Rural floodplain management plans

Water Management Act 2000

Background document to the floodplain management plan for the Gwydir Valley Floodplain 2015

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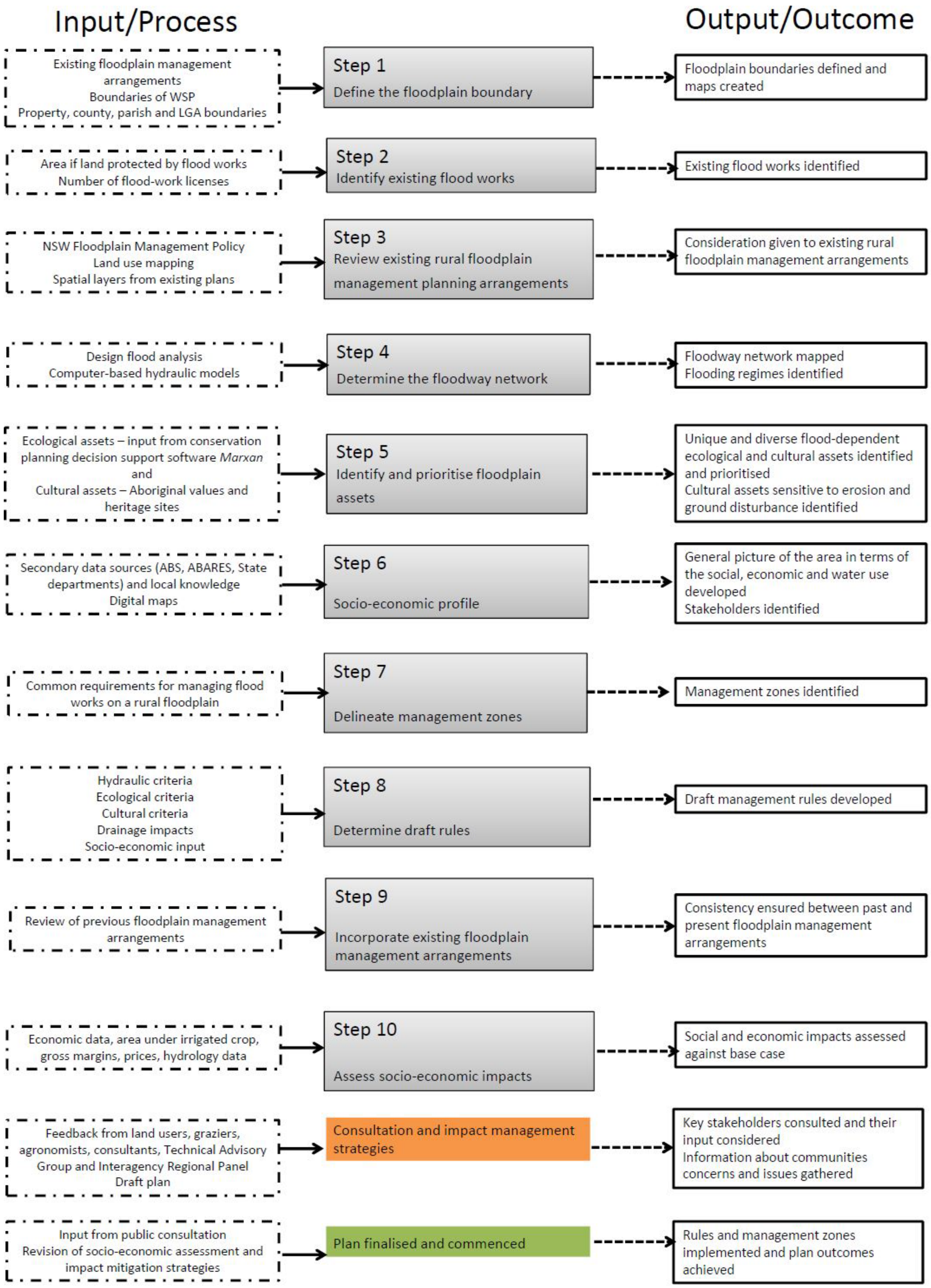


Appendix 2: History of floodplain management in the Gwydir floodplain

Floodplain management planning in the Gwydir floodplain has evolved in response to changing community needs; changes to land and water use; an increased awareness of the importance of floodplain ecology and changes to the legislative and policy framework which govern water management. A detailed history of floodplain management in the Gwydir floodplain is outlined below.

Pre-1970s

Before the 1970s, the NSW Government was not actively involved in managing flood-work developments because agriculture was dominated by low-intensity grazing and there was an absence of earthworks that would affect flooding in the landscape.

In 1912, the NSW Government began to take on a legal responsibility for water management by enacting the *Water Act 1912* (WA 1912). At this time, the legislation did not relate to works on flood prone land remote from a river or lake; however, Part 2 of this Act did provide for the licensing of works which could affect the distribution of floodwaters flowing in, to or from, or contained in, a river or lake. The enactment of the WA 1912 did not initially change floodplain management in the Gwydir; however, this Act would become the principle driver of floodplain management after amendments were made in subsequent decades in response to changes in flood patterns caused by flood works.

From 1960 to 1970, there was a proliferation of uncoordinated channels and levees over large tracts of natural floodplain due to:

- a major program of large dam construction, which led to expectations of an assured water supply
- the consequential replacement of low-intensity grazing by intensive irrigation
- a change in Government policy, which encouraged private irrigation development.

1970–1980

During the early 1970s, major flood events revealed that uncoordinated flood works were causing major changes in traditional flood patterns in many locations. These changes resulted in heavy crop losses and flood damage was experienced in areas that had previously been relatively flood free. In the Gwydir floodplain, the following guideline was produced to help mitigate flooding problems:

- *Guidelines for Mehi River flood plain development* (1971) NSW Water Resources Commission

Primarily in response to the major flood events of the early 1970s, the *Water Resources Commission Act 1976* was enacted in 1976 to investigate, formulate and implement flood mitigation strategies on a valley-wide basis. Under the provisions of this legislation, guidelines, which were levee/floodway schemes, were prepared for the worst-affected areas. The approach aimed to provide floodways of adequate hydraulic capacity and continuity, by restoring or maintaining, as far as practical, the natural pattern of flood channels for the effective conveyance of flood flows. Flood protection of developed land was accomplished by the construction of levees bordering the floodways and was funded and implemented by the benefiting landholders. In the Gwydir, the following guidelines were developed under this Act:

- *Guidelines for flood plain development Gwydir River Moree Area* (1978) NSW Water Resources Commission
- *Guidelines for Carole and Gil Gil Creeks flood plain development Ashley to Mungindi* (c. 1980) NSW Water Resources Commission
- *Guidelines for Boolcarrol to Bulyeroi* (c. 1980) NSW Water Resources Commission
- *Guidelines for Narrabri to Wee Waa* (c. 1980) NSW Water Resources Commission

1984

In 1984, the *Flood Prone Land Policy 1984 was* introduced to overcome the potential sterilisation of floodplains resulting from rigorous planning controls introduced in the 1977 Environment and Planning Circular No 15. The policy aims to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible. The policy requires:

- a merit approach to be adopted for all development decisions
- for both mainstream and overland flooding to be addressed using strategically generated floodplain risk management plans
- flood mitigation works and measures to reduce the impact of flooding
- for action to minimise the potential for flood losses to be balanced by the application of ecologically sensitive planning and development controls.

