to ensure they are fit for purpose. There are 3 main techniques for defining floodways that have been adopted by practitioners to achieve this. These are: indicator techniques, encroachment techniques and conveyance techniques. These techniques are detailed in the following sections and the strengths and limitations of each for identifying floodways is summarised in Table 1.

4.1.1 Indicator techniques

Indicator techniques rely on physical and hydraulic properties to indicate the location of floodways. Historically, indicator techniques have been used to define both floodways and flood storage areas (discussed in Section 4.2.1). They provide a good starting point that can then be checked using another technique, however, they are not generally recommended for use on their own.

The most common indicator technique is that presented in Howells et al. (2003), which uses velocity (V) and velocity depth product (VxD) as the key indicators. The technique derives threshold values for a location. The threshold values that should be used for V and VxD vary between locations and therefore cannot be translated from one location to another.

Other indicators commonly used to identify the presence of floodways are the presence of streams and their stream order (often defined using the Strahler stream classification; see Strahler 1952 and Department of Industry 2018), flood runners, flood-dependent ecosystems, terrain, and aerial photography.

These techniques identify where floodways might be, but do not assess the impacts of obstructions or blockages in floodways, and therefore do not effectively identify floodways in accordance with the manual. This level of identification of likely floodways may be sufficient if the floodplain in question is a broad rural or non-urban floodplain that has not been identified or zoned for future urban growth. In these areas, a lower level of accuracy is acceptable for defining the extent of floodways because the floodplains are generally less constrained and may be less likely to change substantially.

In urban areas or other specific cases where greater accuracy is required, such as where there is a challenge to the classification or where more intense development is proposed in the area, conveyance or encroachment techniques should be used to accurately identify floodways.

Limitations

In most cases, indicator techniques should only be used to provide an estimate of the floodway extent, which is then checked and refined using another technique. The major limitation of this technique is that it can miss floodways that are below the selected threshold.

Manual assessment and cleaning of the raw model output data and interpretation is required by an experienced practitioner to ensure the key requirements of a floodway (see Section 4.1) are maintained. For example, raw model output data often includes 'islands' of flood storage within a floodway, and disconnected floodways (Figure 1). The islands are usually isolated pockets that are just below the indicator threshold value and the practitioner would need to decide whether to include these islands as floodways. Post-processing can also include steps to ensure the continuity and connectivity. Long lengths of secondary flowpath may be mapped as floodway but may not connect to the main floodway (Figure 2). Connection between the main and secondary floodways needs to be added with sufficient width to match the hydraulic behaviour of the secondary flowpath.

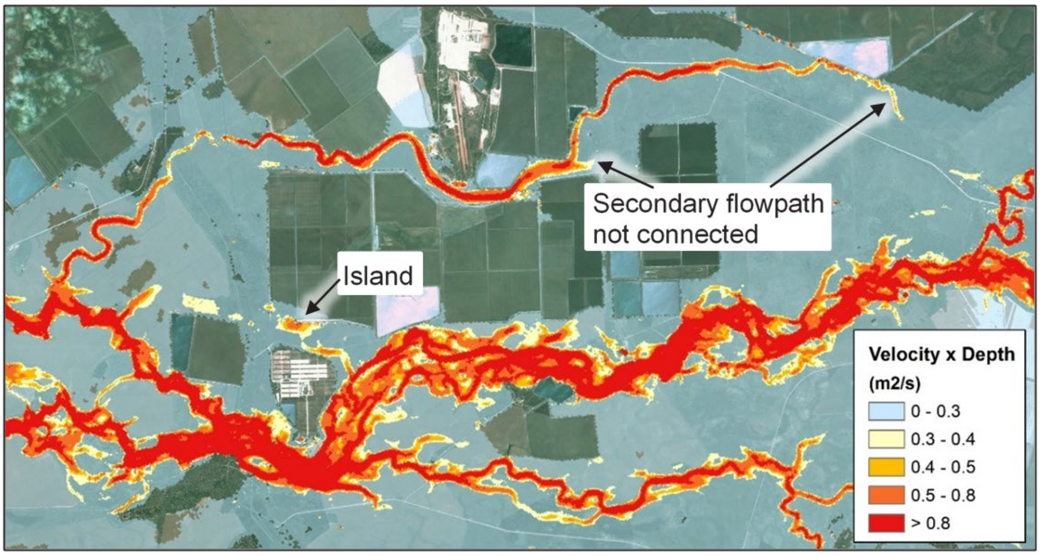


Figure 1 Example of raw VxD requiring manual edits to meet key floodway requirements

Figure 2 Example of manual edits required when using the indicator technique to meet key requirements of a floodway in rural floodplain management plans

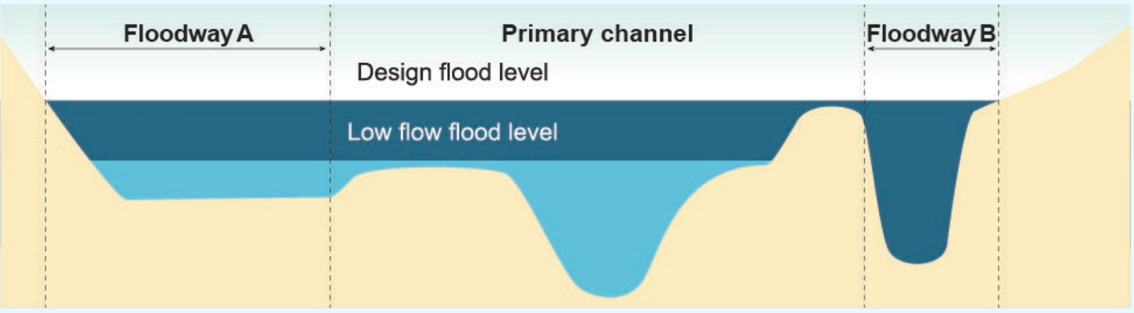
Example: Use of a small flood as an indicator for possible floodways

The Healthy Floodplains Project examined rural flooding in areas of the Murray–Darling Basin. It identified floodway zones that not only took into account flood function but also other factors. These include existing development, historic floodplain management arrangements, ecological assets, cultural values and socioeconomic considerations.

Flood function is identified based on the selection of an appropriate VxD threshold for a valley, that considers the characteristics of the floodplain. The floodways automatically generated are then manually smoothed and checked against a range of other data sources to produce a final floodway network. The additional data used includes:

- modelled extent of a relatively small/frequent flood
- flood aerial photography and satellite imagery from a range of design floods
- spatial watercourse layers, topographical mapping, ADS–40 digital elevation model and LiDAR
- local knowledge from floodplain and environmental managers and communities.

An example of how use of a relatively small flood as an indicator of possible floodways can be seen below. The figure shows that although the design flood would activate both floodway A and floodway B, only floodway B would be identified as a floodway in this case using the VxD threshold alone. By considering the inundation extent of the small design flood, floodway A would also be identified as a floodway. Such floodways may be important for connecting flood-dependent ecological assets and cultural values to floodwater during smaller floods. Small floods are also useful for connecting disjointed floodways, as shown in Figure 1 and Figure 2.



Example of how different indicators can identify different floodways

4.1.2 Encroachment techniques

These techniques can be used to define both floodways and flood storage areas. They have been widely used in industry. They use a trial and error approach and can be used to identify floodways in a one-dimensional (1D) model, or to check and refine floodways in a 2-dimensional (2D) model that have been estimated using another technique.

Encroachment techniques can be used independently of indicator techniques, however, they are generally most efficient when used in conjunction with indicator techniques. Both these approaches are discussed below.

Independent use to identify floodways and flood storage areas (1D models)

In this approach, floodways and flood storage areas are generally assessed together in a 1D model. The practitioner progressively removes the ability of shallow areas in the floodplain to convey flow by filling the very shallow areas (which would be flood fringe) and roughening the slightly deeper areas (which would be flood storage).

The starting point for the initial iterations may be a global set of depth criteria, such as 1 m for the transition from floodway to flood storage and 0.5 m for the transition from flood storage to flood fringe. These are increased or decreased until the impacts near the threshold of acceptability, at which point the criteria for defining the flood function areas need to be changed on a local scale.

Each iteration is run through the hydraulic model and the transition depth from floodway to flood storage and flood storage to flood fringe is adjusted until the change in flood levels is at the acceptable limit. In locations where the increase in flood level is lower than the acceptable limit, the transition depths are increased (to decrease the area of floodway or flood storage). In locations where the increase in flood levels is higher than the acceptable limit, the transition depths are reduced (to increase the area of floodway or flood storage).