The WA 1912 was also amended in 1984 to include Part 8, which allowed the Ministerial Corporation to control all private works on the banks of rivers and lakes and on proclaimed floodplains, which could affect the distribution of floodwaters (referred to as controlled works). Controlled works included earthworks, embankments and levees, as well as access roads, irrigation channels and dams. This provision in the legislation allowed for the designation of floodplains, which are areas where controlled work approvals must be obtained. This provision in the legislation also allowed for the preparation of coordinated floodplain management guidelines for the designated flood affected areas that identify flood ways and the suitable location of levees in consultation with landholders and Local Government. The introduction of Part 8 of the WA 1912 heralded the beginning of the NSW Government's involvement in legally controlling flood-work development and planning to prevent future flood works from causing or exacerbating flooding problems. In the Gwydir, the following guideline was developed under the amended legislation:

- Guidelines for flood plain development Gwydir River downstream of Brageen Crossing (1989) NSW Department of Water Resources

The Lower Gwydir Valley Floodplain was also designated under s.166 of Part 8 of the WA 1912 (18/10/1984).

1986–1989

In 1986, the *Floodplain Development Manual*, which was developed to support the NSW Government's *Flood Prone Land Policy,* was published. The manual related to the management of flood liable land in accordance with section 733 of the *Local Government Act 1993* which exempted councils from liability. The manual applies to urban and rural floodplains across NSW.

In 1989, the *Guidelines for flood plain development Gwydir River downstream of Brageen Crossing* (1989) NSW Department of Water Resources was developed.

1990–1999

In 1995, a general regulation to Part 8 of the WA 1912 was gazetted that prescribed railways (together with associated bridges and railway works) that are vested in Rail Access Corporation and roads (together with associated bridges and roadworks) that are vested in a council or in the Roads and Traffic Authority as exempt from needing a controlled work (flood-work) approval.

In 1999, Part 8 of the WA 1912 was amended to allow for more strategic coordination of controlled works through the preparation of statutory rural floodplain management plans (s.166a). The amendments made rural floodplain management plans the statutory basis for determining flood control works in order to overcome difficulties with assessment of works on an ad hoc basis. The amendments also allowed for areas not designated as part of a floodplain to be covered by Part 8. This meant that works in these areas were now required to be assessed if they could potentially affect flood flow into and out of a stream and affect flooding. Section 166C of the WA 1912 provides guidelines for the assessment of such works. It was also required that rural plans be developed in accordance with the provisions and policies of the *NSW Floodplain Development Manual* and *NSW Flood Prone Land Policy*. Up until this point, the floodplain development guidelines produced were not statutory. The new strategy was developed in response to strong community support for a change in the then current practice. A key objective was to develop the floodplain management plans using community-based floodplain management committees. The process for developing the plans included undertaking:

- flood studies to define the nature and extent of flooding and flood-related issues in technical terms
- floodplain risk management studies to evaluate options in consideration of social, environmental and economic factors to address existing and future flood risk and flood management issues
- rural floodplain management plans to outline strategies to manage flood risk and flood management issues and support the natural functions of the floodplain environment.

To facilitate the revised strategy, a $5 million program was jointly funded by the Natural Heritage Trust and state funding to develop plans in 18 inland rural areas across 30,000 km^2. The amendment was to outline a new process to deliver strategic outcomes to manage flood control works on inland floodplains where these works did not require council consent under rural zonings. Where rural floodplain management plans and development guidelines exist, rural plans replaced the out-dated development guidelines. In the Gwydir, the following rural floodplain management plans were developed as a result of these changes:

- Lower Gingham Watercourse Floodplain Management Plan (adopted June 2006)
- Moomin Creek Floodplain Management Plan (adopted October 2010)

2000

In 2000, the *Water Management Act 2000* (WMA 2000) was enacted to replace the WA 1912 and a range of other Acts dealing with water management to achieve sustainable and integrated management for all water-based activities, including water use, drainage, floodplains and groundwater. The repeal of the WA 1912 has been an ongoing process. The WMA 2000 is the culmination of the NSW water reform process driven by the Council of Australian Governments (COAG). The WMA 2000 contains floodplain management provisions that relate closely to existing provisions under the amended Part 8. Section 29 and 30 detail the core and additional provisions to be considered when developing floodplain management plans. The core provisions require the plans to deal with:

- identification of the existing and natural flooding regimes in the area, in terms of the frequency, duration, nature and extent of flooding
- the identification of the ecological benefits of flooding in the area, with particular regard to wetlands and other floodplain ecosystems and groundwater recharge
- the identification of existing flood works in the area and the way they are managed, their benefits in terms of the protection they give to life and property, and their ecological impacts, including cumulative impacts
- the risk to life and property from the effects of flooding.

The general water management principles of the WMA 2000 also require that the cumulative impacts of water management licences and approvals, and other activities on water sources and their dependent ecosystems be considered and minimised.

2001–2005

In 2001**,** the *Floodplain Development Manual* was revised to make it consistent with a series of improvements to both policy and practice, including the need to:

- consider the full range of flood sizes up to and including the probable maximum flood when developing a floodplain risk management plan
- recognise existing, future and continuing flood risk on a strategic rather than ad hoc individual proposal basis
- support local councils to manage local overland flooding in a similar manner to riverine flooding
- promote the preparation and adoption of local flood plans (prepared under the guidance of SES) that address flood readiness, response and recovery.

In 2005, the *Floodplain Development Manual* was again updated and gazetted as the manual relating to the development of flood liable land for the purposes of section 733 of the *Local Government Act 1993*. The updates reflected the significant change in the roles of state agencies and clarified some planning issues which had led to inconsistent interpretations. The manual supports the NSW Government's *Flood Prone Land Policy* in providing for managing human occupation and use of the floodplain considering risk management principles.

2006–2014

In June 2006, the statutory *Lower Gingham Watercourse Floodplain Management Plan* was adopted under the WA 1912. The *Moomin Creek Floodplain Management Plan* was then adopted four years later in October 2010, also under the WA 1912.

In 2010, the *Healthy Floodplains Project* commenced to reform the management of water on floodplains through the development of floodplain management plans as well as licensing of floodplain harvesting water extractions. In June 2012, Stage 1 of the *Healthy Floodplains Project* was awarded $36 million by the Commonwealth Government, with additional contributions by the NSW Government. The *Floodplain Harvesting Policy 2013* was prepared to guide NSW Government agency staff when implementing the *Healthy Floodplains Project*.

Part 8 of the WA 1912 is expected to be repealed and replaced in 2015 by the floodplain management provisions of the WMA 2000. This transition will allow for the adoption of the proposed *Floodplain Management Plan for the Gwydir Valley Floodplain* (Gwydir FMP). The new floodplain management provisions will allow for the exemption of a specified range of works vested in government agencies as well as certain privately-owned works of a minor nature from approval as flood works.

The Gwydir FMP will consolidate floodplain management measures from existing plans and guidelines and supersede all existing floodplain management plans in the Gwydir Valley Floodplain. Concurrently, the Gwydir Valley Floodplain designated under the WA 1912 will be repealed and a new Gwydir Valley Floodplain designated under the WMA 2000. The designation of the new floodplain will be for the purpose of administering flood works and floodplain harvesting activities.

Appendix 3: Detailed review of existing floodplain management arrangements

The Gwydir Valley Floodplain contains:

- second generation rural floodplain management plans (FMPs) developed under the *Water Act* (*WA*) *1912*
- first generation rural floodplain development guidelines (guidelines) that are non-statutory.

The following sections provide a review of existing floodplain management arrangements by detailing:

- floodplain management principles
- ecological and cultural heritage considerations
- floodway networks
- hydraulic models
- design flood events
- types of controlled works considered for approval
- advertising requirements
- assessment process/criteria for assessing flood-work applications.

Second generation: rural floodplain management plans (WA 1912)

Rural floodplain management plans were statutory documents prepared under Part 8 of the WA 1912 by the Office of Environment and Heritage. The plans were administered by DPI Water when assessing flood-work development applications. In total, these plans cover approximately 12% of the Gwydir floodplain with the *Lower Gingham Watercourse Floodplain Management Plan* (2006) covering ~3% (31,000 ha) and the *Moomin Creek Floodplain Management Plan* (2010) covering ~ 9% (105,000 ha).

Floodplain management principles

Section 166C of Part 8 of the WA 1912 was added as an amendment in 1999 and this section relates closely to the floodplain management provisions of the WMA 2000. Section 166C outlines matters for general consideration. Such matters include:

- the contents of any relevant floodplain management plan or any other relevant Government policy
- the need to maintain the natural flood regimes in wetlands and related ecosystems and the preservation of any habitat, animals (including fish) or plants that benefit from periodic flooding
- the effect or likely effect on water flows in downstream river sections
- any geographical features, or other matters, or Aboriginal interest that may be affected by a controlled work
- the effect or likely effect of a controlled work on the passage, flow and distribution of any floodwaters
- the effect or likely effect of a controlled work on existing dominant flood ways or exits from flood ways, rates of flow, floodwater levels and the duration of inundation
- the protection of the environment
- any other matter relating to the desirability or otherwise of a controlled work.

Ecological and cultural heritage considerations

Areas of ecological and cultural significance were identified and considered when mapping the floodway networks in existing plans.

Floodway networks

The existing plans identified floodway networks, which were the basis for assessing applications to construct controlled works.

Hydraulic models

A one-dimensional MIKE11 model was used to inform the development of the *Moomin Creek Floodplain Management Plan* (2010). The model extended from the anabranch of the Moomin Creek from the Mehi River through to the Moomin Creek at Moomin Plains Gauge. The model included representation of the northern and southern Moomin Creek floodplains and associated floodways as well as Millie Creek and other tributaries.

In order to determine the floodway network and flood distribution, a two dimensional RMA-2 model was set up for the *Lower Gingham Watercourse Floodplain Management Plan* (2006). The model utilises a mesh of interconnected computational points that utilise detailed ground survey undertaken for the project. The model extends from Curragundi Road and the Gingham Channel at Gingham Bridge downstream to the Morialta Road and the Gingham Channel at Woodlands Road. The southern extent roughly follows 1 km south the Watercourse Road while the northern extent lies approximately halfway between the Gingham and Gil Gil Creek channels.

Design flood events

The design floods used in the *Lower Gingham Watercourse Floodplain Management Plan* (2006) and the *Moomin Creek Floodplain Management Plan* (2010) were the 1971 and 1974 floods, respectively.

Types of controlled works considered for approval

The *Lower Gingham Watercourse Floodplain Management Plan* (2006) states that all controlled works would be considered for approval, except in the core wetland area where only stock refuge and infrastructure protection works would be considered. Outside of the core wetland area, stock refuges, infrastructure protection works and access roads may not require approval subject to meeting specified size and design requirements.

The *Moomin Creek Floodplain Management Plan* (2010) states that all controlled works would be considered for approval. Infrastructure protection works that meet conditions specified in the plan are exempt from approval.

Advertising requirements

In both existing plans, the floodway networks are the basis for assessing applications to construct controlled works. Controlled works proposed to be located inside the floodway network are assessed as non-complying and require advertising. Controlled works proposed to be located outside of the floodway network are generally assessed as complying and do not require advertising. Flood control works outside of the floodway network that trigger any issues in regard to the adopted assessment criteria are also assessed as non-complying and required advertising.

Assessment process/criteria for assessing flood-work applications

In the *Moomin Creek Floodplain Management Plan* (2010) and the *Lower Gingham Watercourse Floodplain Management Plan* (2006), flood control works located within floodways and outside delineated areas are assessed as non-complying works. Non-complying works require a detailed investigation of the hydraulic, environmental, social and economic impacts of the proposal. The cumulative impact of these proposals on flood characteristics is also required to be comprehensively addressed. In many cases applications for non-complying works will be refused or require the modification or removal of works.

Flood control works outside of the floodway network are assessed as complying if they do not trigger any issues in regard to the adopted assessment criteria. The landholder is required to provide the necessary supporting information to demonstrate the application is a complying work.

The assessment criteria for the two floodplain management plans are summarised in Table A3.1 and outlined in detail in Table A3.2.

Table A3.1: Summary of assessment criteria in current floodplain management plans in the Gwydir Valley Floodplain

Historical	Socio-economic	Ecological	Flooding
Old guidelines	Disruption to daily life	Wetland connectivity	Natural flooding characteristics
Concerns and objections	Health impact	Floodplain flora and fauna	Hydraulic capacity
	Cost of the works	Soil condition and structure	Pondage and flow duration
	Infrastructure damage	Fish passage	Redistribution
	Equity	Cultural sites	Flow velocities
	Land use and restrictions	Groundwater recharge	

Table A3.2: Assessment criteria used to assess flood control work applications in previous floodplain management plans

Assessment criteria	Detail (from Moomin Creek)	Difference in Lower Gingham Watercourse FMP (if any)
	Historical assessment criteria (for existing flood control works only)	
Old guidelines	Works that comply with the *Guidelines for Moomin Creek Floodplain Development* (WRC 1978) will typically be accepted, unless additional information and/or flood observations illustrate that the works have a significant adverse impact on flood flows	Additional reference to previous approvals will also be normally accepted. Reference to original *Carole Creek Guidelines* instead of *Moomin Creek*
Concerns and objections	Any ongoing objections from neighbouring landholders must be taken into consideration during the assessment process	The same
	Socio-economic assessment criteria	
Disruption to daily life	Unless previously agreed among all affected landholders, flood control works should not result in significant disruption to the daily life of surrounding landholders (e.g. property access)	No reference made to agreement between landholders being taken into consideration
Health impact	Flood control works should not impose potential negative health impacts or stress on surrounding landholders	The same
Cost of the works	The associated cost and benefit of undertaking the works should be warranted. In some cases it may be necessary to undertake a cost–benefit analysis (preliminary assessment may be adequate) in order to weigh up the hydraulic and/or environmental benefits of undertaking the works against the required expenditure. This must be determined through consultation with the affected stakeholders and DPI Water	The same
Infrastructure damage	Flood control works should not have detrimental impacts, including increases in peak flood levels and drainage times, on any individual landholder or on community infrastructure	The same
Equity	A landholder's development proposal should not limit the future potential of other landholders to develop: • all current landholders should be allowed a reasonable area of protection, depending on the flood pattern across their property. (This does not mean that all holdings will get an equal share of flood protection) • new landholders should be aware of previous agreements held between property holders regarding floodways, as these agreements should hold with changes in property ownership. The onus is on the new proprietor to understand the inter-property arrangements of mutual floodways (this is the 'buyers beware' principle). This is a legal issue and not one that the FMP attempts to cover; however, it is recommended that written proof regarding these agreements should be kept in case a legal issue arises.	Additional reference to some current landholders may only be allowed stock refuge areas depending on flood patterns on their properties.
Land use and restrictions	Past and current land uses are to be considered. This FMP does not control or limit land use, except where it is an important factor associated with 'flood-work control' approvals	Not in Lower Gingham FMP