Limitations

Use of this technique alone to identify floodways and flood storage areas is generally only undertaken when using 1D models. It is a simple trial and error process. However, the accuracy of this method can be limited by the simplified representation of flowpaths in 1D models, which means that cross flows (which are more accurately represented in 2D models) are often ignored as it is assumed that floodwaters can freely and easily move between the right and left overbank and the channel. This often results in floodways that are too narrow at critical locations, and manual adjustment to widen flowpaths at these locations may be required.

Validating floodways and flood storage areas identified using other techniques (2D models)

For 2D models, the extent of the floodway and flood storage areas may be estimated using an indicator or similar technique. The encroachment technique may be used to check results by moving the boundaries of the floodways and flood storage areas inward or outward until acceptable impacts near the threshold of acceptability are achieved. This may help to limit the number of iterations to accurately define floodways and flood storage areas.

Limitations

This technique is considered unsuitable on its own for identifying floodways in 2D models because it generally requires a large number of iterations to identify the floodway extent.

4.1.3 Conveyance techniques

These techniques can be used to define floodways. They are not effective in determining flood storage areas.

Conveyance techniques are the most robust option for identifying floodways because they determine the relative contribution of parts of the floodplain to flow conveyance. Using this type of approach, it is possible to categorise the contribution to flow conveyance of each part of the floodplain. This means the determination of the floodway is not subjective but is numerically derived and reproducible.

Thomas and Golaszewski (2012) presented research on a rigorous conveyance technique developed for application to all river and floodplain systems. The approach identified floodways as the area within each flowpath that conveys 80% of the peak flow. This approach begins by first defining the centreline of the flow, which is quite different to the encroachment technique. In the conveyance technique, the VxD product represents the unit width flow, which can be aggregated (perpendicular to the flow direction) to calculate the width required to convey a fixed percentage of the flow. Alternatively, a simplified approach can be used where the outcome from a detailed VxD summation is approximated by comparing fringe to centreline VxD.

This technique was refined by WMAwater Pty Ltd (2018) and Albert et al. (2018). This refinement aimed to create a robust, reproducible technique by which the floodway is defined as a width in which a set percentage of the flow is conveyed. This technique can be used for any catchment using a 2D or 1D–2D model (i.e. a combination of 1D and 2D). It can be used when highly reproducible and objective floodway definition is required.

Even though the definition of floodways does not relate specifically to velocity or depth of flow, but rather to the significance of conveyance or discharge and hydraulic impacts of blockage, by basing the floodway width on the relative VxD this technique provides a quasi-determination of the discharge on a width basis. It does not, however, totally remove the need for further interpretation and refinement, especially in complicated floodplains.

This technique aims to first eliminate sections of the floodplain that do not convey flow, such as areas of very low peak velocity or where, based on flow angle criteria, the flow vector is unacceptably different to the direction of the main flow (often indicating eddies).

Calculating cross-sections

The total VxD across the 'conveyance-applicable' cross-section is calculated, and the floodway is defined as the area that conveys a percentage of the total VxD. The percentage VxD required will vary slightly for different systems, however, test cases have shown that many catchments fall in the range of 80% to 90% of the applicable width based on an impact of 100 mm change in water level. By testing the 80% case, a simple formula can be used to determine the exact percentage required to meet the impact threshold (see Appendix A, Step 3). This removes many iterations and the results of encroachment testing can be used to vary the exact percentage in different parts of the floodplain. The conveyance technique allows for a holistic and objective identification of floodways for the entire study area. Identifying floodway centrelines first reduces the risk of a floodway being fitted around existing or proposed development, which can occur with the encroachment technique, instead of the other way around.

Detailed explanation of this technique and an example of it being used to identify floodways is presented in Appendix A.

Limitations

The major limitations of this technique are that the floodway centreline is drawn manually based on the maximum VxD values, which makes it somewhat subjective, and that the floodway edge is slightly sensitive to where the crosslines are terminated. Floodways can only be generated correctly if all flowpaths are identified correctly.

Unless specifically tested, this technique can create floodways in new locations, which can impact flood levels, distribution and change inundation times beyond acceptable limits.

This technique requires iterations to determine the required conveyance percentage to define floodways, and some edits to smooth and combine the initial floodway polygons. It is also quite laborious if the practitioner is unable to automate the process and the steps are completed manually. However, the floodways produced are smoother and more continuous than what would be produced by the indicator technique, and if the process is automated, it requires less manual editing.

4.2 Identifying flood storage

After floodways have been established, flood storage areas should be identified, however, not all floodplains include storage areas.

Flood storage has often been defined by practitioners as areas outside the floodway that reach a specified depth of flooding (e.g. greater than 1 m). This approach does not consider the impacts of filling or isolation of these areas on flood behaviour. It may, therefore, inaccurately estimate the scale of the flood storage area and not clearly indicate the areas of the floodplain where flood storage is an issue that needs to be considered in management.

The manual and the *Australian disaster resilience handbook* 7*: Managing the floodplain* (AIDR 2017) relate the definition of flood storage areas to their flood storage function, as areas that, if filled or isolated from flooding, would cause a notable increase in flood levels. While depth can be used as an indicator, further analysis is required before defining the area as a flood storage area.

There are 2 main techniques for defining flood storage – the indicator and encroachment techniques. These techniques are detailed below, and the strengths and limitations of each technique for defining flood storage is summarised in Table 2.

4.2.1 Indicator techniques

Indicator techniques can be used for an initial assessment of flood storage in a floodplain. Possible indicators for identifying flood storage include:

- depth criteria. It is possible to identify flood storage as areas outside the floodway that reach a specified depth of flooding. Examining flood depth maps can provide an indication of areas where depths of the areas are significant in size relative to the area of the floodway. This may indicate an area for further consideration as a flood storage area
- examination of hydrographs at different points in the floodplain. Checking hydrographs at points along the floodplain and comparing these (considering intermediate inflows and flow travel times) can give an indication of the presence of flood storage areas. A hydrograph that is flatter when compared to the upstream hydrograph indicates that water is flowing into the floodplain faster than it is flowing out. This can indicate there is flood storage in this area of the floodplain. The significance of this flood storage can relate to the scale of reduction in flows and the subsequent impacts on flood levels
- distribution of water across the floodplain. Similar to the conveyance technique for defining floodways, taking crosslines to examine the distribution of water across the floodplain (perpendicular to flow) can indicate the presence of flood storage areas.

Indicator techniques

As for floodways, indicator techniques can be used to identify where flood storage might be located. However, they do not involve assessing the impacts of fill in, or isolation from, flooding of flood storage areas and therefore do not provide all the information required to support management. For example, they may over or underestimate the importance of flood storage.

Limitations

The limitations of using an indicator technique to identify flood storage areas are the same as those for floodways (Section 4.1.1).

4.2.2 Encroachment techniques

These techniques are widely used in industry to define flood storage areas and floodways or refine the areas derived from other techniques. The application of these techniques and their limitations are discussed in Section 4.1.2.

4.3 Identifying flood fringe

Flood fringe is the remaining area in the flood extents for the event that is not defined as either floodway or flood storage. Flood fringe areas are areas where development will not impact on broad flood behaviour due to alteration of flow conveyance and storage.

Development of these areas and the broader catchment can alter run-off characteristics and can separately impact on flood behaviour. These impacts need to be considered in management (see FRM guideline FB01).

Table 1 Strengths and limitations of different techniques for defining floodways

Key aspects	Flood function technique		
	Indicator	**Encroachment**	**Conveyance**
Criteria used to define floodways	Depth, Velocity, Q, VxD	Iterative – changing floodplain depths/roughness	Use percentage of conveyance to derive floodway widths
Model type	1D–2D or 2D	1D, or 1D–2D or 2D with another technique	1D–2D or 2D
Most appropriate catchment type	Rural and overland flooding	Urban	Urban
Reproducible	✓	✓	✓
Objective	✓	x becomes subjective with iterations	✓
Produces smooth and continuous floodways	x requires manual refinement	✓	✓
Defines floodways based on landform and hydraulic behaviour, not existing or preferred land use	✓	x susceptible to prioritising existing development	✓
Includes all in-bank sections of a waterway within the floodways	x requires manual refinement	✓	✓
Includes full width of structures, constrictions and narrow points in floodways	x requires manual refinement	✓	x requires manual refinement
Ensures the definition of floodways does not create floodways in new locations, or impact flood levels, distribution, or change inundation times beyond acceptable limits	x only if tested	✓	x only if tested
Ease of use	✓	x	x

Table 2 **Strengths and limitations of different techniques for defining flood storage**

Key aspects	Flood function technique	
	Indicator	Encroachment
Criteria used to define flood storage	Depth	Iterative – changing floodplain depths/roughness
Model type	1D–2D or 2D	1D, or 1D–2D or 2D with another technique
Most appropriate catchment type	Rural and overland flooding	Urban
Reproducible	✓	✓
Objective	✓	x becomes subjective with iterations
Produces smooth and continuous flood storage areas	x requires manual refinement	✓
Defines flood storage based on landform and hydraulic behaviour, not existing or preferred land use	✓	x susceptible to prioritising existing development
Ensures the definition of flood storage areas does not impact flood levels, distribution, or change inundation times beyond acceptable limits	x only if tested	✓
Ease of use	✓	x

5. Selecting a technique

The decision on which technique to select to identify flood function areas for a particular study should be made by an experienced practitioner when specifying or undertaking the work. It should take into account factors such as the characteristics of the floodplain under investigation, time and budget constraints, the aim of the study, social issues, data availability and modelling options. It should also consider the strengths and limitations of each technique as outlined in this guideline and summarised in Table 1 and Table 2, and consider advances in techniques and relevant techniques that may become newly available.

The technique used to identify flood function areas should be robust and reproducible to ensure flood function can be preserved and meet the requirements outlined in Section 4. It should also ensure that management of the floodplain considers the sensitivity of these areas to blockage (including by filling and structures). The end results of any analysis need to be carefully reviewed by experienced professionals to consider if they are reasonable and fit for purpose.

5.1 Qualities of a good technique

A good technique for identifying flood function areas needs to:

- use calibrated and validated models wherever possible
- be reproducible and objective
- define the limits of the flood function areas based on the landform and hydraulic behaviour during floods, and not existing or preferred land use
- define flood function areas across the full range of potential floods as these areas vary with the magnitude of the flood. This is important because, as floods become larger:
    - floodway areas will generally expand
    - flood storage areas will generally extend further from the waterway
    - new floodways or flood storage areas may form in areas that had a different function or where dry during small floods
    - in some cases, particularly rural floodplains, floodways that are critical to provide water to flood-dependent assets (such as ecosystems or heritage sites) during small events may be drowned out in larger floods and no longer meet the hydraulic definition of floodways. They do, however, remain essential flowpaths to support these communities and need to be protected for that purpose

  As a minimum, this will generally include the defined flood event (DFE), a flood rarer and more frequent than the DFE, and the PMF or a similar extreme flood. However, project specifications may require assessment for additional events

- include a review of results to ensure the defined flood function areas are not overly constrained. If a defined floodway is too narrow it will not be able to convey sufficient flood flows. This can lead to new floodways developing in other locations, and flood levels, distribution and/or inundation times changing beyond acceptable limits. If flood storage areas are overly constrained, flood levels, distribution and/or inundation times can be changed beyond acceptable limits.

  This review should include checking the defined flood function areas for key events. Understanding the range of events as indicated above supports this. For example, for the DFE of the 1% annual exceedance probability (AEP) flood the flow of a slightly larger event (e.g. the 0.2% AEP flood) to see if new flowpaths develop through existing development or land identified for more intensive development.

A good technique for identifying floodway areas should produce areas that:

- are smooth and continuous to and from waterbodies and transition into and out of waterbodies
- include all the in-bank sections of a waterway (where the majority of flow is conveyed) including as it enters and leaves a waterbody and some of the floodplain
- include the full width of hydraulic structures (bridges and culverts) in the floodway, except for very wide bridges.

A good technique for flood storage areas should be based on their flood function and not simply the depth of flooding. This requires practitioners to consider the floodplain in question and determine what constitutes 'important' storage and the level of impact from filling that would adversely affect flood function.

5.2 Location and context

The scale of the assessment and the level of accuracy needed in defining flood function will vary based on the specific circumstances of the floodplain under investigation, and this can influence the technique that should be used.

5.2.1 Scale of assessment

Strategic studies by councils

Identification of flood function areas should generally be undertaken at a strategic scale as part of flood studies and FRM studies undertaken for councils. This enables the study to consider cumulative impacts of changes and their significance, so this can inform decisions.

Flood impact and risk assessments (FIRAs) for developments

FIRAs (see FRM guideline LU01) are generally undertaken for the assessment of development and infrastructure projects. They are generally undertaken to assess and address the impacts and risks associated with the development and generally cannot effectively consider changes outside the scope of the project. For flood function, FIRAs for these projects should only generally be used to:

- define flood function areas when no broader information is available. The acceptable limits for impacts for the definition of floodways for site-specific assessments are generally set by councils. They are different to those set by councils for cumulative impacts (see FRM guideline FB01)
- refine existing flood function areas, where this can be clearly justified. Justification should not be made on the basis of indicator techniques alone. Site-specific assessments should not be used to overturn strategic and/or floodplain-scale assessments of flood function.

5.2.2 Broad rural and non-urban areas not identified or zoned for future urban growth

In broad rural floodplains and in non-urban areas that have not been identified or zoned for future urban growth, a lower level of accuracy is all that is generally needed to define the extent of floodways and flood storage areas. In these areas, the floodplains are generally less constrained and less likely to change substantially, therefore, the techniques used to derive flood function areas in these areas can be indicative (Sections 4.1.1 and 4.2.1).

If more accuracy is required in a specific case, such as where there is a challenge to the classification, conveyance techniques (Section 4.1.3) may be appropriate to define floodways and encroachment techniques (Section 4.2.2) may be required to define flood storage. However, validation with encroachment techniques or equivalents is generally not considered necessary.

5.2.3 Urban areas and areas identified or zoned for future urban growth

In urban areas and in areas identified or zoned for future urban growth the extent of the flood function areas generally needs to be defined with greater certainty.

Preliminary classification

The indicator technique can be used to provide a preliminary classification of floodways and flood storage areas (Sections 4.1.1 and 4.2.1 respectively), however, the results need to be assessed for the key floodway and flood storage descriptors. That is, the technique should produce a floodway that is continuous, with blockages or fill resulting in increases in flood levels less than the identified acceptable limit (discussed in Section 3). This technique may be suitable where there is no debate or challenge to the classification.

Detailed classification

In areas where a robust result is needed or disputes about the location and extent of flood function areas need to be resolved, it is recommended the conveyance technique (Section 4.1.3) generally be used to define floodways, and the encroachment technique generally be used to define flood storage (Section 4.2.2).

5.2.4 Overland flooding

Defining flood function areas in overland flooding is complex. In the upper reaches of an urban system where no formal watercourse exists it is important to maintain flowpaths. Once a watercourse exists, whether natural, constructed or piped, it is essential the flowpath required to convey water in excess of conduit capacity is mapped.

These floodways or flowpaths often take a different path to the conduit system. They generally aim to ensure floodwaters return to the natural watercourse and preference flow in roads and open spaces over the developed parts of urban lots.

Due to the complexity of flowpaths in overland flow, the conveyance or encroachment techniques are difficult to use. The indicator technique is likely to be the most appropriate technique for identifying floodways and flood storage in overland flooding areas (Sections 4.1.1 and 4.2.1). Large flood storage areas are not common in overland flooding and may not be present.

5.3 Special considerations

In some circumstances, practitioners must take particular care when identifying flood function areas. These include areas where the flow transitions into or out of a waterbody, splits or converges, at structures, and at locations where flow is constricted. In areas where these circumstances are present, a more detailed modelling technique or manual refinements may be required to ensure they are accurately represented.

5.3.1 Transitional areas into and out of waterbodies

In some cases, floodways will transition into flood storage areas such as swamps, lakes, other waterbodies, or areas of low relative velocity. These transition zones have some of the characteristics of both categories. The challenge is that these areas often have large areas of low velocity and high depth flow that conveys a significant amount of water.

Excluding waterbodies, these areas are often used for environmental, agricultural or recreational purposes as they flood relatively frequently and can be classified as secondary floodways. These areas are typically sensitive to changes in flood behaviour and should not be significantly obstructed, but an occasional building, shed or small stock refuge in a broad floodway or large flood storage area will generally only have limited local impacts, particularly in rural areas.