Assessment criteria	Detail (from Moomin Creek)	Difference in Lower Gingham Watercourse FMP (if any)
	Ecological assessment criteria	
Wetland connectivity	Flood control works should not block or restrict natural flowpaths or floodways that supply wetland areas, nor alter the flooding regime to these areas	Additional reference to flood control works should not have a significant impact on the ecological character of Ramsar wetlands
Floodplain flora and fauna	Flood control works should not isolate flood-dependent ecosystems from flood flow. The potential impact on habitat availability and threatened species may need to be assessed.	Reference to flood-dependent stands of vegetation instead of ecosystems.
Soil condition and structure	Flood control works should not impose negative impacts on soil structure or condition. For example, works should not increase the potential for scour and erosion and should not block flow to significant areas of floodplain soils	The same
Fish passage	Flood control works should not significantly block or restrict the free passage and migration of fish within the floodplain environment	The same
Cultural sites	Unless an agreement has been reached with DECCW and the local Aboriginal Land Council, flood control works should not destroy or damage any Aboriginal site or relic and should not block or restrict the delivery of flood flows to historically scarred and carved trees that rely on flooding regimes	The same
Groundwater recharge	Flood control works should not block or restrict flood flow to identified groundwater recharge areas	Not in Lower Gingham FMP
	Flooding assessment criteria	
Natural flooding characteristics	Flood control works should not result in a significant departure from the natural flooding pattern of the floodplain (after taking into account existing floodplain development)	In principle, the same. Reference to maintain the natural flooding and drainage pattern of the floodplain. No reference to taking account of existing floodplain development
Hydraulic capacity	Flood control works should not reduce the hydraulic capacity and continuity of floodway areas, but should enable the orderly passage of floodwaters through the floodplain	The same
Pondage and flow duration	Flood control works should not significantly affect pondage duration on the developed floodplain or cause flood peak travel time to unduly accelerate to downstream users	The same

Assessment criteria	Detail (from Moomin Creek)	Difference in Lower Gingham Watercourse FMP (if any)
Redistribution	Acceptable increases in peak flood levels and percentage peak flow redistribution, as a result of flood control works, should be assessed against the following guideline values: • increase in peak levels on a neighbour's boundary to be a maximum of 0.2 m above pre-development levels • no significant redistribution of peak discharge (less than 5% of the pre-development redistribution) Each case should be assessed individually against the above guideline values; a more satisfactory outcome may be achieved by holding discussions with all affected landholders. Applications for works that exceed the above redistribution guidelines will be considered as non-complying works and must be subject to the Part 8 approval application process. Such works will generally not be approved unless an agreement has been reached between the applicant, DPI Water and downstream landholders and the relevant environmental criteria have been met	Change to guideline values: • increase in flood levels on a neighbours boundary be a maximum of 0.15 m • no significant redistribution of the peak discharge – less than 2% for individual works and 5% cumulative be used to guide the assessment of propose or existing flood control works
Flow velocities	Flood control works should not significantly increase velocities of flood flow within floodways. Velocities should be an order that does not significantly increase erosion and siltation under various land uses. As a general rule, and using the figures below as the maximum/limiting flow velocities, velocities should not increase by more than 50% from the pre-development flow velocities. Maximum permissible velocity (m/s) for the following ground conditions are: • bare soil – 0.4 • crop – 0.6 • native tussocky grass – 0.8.	The same

First generation: rural floodplain development guidelines (non-statutory)

Rural floodplain development guidelines cover approximately 17% (189,000 ha) of the Gwydir floodplain. The guidelines were not statutory documents and were developed for issue to landholders. They outline a system of floodways which should remain unobstructed by any future development. The guidelines suggest areas which could be protected from flooding by levees, should the landholders concerned desire. Considerable flexibility existed in locating the floodways on individual properties; however, it was generally recommended to not affect inlet and outlet conditions at upstream and downstream property boundaries. DPI Water could use the information contained in the guidelines to assist with their assessment of flood control work development applications.

Floodplain management principles

The planning of guidelines was based upon the following principles (Burton et al. 1997):

- the proposed system of floodways should conform as closely as was reasonably possible to the natural drainage pattern
- the area of flood-protected land should be maximised, provided that no other properties were adversely affected as a result
- all floodways should be maintained in a clear condition, free of obstructions but could, where possible, be sown to grain crops
- existing levees and banks extending across the direction of flow and causing an undesirable redistribution of floodwaters should be reduced to ground level
- floodways should discharge as closely as practicable to the location of natural floodways
- the exit of floodwater from floodways should be at rates and depths similar to those which would be experienced under natural conditions
- local drainage should be the responsibility of individual landholders.

Ecological and cultural heritage considerations

By maintaining the flow paths as naturally as possible, it was generally accepted that flood-dependent ecological and cultural assets were adequately considered. Floodways were arranged to include various swamps.

Floodway networks

The guidelines suggest areas which could be protected from flooding by levees, should the landholders concerned desire to do so.

Hydraulic models

Hydraulic calculations were used to determine if the capacity of the floodways was consistent with flow distribution and of an adequate width to maintain the passage of floodwater through the area.

Design flood events

Design flood events were generally the largest historic flood at the time the guideline was prepared.

Assessment process/criteria for assessing flood-work applications

The guidelines did not contain assessment criteria to be used by DPI Water licensing staff.

Types of controlled works considered for approval

The guidelines did not put restrictions on the types of flood works that would be considered for approval. Nor did the guidelines specify that any flood works would be exempt from needing an approval.

Advertising requirements

The guidelines did not contain advertising requirements to be used by DPI Water licensing staff. All flood-work applications would require advertising in guideline areas in accordance with Part 8 of the WA 1912.

Outcomes from flood studies

Phase B of the Draft Biniguy to Moree Flood Risk Management Study Preliminary Floodplain Management Study was prepared in May 2005 and is not a legal document. This study was not progressed into a floodplain management plan because the *Healthy Floodplains Project* was initiated and the information was intended to be included in the floodplain management plan for the Gwydir Valley Floodplain. However, it evaluates management options in consideration of social, environmental and economic factors to be able to address existing and future flood risk and flood management issues.

Floodplain management principles

See second generation – rural floodplain management plans.

Ecological and cultural heritage considerations

Areas of ecological and cultural significance were identified and considered when mapping the draft floodway network.

Floodway networks

A floodway network was delineated as part of the study.

Hydraulic models

The *Draft Biniguy to Moree Flood Risk Management Study* utilised a one-dimensional MIKE11 model that extended from the Gwydir River at Gravesend Road Bridge Gauge downstream to beyond Tyreel Regulator. The model included the anabranches of the Mehi River and Carole Creek as well as other major breaks. The floodplain was represented by a complex network of floodways between the main branches and included inflow from a number of tributaries such as Mosquito, Slaughterhouse and Mia Mia Creeks.

Design flood events

The design flood used was the 1976 flood.

Assessment process/criteria for assessing flood-work applications

The hydraulic, socio-economic and ecological assessment criteria adopted for the Moomin Creek Floodplain Management Plan were recommended to be used for the Biniguy to Moree area. See second generation rural floodplain management plans for further details. The study does not outline an intention to restrict the types of flood works that would be considered for approval. Nor does the study propose for certain flood works to be exempt from needing an approval.

Advertising requirements

See second generation rural floodplain management plans.

Area not covered by an existing management measure

The area not covered by existing management measures was approximately 72% (824,000 ha) of the Gwydir floodplain. This area can be split into areas that were:

- part of the previous designated Gwydir floodplain
- part of the designated Lower Namoi floodplain
- not designated as part of a floodplain.

Flood-work applications for areas not covered by an existing management measure that were part of a designated floodplain would have been assessed under Part 8 of the WA 1912.

Areas not designated as part of a floodplain were also covered by Part 8. Amendments to Part 8 of the WA 1912 were introduced in 1999 to allow works in these areas to be assessed if the work could potentially affect flood flow into and out of a stream and affect flooding. Section 166C of the WA 1912 provides guidelines for the assessment of such works.

In these areas, all flood-work applications would have been considered for approval and there were no exemptions.

168B 3b of the WA 1912: A controlled work is to be assessed as a non-complying controlled work if the controlled work is situated or proposed to be constructed in an area that is not the subject of a floodplain management plan.

Appendix 4: Flood frequency analysis

A flood frequency analysis for gauging stations throughout the Gwydir valley was undertaken to assist with predicting design floods for the valley plan. The technique involved using observed peak flow (flood volume) data to calculate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. These statistical data were then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various flows as a function of recurrence interval or exceedance probability.

Annual flood series were used as data inputs because the values will likely be independent and the series can be easily extracted (IEA 1987). The annual flood series comprises of the highest instantaneous rate of discharge in each year of record.