5.3.2 Structures, constrictions and narrow points

Structures, constrictions and narrow points may require detailed investigation by a practitioner skilled and experienced in flood hydraulics. These may occur at:

- structures, such as bridge piers or culverts where they cross a flowpath. A detailed investigation should be conducted to determine whether all or only part of the width of the structure is a floodway or the floodway extends further as the structure overtops
- flow constrictions or where waterways narrow. In a developed area this could be where the flowpath is constricted by buildings. In a larger floodplain it could be where the flow transitions into or out of a natural gorge. At these locations it is important the flow capacity of the floodway is maintained, and it may be reasonable to define the entire width of the flowpath as a floodway.

5.3.3 Flow divergence and convergence

Flow divergence and convergence means that the percentage of flow conveyed at any one point can vary between the main and secondary flowpaths. In these cases, the practitioner should take care to assess whether both flowpaths are part of the floodway or if one flowpath is dominant. This can be undertaken by examining hydrographs at various cross-sectional widths. This is illustrated in Figure 3 and Figure 4 below. Figure 3 shows the centrelines where flow splits between the creek (main channel flowpath) and a road (road flowpath). Figure 4 shows flow hydrographs taken from a cross-section for each of the flowpaths. The creek flowpath is shown in blue, and the road flowpath as red dashes. From these hydrographs it is clear that the creek is the dominant flowpath.

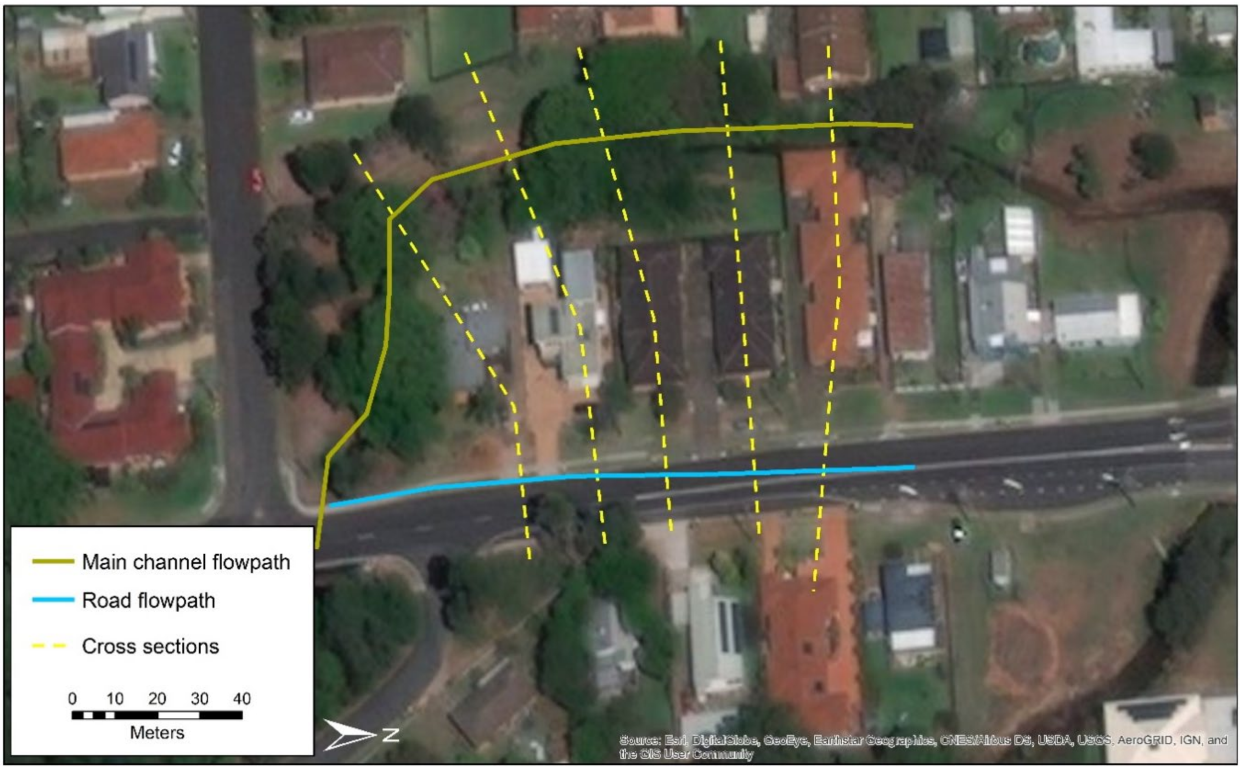


Figure 3 **Location of flowpath split**

Source: WMAwater 2018

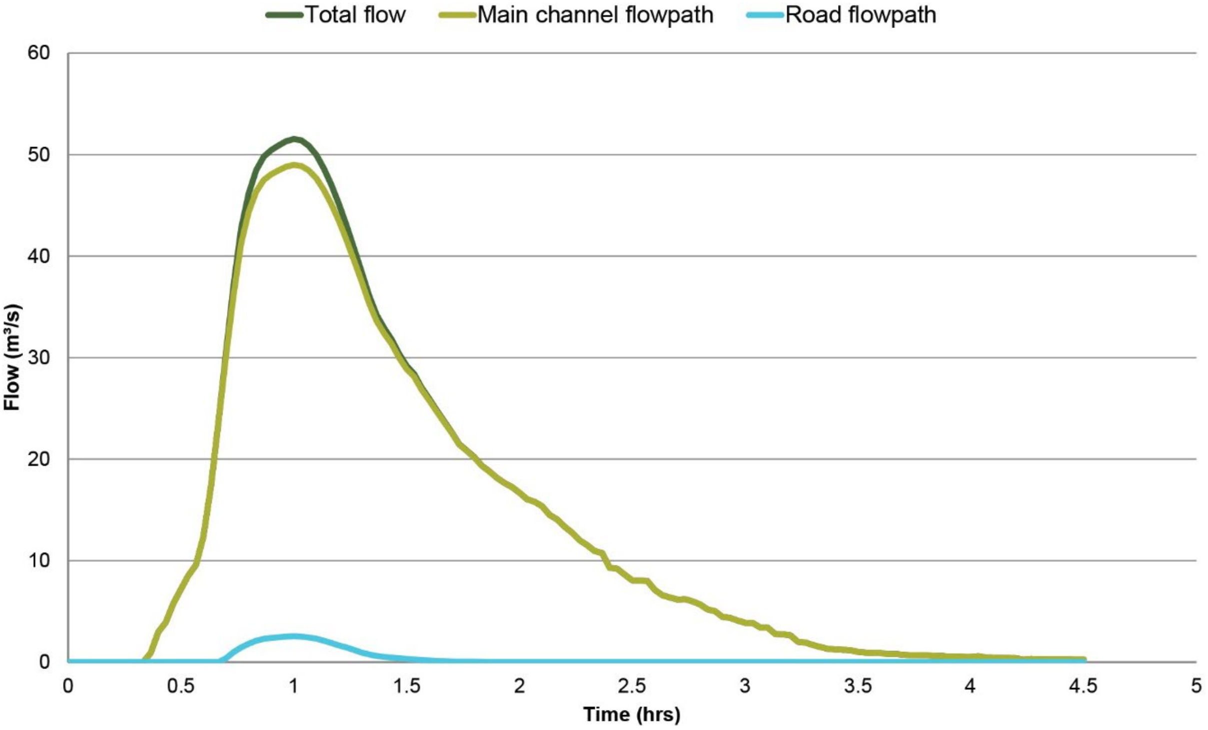


Figure 4 **Assessment of cross flow between flowpaths**

Source: WMAwater 2018

5.4 Modelling options

Models can be 1D, 2D, or 1D–2D. The type of model that should be used depends on data availability, the level of complexity of overbank flows, the required level of model accuracy, and time and resources.

5.4.1 Key differences between models

1D models do not provide cross-sectionally varied velocities, and therefore are limited to encroachment analysis, however, by the same token an advantage of 1D models is that they are quick to run simulations. Therefore, if undertaking an encroachment analysis, a 1D model may be more efficient. The biggest disadvantage of 1D models is that they assume flow can efficiently redistribute between the left and right overbank and the channel between cross-sections. This assumption can lead to an underestimation of encroachment impacts and ultimately flood function. This highlights the importance of considering the smoothness of the floodway definition between sections.

The high-resolution results provided by a 2D model allow for reliable analysis of flood flow and conveyance on more complicated river systems, particularly shallow floodplains and split flowpaths. An additional advantage of 2D models is that flowpaths do not need to be identified by the practitioner because they are computed directly as a function of the model terrain and the applied flows. However, 2D models typically require significantly more survey data and computation time. They also require a compromise between the number of grid elements (cells) and run time. This is of particular importance with fixed grid models, where fewer/larger grid elements mean faster model run times, but reduced ability to accurately capture sub-grid scale features such as creeks and hydraulic structures. This is less of an issue for flexible mesh 2D models where the mesh resolution can be increased (more/smaller cells) around features that require more detailed modelling and decreased (fewer/larger cells) in areas that do not.

Integrated 1D–2D models use a 1D domain to model the main channel(s) and/or structures (such as culverts, bridges or pipes), which is connected dynamically to a 2D domain that models the broader flow area. They have advantages of both 1D and 2D models and provide a comprehensive, efficient and accurate representation of the floodplain by making the most of both 1D and 2D model capabilities. For example, the use of 1D models allows accurate representation of sub-grid scale features, such as creeks and hydraulic structures.

Book 6 Chapter 4 of *Australian rainfall and runoff* (Ball et al. 2019) provides more advice on models and model selection.

6. References

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More information

Flood risk management manual, guidelines and tools

See links on the following Department of Planning and Environment (DPE) webpages:

- Flood risk management manual
- Flood risk management guidelines
- 'Administration arrangements: flood risk management guideline AG01'

Other links

- Floodplain Management Program – DPE Environment and Heritage Group webpage
- Healthy Floodplain Project – DPE Water webpage
- Lower Darling Rivers Indigenous Nations

Appendix A – Conveyance technique example

Introduction

This example illustrates the methodology used to determine the extent of floodways as a percentage of conveyance using the velocity depth product (VxD) layer.

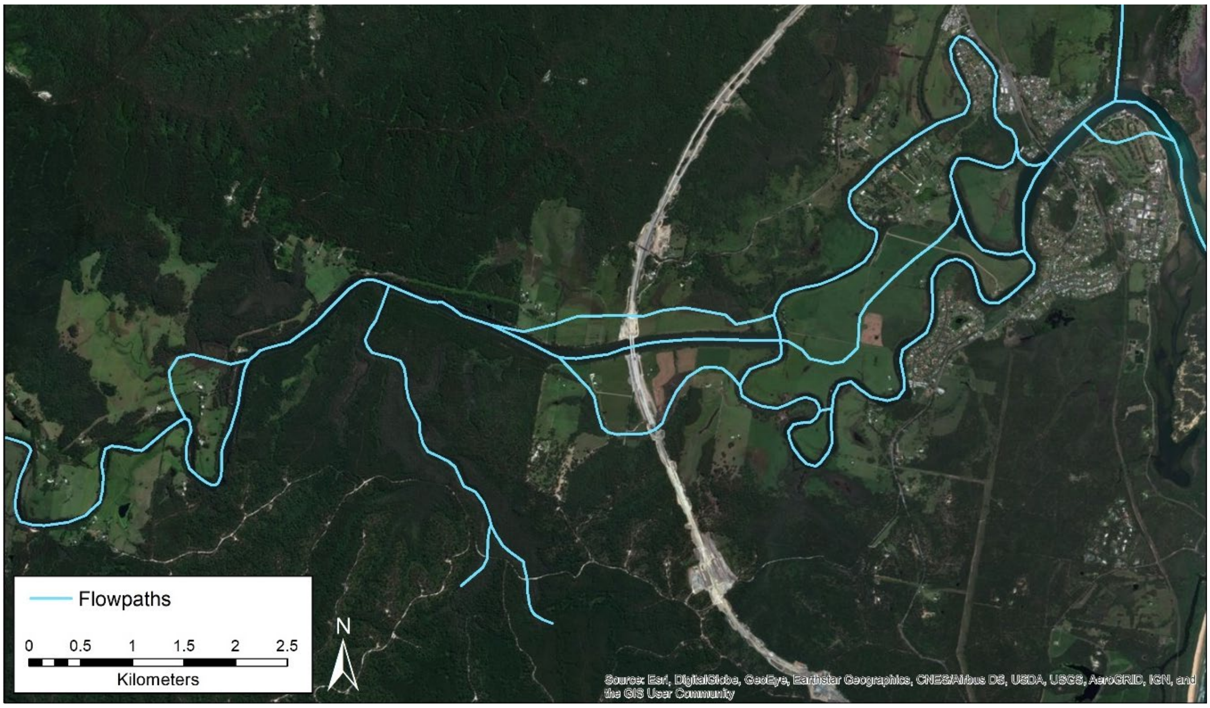
This approach determines the contribution of each VxD grid cell to flow conveyance allowing the percentage conveyance to be calculated.

The methodology below defines the width of the floodway in 3 main steps, which each have sub-steps. Note that this example shows the manual method for completing each step. Code can be written to automate the process.

Step 1 – Establish centrelines and crosslines

Step 1.1 – Establish floodway centreline

The first step involves establishing a floodway centreline or skeleton flowpath. Often floodplains will have multiple floodways, which requires multiple centrelines to be drawn, as shown in Figure 5.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 5 **Digitised river centreline with additional flowpaths that develop in larger events**

The floodway centreline can be created by examining gridded VxD data (Figure 6). The floodway centreline should be drawn through the centre of the area of highest values in the VxD grid. The centreline can be drawn using most GIS software.

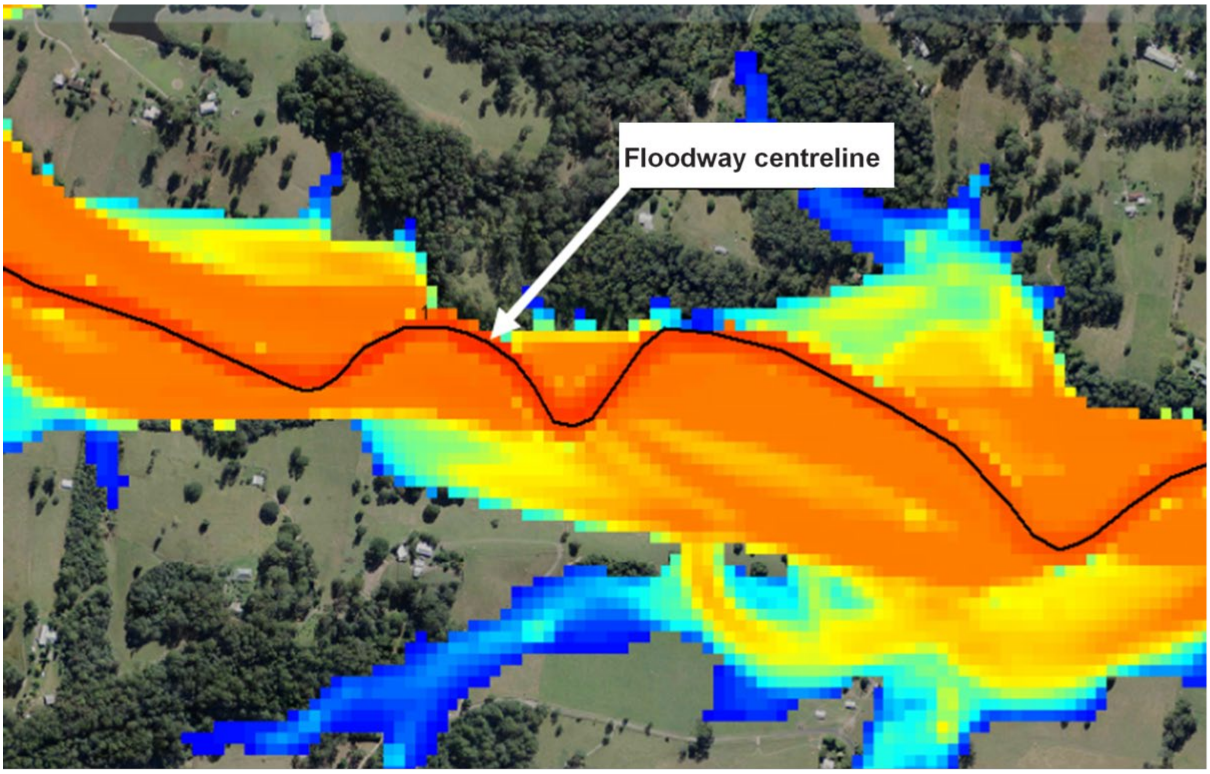


Figure 6 **An example flow line, drawn through the centre of a flowpath on the VxD grid**

Step 1.2 – Establish crossline frequency and determine the practical limit of effective flow width

This step involves establishing the frequency and width of crosslines along the flow centreline. In this example, using a 15-m grid 2D model of a large (approximately 1,000 km^2) coastal catchment in New South Wales, the width of the floodway is calculated at crosslines every 60 m along the flow centreline. This is equivalent to one-quarter the resolution of the grid cells.