Annual flood series were obtained from six gauging stations throughout the Gwydir valley. These stations were chosen based of their location, length of observed record and the measure of reliability (Table A4.1).

The gauges at Gravesend and Pallamallawa were chosen because they are located in the upper part of the study area and have a long period of record. The Pallamallawa gauge is also downstream of the major tributaries of the Gwydir River and above the offtake of the first major distributary, the Mehi River. It is the gauging point at which the highest flows in the Gwydir River are recorded (CSIRO 2007). The Yarraman and Moree gauges were selected because they measure inflows to the Gwydir Wetlands. The Clarendon Bridge gauge was selected because it captures flows from Gurley Creek while the Gingham Bridge gauge is located in the lower portion of the wetlands.

Table A4.1: Details of selected gauging stations within the Gwydir valley

Station no.	Name	Period of annual flow series	No. of years	% of gauged flows
418013	Gwydir R. at Gravesend	1946-2012	67	52
418001	Gwydir R. at Pallamallawa	1973-2012*	40	70
418004	Gwydir R. at Yarraman	1971-2012*	42	62
418002	Mehi R. at Moree	1978-2012	35	55
418067	Moomin Ck at Clarendon Br.	1994-2012	19	60
418079	Gingham at Gingham Br.	1998-2012	15	65

* floods prior to 1976 were not adjusted for mitigation impacts of Copeton Dam

A Log-Pearson Type III distribution was fitted to annual series of flood peaks for each of the gauges. A Log-Pearson Type lll distribution is biased by low flows so these were removed from the analysis to improve the fit. An expected probability adjustment was also made using the procedure set out in Australian Rainfall and Runoff (ARR 1998) as the recorded flood peaks are only a small sample of peaks that actually occur over a longer duration. ARR 1998, recommends implementing the expected probability adjustment to remove bias from the estimate. The resulting frequency curve along with the 90 per cent confidence limits is shown in Figure A4.1.

The annual flow series for each calendar year was obtained from either published reports or extracted from *Hydstra* (time series data management system). Gaps in the annual series were filled by first checking the daily flow record of an upstream gauge for a major flow event over the gap period. If no flow event occurred, it was assumed that the highest recorded peak was the highest peak for that year.

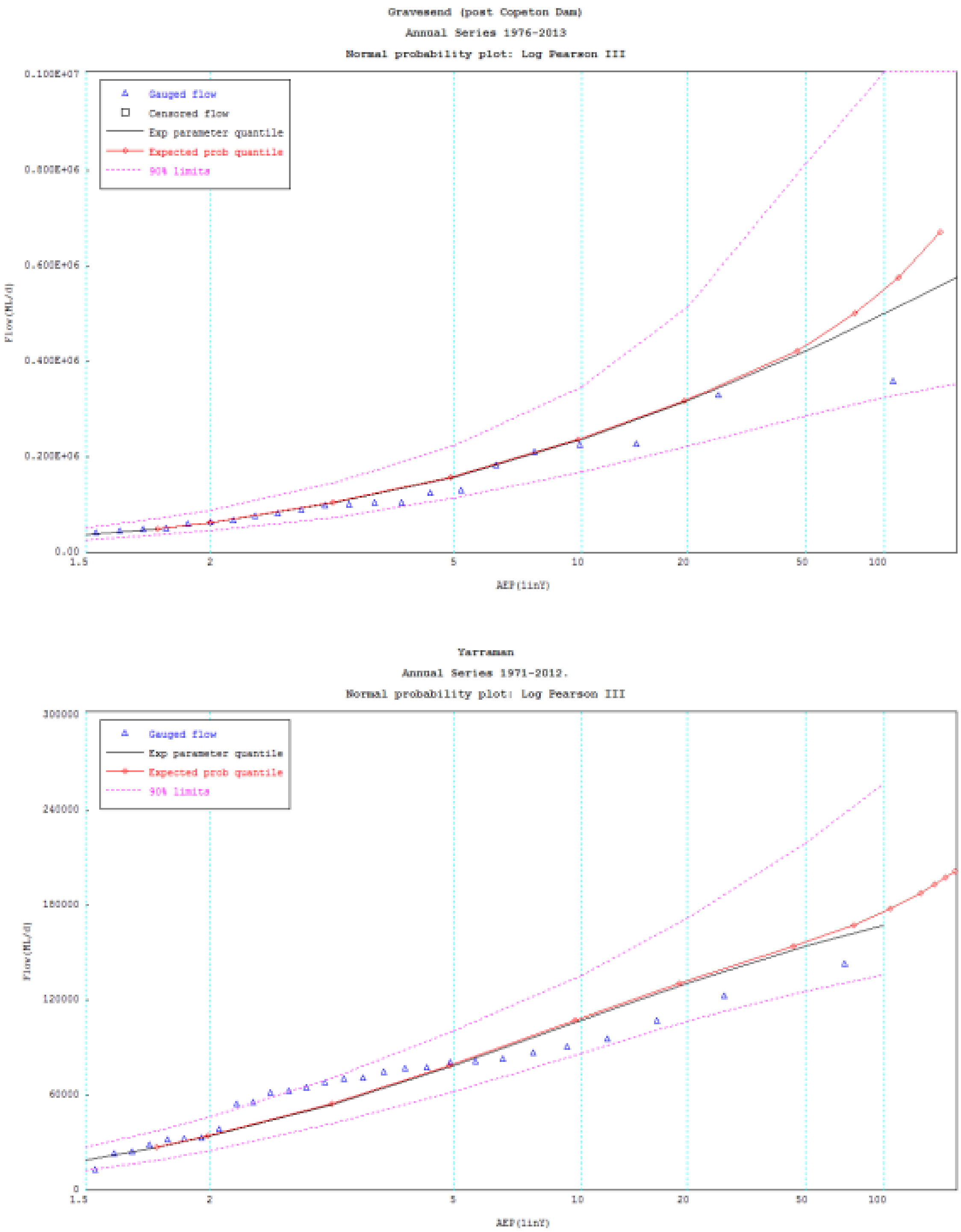
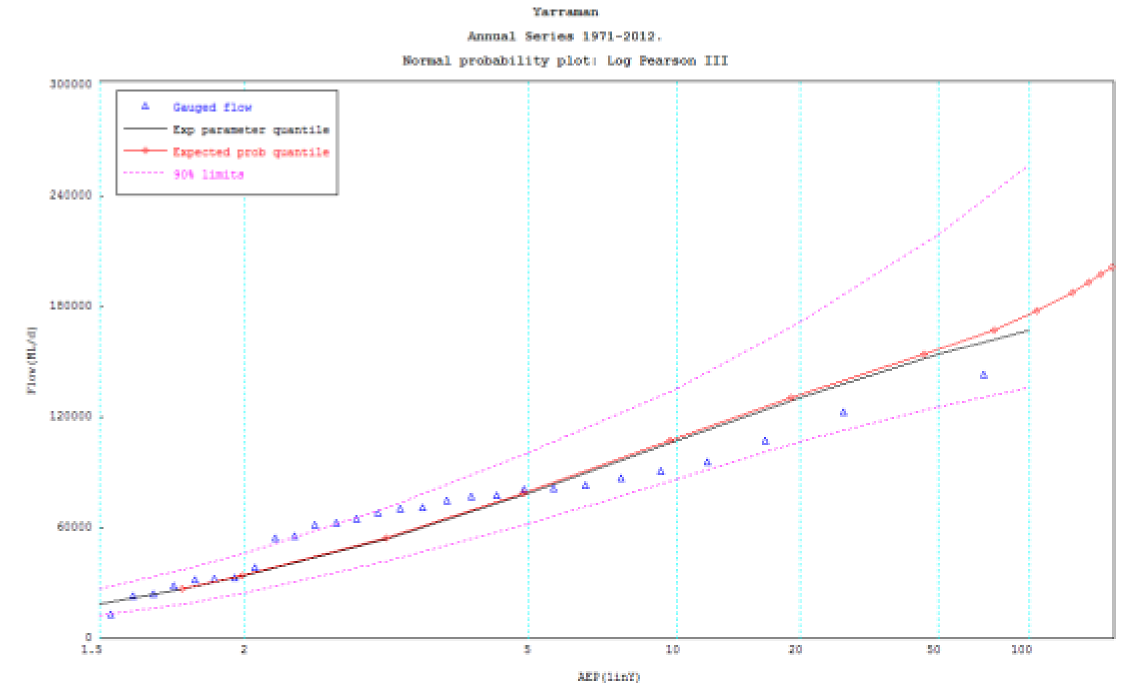