Crosslines should be created equidistant along the centreline, perpendicular to flow. The distance that should be used is dependent on the size and complexity of the floodway and the level of detail required in the analysis.

Single flowpath

Where there is only one flowpath, crosslines should be as wide as the practical limit of effective flow (Figure 7). This aims to exclude areas of the floodplain that contain eddies or trivial velocities, indicating a low conveyance at the peak of the flood. The practical limit of effective flow should be set, and crosslines should be terminated, once velocity approaches zero or when the direction of flow deviates significantly from the main channel direction. In this example, crosslines are terminated once the direction of flow changes by 135°, but values between 90° and 180° have been found to work. In this example, the change in flow direction was more significant, so a velocity threshold wasn't used.

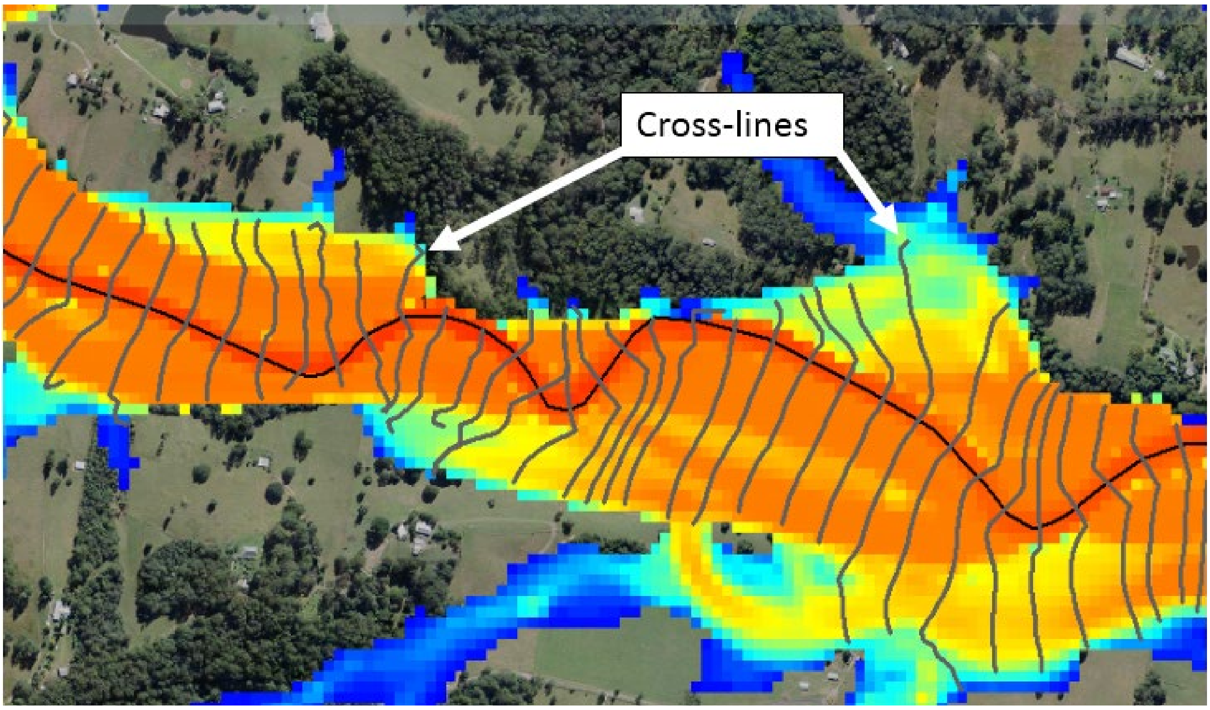


Figure 7 Crosslines are placed perpendicular to the flow direction

Multiple flowpaths

Where there are multiple flowpaths present, crosslines should be terminated at the minimum VxD between each flow centreline (Figure 8).

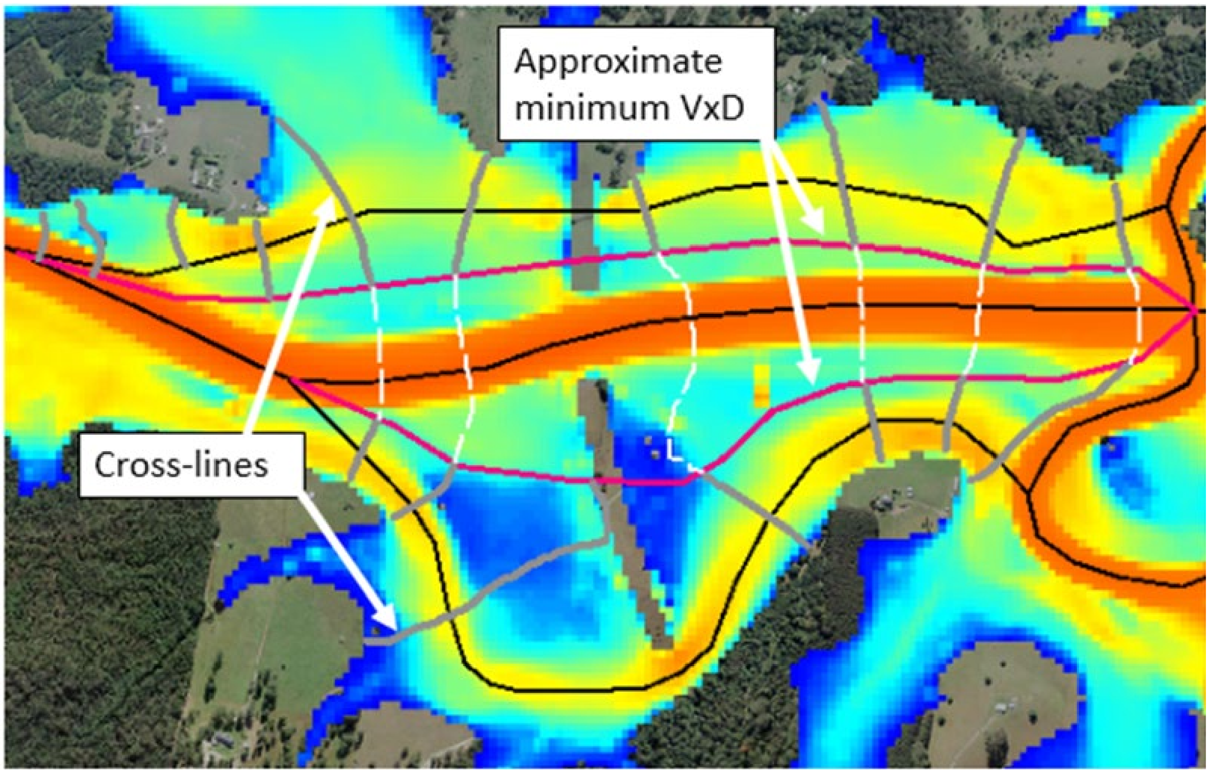


Figure 8 Where there are multiple flowpaths, crosslines should extend to the minimum VxD between the flowpaths

Step 1.3 – Create calculation points on crosslines

Once the crosslines have been created, place calculation points on each crossline at an interval no greater than the size of a single grid cell (Figure 9). The more points that are placed on each crossline, the better the accuracy of the analysis. Note that most GIS programs will allow the user to automate this process by converting polylines to points.

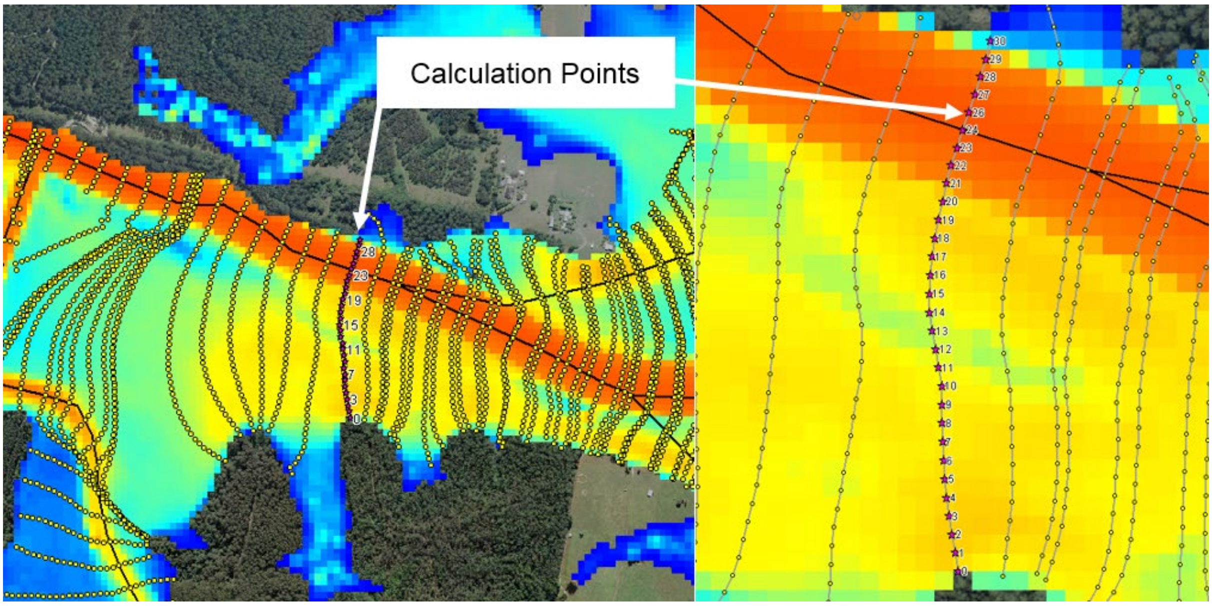


Figure 9 **Points are placed along the crosslines**

It is also useful to assign each point an identifier (ID) that references the flowpath and crossline it occurs on, to identify calculation point values in the following step.

Step 2 – Construct the floodway

Step 2.1 – Identify the VxD values at each calculation point

Extract the VxD value at each calculation point along all crosslines and record the values in the point layer attribute table.

Step 2.2 – Export crossline data to determine floodway extent at each crossline

Once a VxD value has been identified and assigned to each point, export the data in comma delimited (.csv) format.

When the data are in a spreadsheet, starting from the floodway centreline and working outwards to each end of the crossline, number the VxD values (column 2, ‘Point ID’, Table 3) in order from largest to smallest for each crossline (column 3, ‘VxD’, Table 3) – this gives the order of summation (column 4).

Calculate the cumulative VxD (column 5, Table 3) by summing the VxD values one-by-one in the order of summation and take note of the total VxD, which is the highest number in the cumulative summation column. The total VxD can also be calculated by simply summing all the values in the VxD column (column 3, bottom row, Table 3).

Once the cumulative sum of VxD and the total VxD have been calculated, these values can be used to calculate the cumulative VxD percentage (column 6, Table 3). This is done by dividing the cumulative VxD sum at each point by the total VxD.

As a starting estimate, the floodway extent should be set at 80% of total conveyance, as calculated in the cumulative VxD percentage column. The points either side of the centreline that are less than or equal to approximately 80% represent the extent of the floodway (column 7, Table 3). The remaining 20% can be evenly split on either side of the floodway, but more often it will be distributed on one side more than the other. This is shown in Table 3, where 19.9% of remaining flow is on one side of the floodway and only 0.1% of flow is on the other side.

Note that for crosslines representing flow under culverts or bridges, the floodway extent must be set at 100% of total conveyance.

Table 3 Example calculations for defining the floodway extent at a crossline

	Point ID	VxD	Order of summation	Cumulative VxD (sum)	Cumulative VxD (%)	
Column: 1	2	3	4	5	6	
	0	0.53	29	121.65	99.65%	
	1	1.22	28	121.12	99.21%	
	2	1.22	27	119.9	98.21%	
	3	1.42	26	118.68	97.21%	
	4	1.49	25	117.26	96.05%	
	5	1.21	24	115.77	94.83%	
	6	1.18	23	114.56	93.84%	
	7	1.21	22	113.38	92.87%	
	8	1.31	21	112.17	91.88%	
	9	1.41	20	110.86	90.81%	
	10	1.29	19	109.45	89.65%	
	11	0.87	18	108.16	88.60%	
	12	0.71	17	107.29	87.88%	
	13	0.99	16	106.58	87.30%	
	14	1.24	15	105.59	86.49%	
	15	1.4	14	104.35	85.48%	
	16	1.53	13	102.95	84.33%	
	17	1.6	12	101.42	83.08%	
	18	1.57	11	99.82	81.77%	
	19	1.43	10	98.25	80.48%	**Floodway extent**
	20	2.21	8	95.38	78.13%	
	21	8.1	7	93.17	76.32%	
	22	13.28	5	76.9	62.99%	
Centreline ➔	23	16.44	1	16.44	13.47%	
	24	16.44	2	32.88	26.93%	
	25	16.91	3	49.79	40.78%	
	26	13.83	4	63.62	52.11%	
	27	8.17	6	85.07	69.68%	
	28	1.44	9	96.82	79.31%	
	29	0.31	30	121.96	99.90%	
	30	0.06	31	122.02	99.95%	
	31	0.06	32	122.08	100.00%	
Total VxD		**122.08**				

Step 2.3 – Connect floodway extent at crosslines

Connect the outermost points of the floodway extent for each crossline (points 19 and 28 for the example crossline shown in Table 3) to create the edge lines of the floodway. The resultant polygon is the floodway extent. Figure 10 shows an example of such edge lines.