Figure A4.1: Flood frequency curves for Gravesend (post Copeton Dam) and Yarraman

A flood frequency analysis was also undertaken on flood volumes at Yarraman to demonstrate that the annual exceedance probability (AEP) of floods may vary depending on whether it is calculated using peak discharge or flood volume. Table A4.2 and Figure A4.2 show that the 2012 flood event had one of the highest peak discharges on record at Yarraman with an AEP of one in 70; however, the 2012 flood volume was significantly smaller when compared to other floods at Yarraman as it only had a one in six AEP. The 2004 flood event at Yarraman had similar AEPs for both peak discharge and flood volume.

Table A4.2: Comparison of AEPs derived from discharge and volume for selected floods at Yarraman

Type	Flood AEP (1 in Y)			
	1976	2004	2011	2012
Discharge (ML/d)	16	4	9	70
Volume (ML)	26	3	11	6



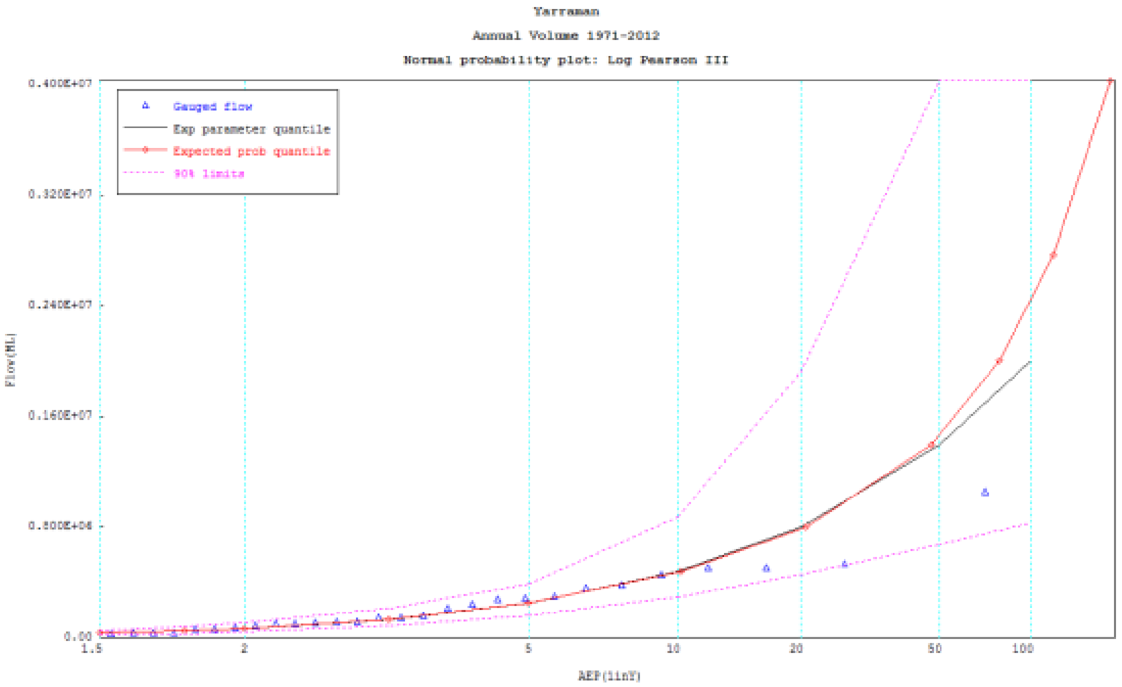


Figure A4.2: Comparison of flood frequency plots derived from peak discharges and flood volumes at Yarraman

Appendix 5: Availability of stream flow data

Stream flow data is available from 44 gauging stations in the Gwydir floodplain that are run and operated by DPI Water (Table A5.1). There are another three gauging stations run and operated by DPI Water that are located within one kilometre of the floodplain boundary (Table A5.1). There are 15 additional DPI Water-operated gauging stations that have since been disconnected (Table A5.1). Flow measurements in the Gwydir floodplain commenced in 1929 on the Gwydir River at Yarraman Bridge (Table A5.1).

Table A5.1: Forty-seven DPI Water gauging station sites have operated in the Gwydir floodplain (with a 1 km buffer)

Site	Site name	Commence	Cease
418004	GWYDIR RIVER AT YARRAMAN BRIDGE	1/08/1929	N/A
418011	CAROLE CREEK AT D/S REGULATOR(BELLS CROSSING)	28/06/1939	N/A
422018	GRAWAN CREEK AT OLD POCKATAROO	19/06/1965	N/A
416027	GIL GIL CREEK AT WEEMELAH	30/03/1968	N/A
418036	GWYDIR RIVER D/S BOOLOOROO WEIR	26/07/1972	N/A
418037	MEHI RIVER AT D/S COMBADELLO WEIR	27/07/1972	N/A
418062	MOOMIN CREEK AT OFFTAKE	27/07/1972	N/A
418043	GWYDIR RIVER AT TAREELAROI WEIR-STORAGE GAUGE	5/05/1976	N/A
418044	MEHI RIVER D/S TAREELAROI REGULATOR	5/05/1976	N/A
418042	GWYDIR RIVER AT D/S TAREELAR0I WEIR	20/10/1976	N/A
418049	MALLOWA CREEK AT REGULATOR	3/05/1977	N/A
418046	MALLOWA CREEK AT KAMILAROI WEST	3/05/1977	N/A
418059	MEHI RIVER U/S GUNDARE REGULATOR	17/05/1977	N/A
418047	MEHI RIVER AT COMBADELLO WEIR-STORAGE GAUGE	20/06/1977	N/A
418061	MOOMIN CREEK AT ALMA BRIDGE (DERRA ROAD)	16/11/1978	N/A
418058	MEHI RIVER AT BRONTE	21/11/1978	N/A
418051	GWYDIR RIVER AT BOOLOOROO WEIR-STORAGE GAUGE	25/01/1979	N/A
418053	GWYDIR RIVER AT BRAGEEN CROSSING	7/05/1980	N/A
418055	MEHI RIVER AT NEAR COLLARENEBRI	11/06/1980	N/A
418052	CAROLE CREEK AT NEAR GARAH	9/07/1980	N/A
418060	MOOMIN CREEK AT GLENDELLO	23/03/1984	N/A
418063	GWYDIR RIVER (SOUTH ARM) AT D/S TYREEL OFFTAKE REGULATO	10/09/1985	N/A
416051	MACINTYRE RIVER AT YARROWEE	2/03/1987	N/A
416052	GIL GIL CREEK AT GALLOWAY	27/05/1987	N/A
418065	GWYDIR RIVER AT TYREEL STORAGE GAUGE	12/06/1987	N/A
418066	GWYDIR RIVER AT MILLEWA	2/06/1988	N/A
418067	MOOMIN CREEK AT CLARENDON BRIDGE (HEATHFIELD)	2/06/1988	N/A

Site	Site name	Commence	Cease
418068	MEHI RIVER AT U/S BALLIN BOORA CREEK	2/06/1988	N/A
418070	MOOMIN CREEK AT MOOMIN PLAINS	21/03/1994	N/A
416054	GIL GIL CREEK AT BOOLATAROO	5/12/1996	N/A
418077	GINGHAM CHANNEL AT THE WATERHOLE	8/04/1997	N/A
418078	GWYDIR RIVER AT ALLAMBIE BRIDGE	8/04/1997	N/A
418074	GINGHAM CHANNEL AT TERALBA	9/04/1997	N/A
418079	GINGHAM CHANNEL AT GINGHAM BRIDGE	6/05/1997	N/A
418076	GINGHAM CHANNEL AT TILLALOO BRIDGE	8/05/1997	N/A
418080	BIG LEATHER WATERCOURSE AT WOODBINE	13/05/1998	4/07/2001
418081	GINGHAM CH AT WOODLANDS ROAD	14/05/1998	4/07/2001
418082	LOWER GWYDIR RIVER AT CAIDMURRA BRIDGE	14/05/1998	4/07/2001
418083	GINGHAM CHANNEL AT WETLANDS ROOKERY	2/08/2000	N/A
418085	MEHI RIVER D/S GUNDARE REGULATOR #2	21/11/2002	N/A
41810034	Big Leather @ Old Dromana	2/03/2005	N/A
41810036	Big Leather @ Troy	2/03/2005	N/A
41810038	Gingham Channel @ Crinolyn	3/03/2005	N/A
41810041	Big Leather @ Homebush	3/03/2005	N/A
418086	CAROLE CREEK AT MIDKIN CROSSING (DS MARSHALLS PONDS)	6/10/2005	N/A
418087	MEHI RIVER AT CHINOOK	23/05/2006	N/A
418001	GWYDIR RIVER AT PALLAMALLAWA		N/A

Appendix 6: RORB model building and calibration

Tycannah Creek catchment was a gauged catchment selected to calibrate the RORB model so that the parameters could be transferred to the ungauged catchments. Tycannah Creek catchment was selected because it:

- gauged and has a good period of streamflow data
- similar to ungauged catchments
- is in close proximity to ungauged catchments.

Catchment delineation

Tycannah Creek was delineated into 20 sub-catchments using the Shuttle Radar Topography Mission (SRTM) 30 m Digital Elevation Model (DEM). The process was in accordance with the guidelines within the RORB user manual with regard to the size of catchment areas, branching and the location of gauging stations. The catchment outlet was defined as the junction with the Mehi River.

The catchment area of Tycannah Creek was estimated to be 1037 km^2. Stream lengths and the location of sub-catchment centroids were estimated using ArcGIS.

Daily rainfall data

Daily rainfall stations were selected if they were active during the calibration period and in an appropriate location. The only daily rainfall stations active during the calibration period were located just outside of the catchment and are shown in Table A6.1. All rainfall data was obtained from the Bureau of Meteorology. The daily rainfall totals were taken each day at 9:00 am.

It was found that rainfall total for a range of storm events was non-uniform over the catchment. For this reason, it was decided to Thiessen weight the rainfall stations to improve the estimation of rainfall on each sub-catchment.

Table A6.1: Details of rainfall used in calibration

Station no.	Name	Period of record
053115*	Moree Aero	1995 – 2013
054014	Bingara (Derra Derra)	1899 – 2006
054090	Bingara (Pallal)	1999 – 2013
054125	Caroda (Roseberry Park)	1967 – 2013

* this is an automatic weather station

Hourly rainfall data

No hourly rainfall (or intensity) stations were located within the catchment. The closest pluviometer station was located at Moree Aero (053115) which is approximately 50 km from the centroid of Tycannah Creek catchment.

Moree Aero is an automatic weather station and is owned by the Bureau of Meteorology. The station measures rainfall every half an hour.

Due to the lack of pluviometer stations within the catchment, daily rainfall from appropriate stations was converted to three hour pluviometer data using the temporal pattern from the Moree Station. Hence, it was assumed that the rainfall recorded at each daily recording station followed the temporal pattern recorded at the Moree pluviometer.

Flow data

Tycannah Creek at Horseshoe Lagoon (GS 418032) is a gauging station located approx. 10 km downstream from the centroid of the catchment. This gauge is owned and operated by DPI Water and has a period of record from 1971–2013; however, hourly flow data is only available from 1979 onwards. The rating of the gauge was recently revised after several high flow gaugings (approx. 1 m above top of bank) were undertaken during the 2012 flood. Flows at GS 418032 are now gauged to 58 % of flows.

A large number of floods have been recorded at Tycannah Creek at Horseshoe Lagoon. The hydrographs of these floods and their peak discharge are shown Figure A6.1 and Table A6.2.

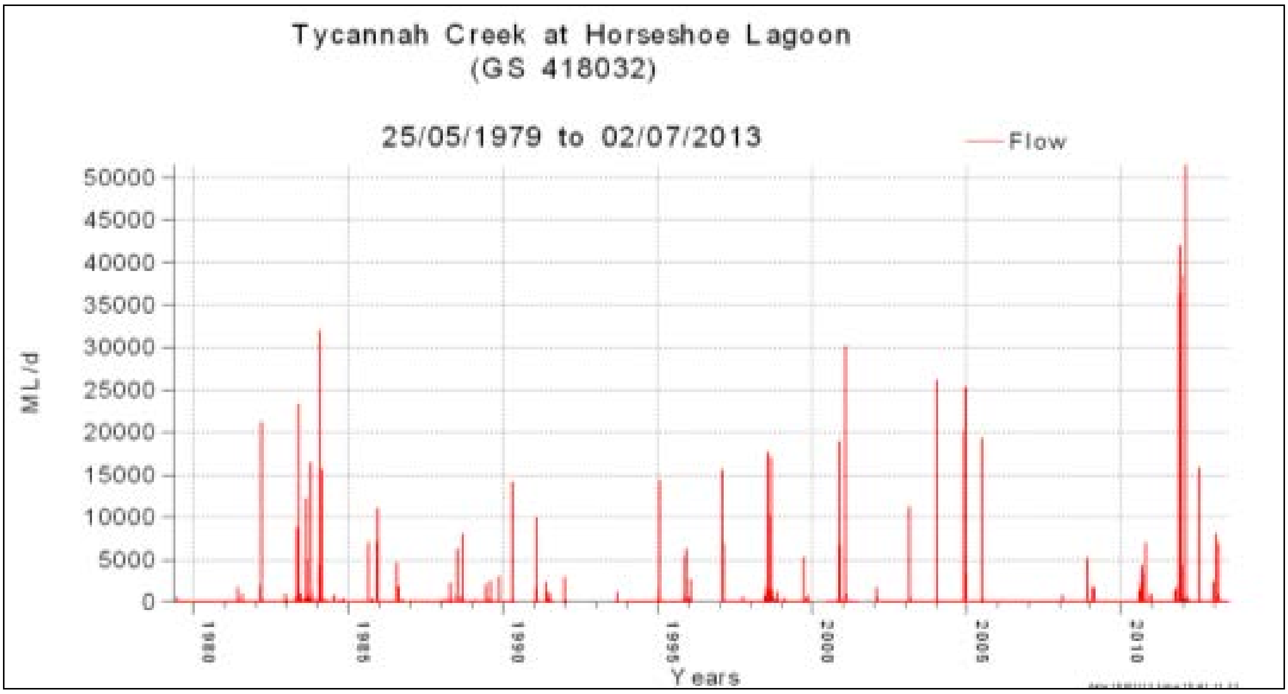


Figure A6.1: Observed floods at Tycannah Creek at Horseshoe Lagoon

Table A6.2: Details of observed floods at Tycannah Creek at Horseshoe Lagoon

Flood rank	Date	Peak discharge (m^3/s)
1	Feb 2012	600
2	Nov 2011	490
3	Dec 2011	450
4	Jan 1984	370
5	Jan 2001	350
6	Jan 2004	300
7	Dec 2004	290
8	May 1983	270
9	Mar 1982	250
10	July 2005	220

RORB input files

The RORB input files were divided into catchment and storm files for each event. The catchment files contain all the data pertaining to the catchment including:

- sub-catchment areas, layout and impervious fraction
- stream length and channel type
- gauging station location
- storage information.