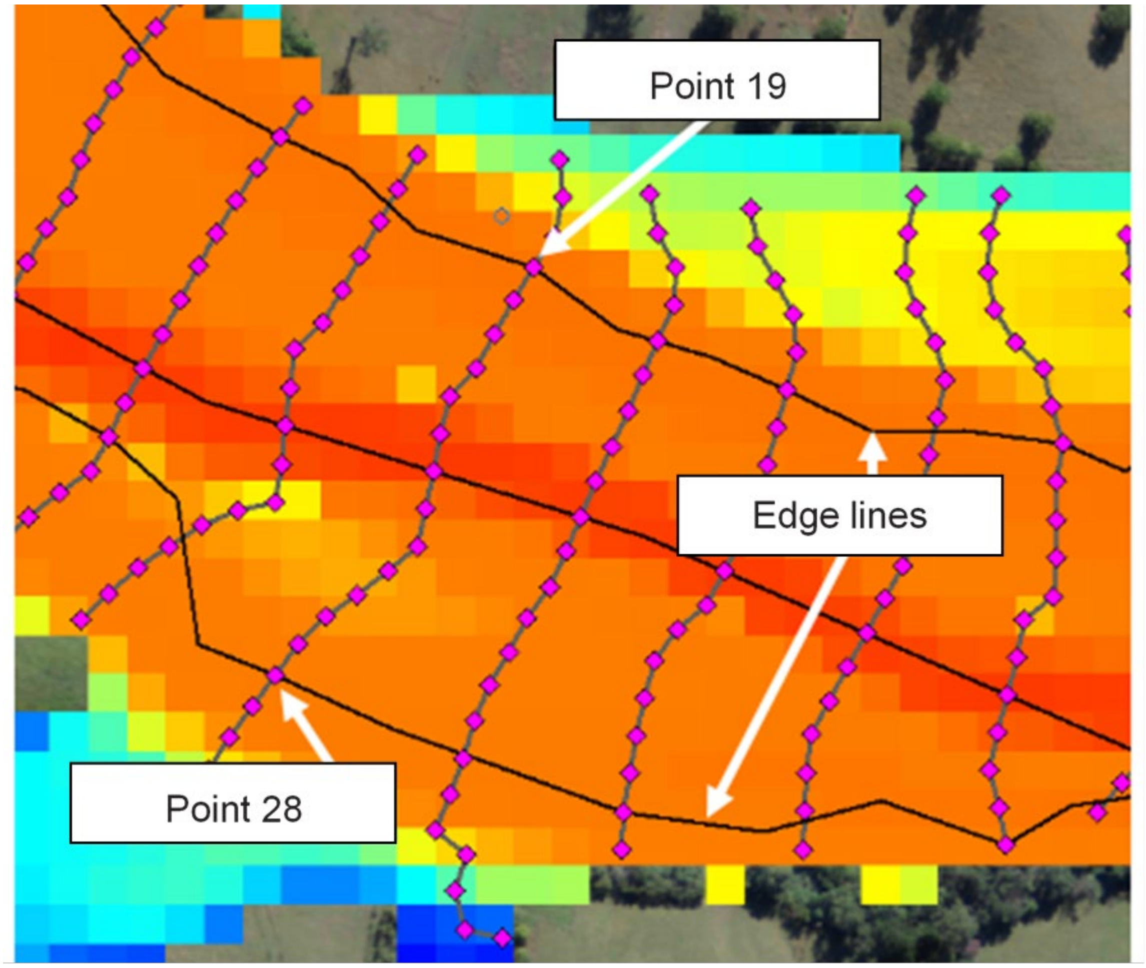
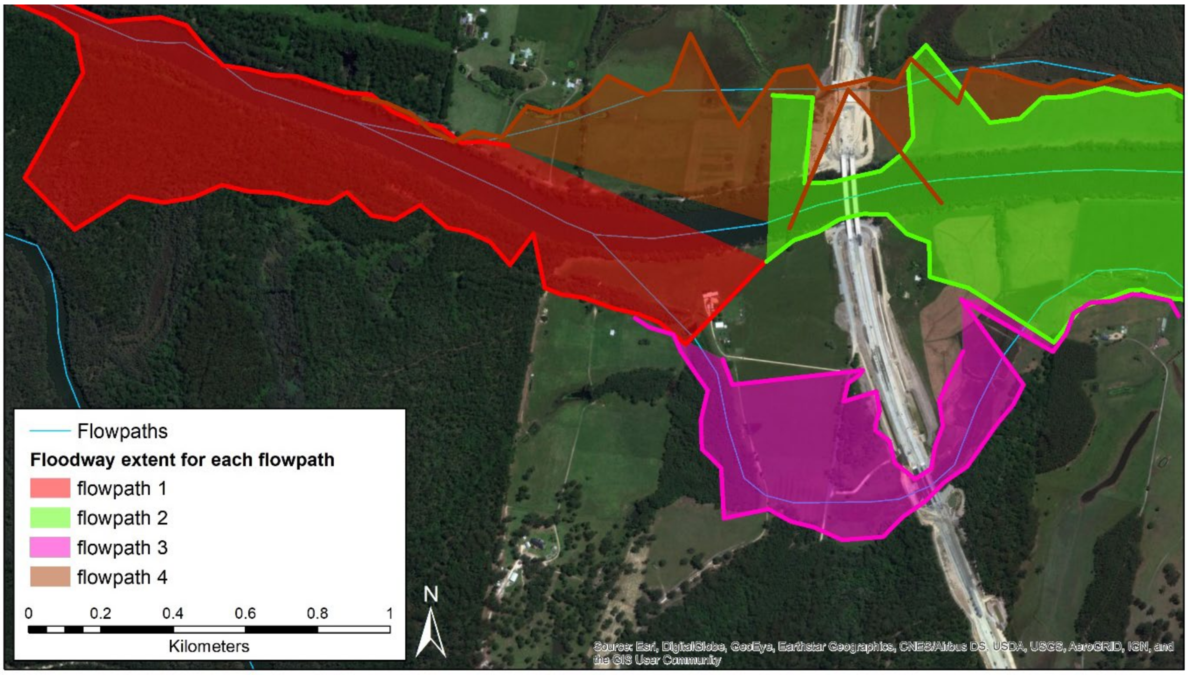


Figure 10 **Example of edge lines created from outermost points of floodway extent**

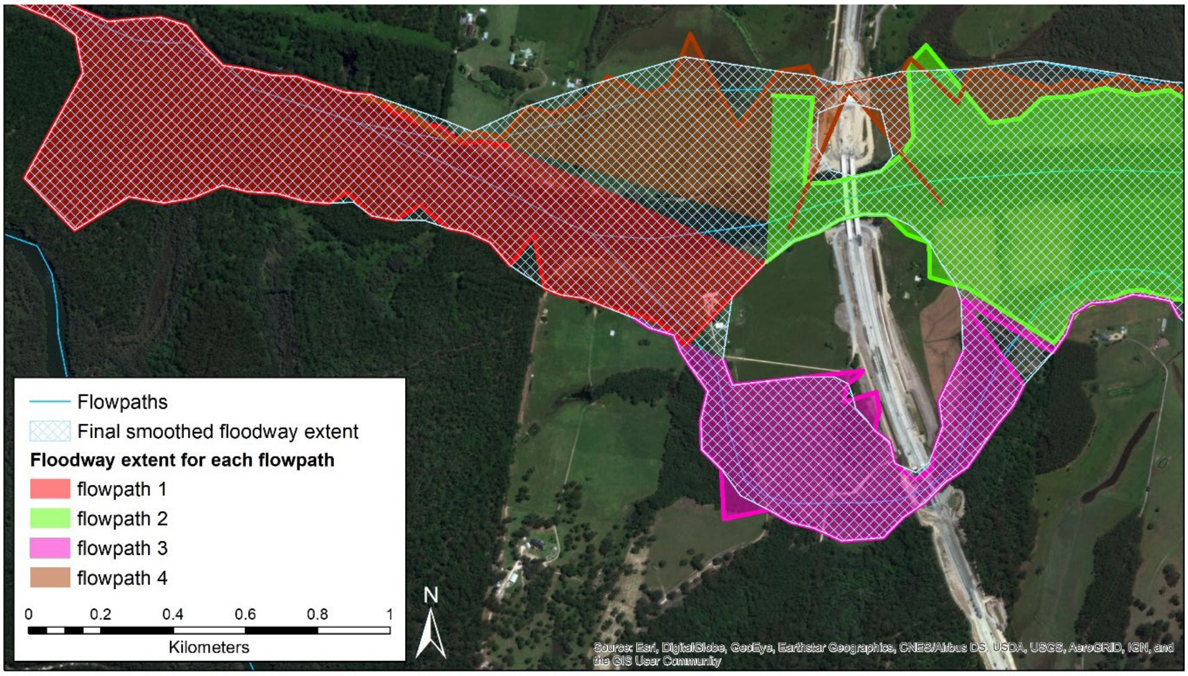
Connecting floodway extent with multiple flowpaths

Creating the polygon for the floodway extent is relatively simple for a single centreline but becomes more complex where centrelines (flowpaths) diverge or converge. For a single centreline, the floodway polygon can be drawn through the calculation points representing the required conveyance and then smoothed. Where there are multiple centrelines, a floodway polygon is drawn for each centreline, and then the polygons are smoothed and joined into one. An example of this is shown in Figure 11 and Figure 12 where blue represents the flow centrelines, the coloured regions (red, green, maroon and pink) are the floodway extents for each of the flow centrelines, and the light blue hatching in Figure 12 is the final floodway extent.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 11 Example of floodway extents for multiple flowpaths



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 12 Example of smoothed floodway extent for multiple flowpaths

Step 3 – Check floodway width

Step 3.1 – Calculate required conveyance

Once the floodway polygon has been created, it should be checked to make sure it conveys flow sufficiently. This is commonly done by increasing the Manning's roughness (n) on the floodplain area outside the floodway polygon. If this test shows a significant impact to flood level (e.g. of greater than 0.1 m), the formula below can be used to determine the conveyance percentage that should have been used to define the floodway.

$$1 - S\left(\frac{1 - C_{test}}{I_{test}}\right) = C_{required}$$

where S is the change in flood level that would be significant for the floodplain under investigation, C_{test} is the conveyance percentage tested and I_{test} is the impact resulting from the tested conveyance percentage. Note that the change in flood level that would be considered significant should be determined by an experienced practitioner, giving consideration to the conditions in the floodplain under investigation, including the sensitivity of communities, structures and ecological communities, and the accuracy of the model used.

For example, if the floodway was initially defined using a conveyance percentage of 80%, a significant change in flood level was defined as an increase of 0.1 m, and this was found to result in an impact of 0.3 m, the calculation would be:

$$1 - 0.1\left(\frac{1 - 0.8}{0.3}\right) = 0.93$$

This shows that the floodway should be defined using a conveyance of 93%.

Step 3.2 – Redefine floodway extent

If the calculation in Step 3.1 indicates that floodways should be defined using a conveyance other than the starting estimate of 80% (see Step 2.2), return to Steps 2.2 and 2.3 and repeat the process of identifying the outermost points of the required conveyance and connecting the floodway extent at each crossline.