The storm file provides the program with information on the rainfall across the catchment. This data includes:

- rainfall depths and temporal distributions over the catchment
- time steps and model duration
- number of rainfall bursts.

Calibration results

Calibration of the model was undertaken to determine the appropriate parameter values for k_c (dimensional coefficient), m (dimensionless exponent), initial loss and continuing loss. The parameter k_c is related to the time delay of the flood routing and m defines the non linearity of the catchment. Initial and continuing losses determine the rainfall excess of the storm. Parameter values were varied based on accepted values of the parameters to produce a good fit between gauged and modelled flows. The values for k_c were based on the default equation in the RORB manual (Laurenson 2010) and catchment area. The parameter m was maintained at the recommended value of 0.8. The calibration sought to achieve a consistent k_c and continuing loss for the model but the initial loss was varied for individual storms.

Model calibration was based on the three largest floods over the period of record. Two of these floods occurred during a very wet period in late 2011 and early 2012. The largest calibration event was the 2012 flood that resulted in a peak discharge of approx. 600 m^3/s. The other two calibration events occurred in November 2011 and December 2011 with peak discharges of 490 m^3/s and 420 m^3/s respectively. Rainfall and flow data was collected for all events.

February 2012

On 31 January 2012 there was a significant rainfall event over Tycannah Creek catchment and the surrounding area. The catchment was significantly wet due to receiving above average rainfall in the preceding three months. From midnight on 31 January to 9 am on 3 February a total of 192 mm of rainfall was record at Moree Aero, however, significantly higher rainfalls were received in other gauges. Daily rainfall depths from the closest gauges to the catchment were reviewed and summarised in Table A6.3. It is noted that the rainfall totals were not uniform over the study area as there was a 100 mm total rainfall difference between Moree Aero and Bingara (Pallal). The Bingara gauge is located to the west of the Nandewar Range which runs from north to south and separates Bingara from the Tycannah Creek catchment. Rainfall west of this range is typically lower due to rainfall events being associated with frontal systems that move from east to west.

Table A6.3: Rainfall depths and stations for February 2012 storm

Rainfall station	Station no.	Rainfall total (mm)
Moree Aero	053115	192
Bingara (Pallal)	054090	293
Caroda (Roseberry Park)	054125	252

For this storm event, a single pluviometer station was available at Moree. Moree is a significant distance from the centroid of the catchment so appropriate daily rainfall stations were selected and converted to “pluviometer stations” using the temporal pattern from the Moree Station.

The catchment was reasonable wet prior to the commencement of this storm event. Consequently, a baseflow of approx. 1 m^3/s was present in the observed hydrograph. This baseflow was removed from the observed hydrograph prior to calibration.

A timestep of three hours was used for the calibration of the February 2012 flood. This was due to the time of rise of the hydrograph being approx. 10-15 hours.

A k_c of value of 70.9 and m value of 0.8 was selected to best fit the general shape of the hydrograph.

The model was run in the FIT mode which, based on the initial loss, calculated the continuing loss to ensure equal volumes for the gauged and modelled flows. An initial loss of 25 mm and continuing loss of 2.32 mm/hr was determined to be appropriate for this event.

The model was matched to the first peak flow of 501 m^3/s however, there was a significant difference between the observed and modelled second peak flow. The difference was probably due to data errors such as flow recording errors, rainfall variability and baseflow separation errors. The plot of the gauge flows to modelled flows from RORB is shown in Figure A6.2.

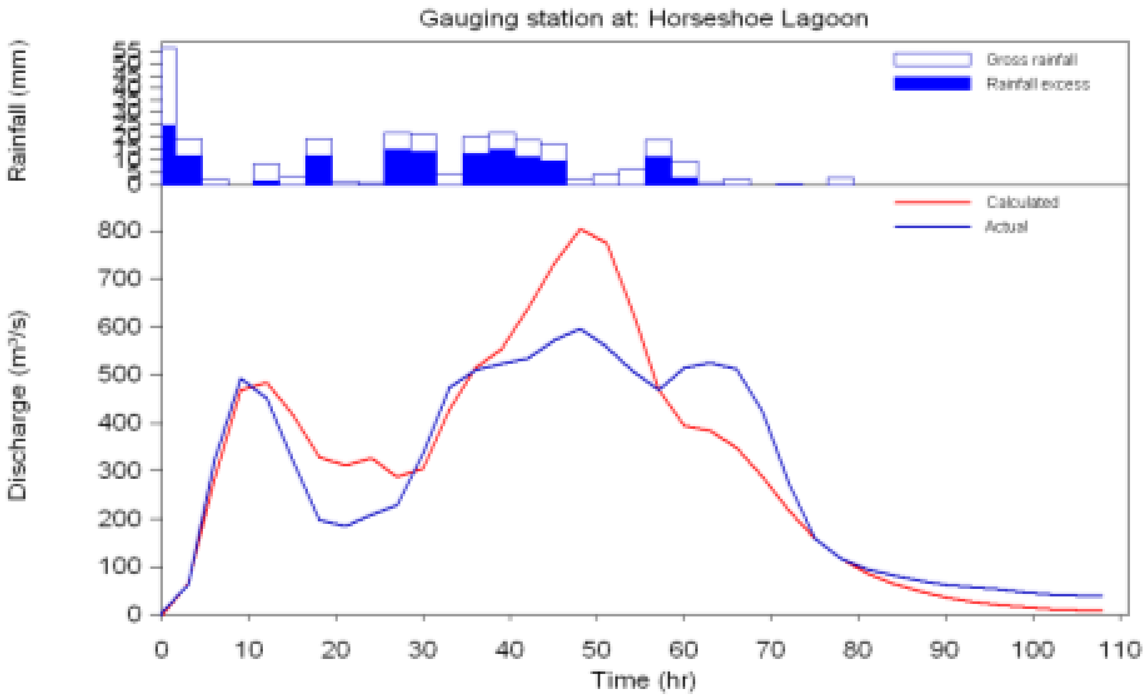


Figure A6.2: Hyetograph and calibrated hydrograph for the February 2012 flood event November 2011

The November 2011 storm occurred over three days with significant rainfalls across the catchment. The catchment had received very little rain (< 10 mm) in the five weeks prior to this event. Consequently, the catchment was dry and there was no baseflow present.

The storm commenced on the morning of 23 November 2011 and Tycannah Creek peaked at noon on 26 November 2011. A timestep of three hours was used for the calibration of this event. The model was constructed with a single rainfall burst. Moree had the only pluvio data for the area so daily rainfall totals at Bingara and Caroda were converted to three hourly data using the temporal pattern from the Moree Station. The total rainfall depths around the catchment for this event are shown in Table A6.4.

Table A6.4: Rainfall depths and stations for November 2011 storm

Rainfall station	Station no.	Rainfall total (mm)
Moree Aero	053115	221
Bingara (Pallal)	054090	232
Caroda (Roseberry Park)	054125	220

Rainfall across the catchment was reasonably uniform with rainfall totals of around 230 mm. This is uncommon for storm events in this area.

An m value of 0.8 and kc value of 70.9 was selected to best fit the general hydrograph shape. The calibrated initial loss was 59 mm and continuing loss 2.76 mm/hr. The plot of the calibrated hydrograph is shown in Figure A6.3.

The rise and fall of the modelled hydrograph matched well to the observed. The timing of the hydrographs also matched well; however, the gauged peak was 15 % less than the modelled hydrograph. This result was most likely due to errors in the adjusted pluviometer data.

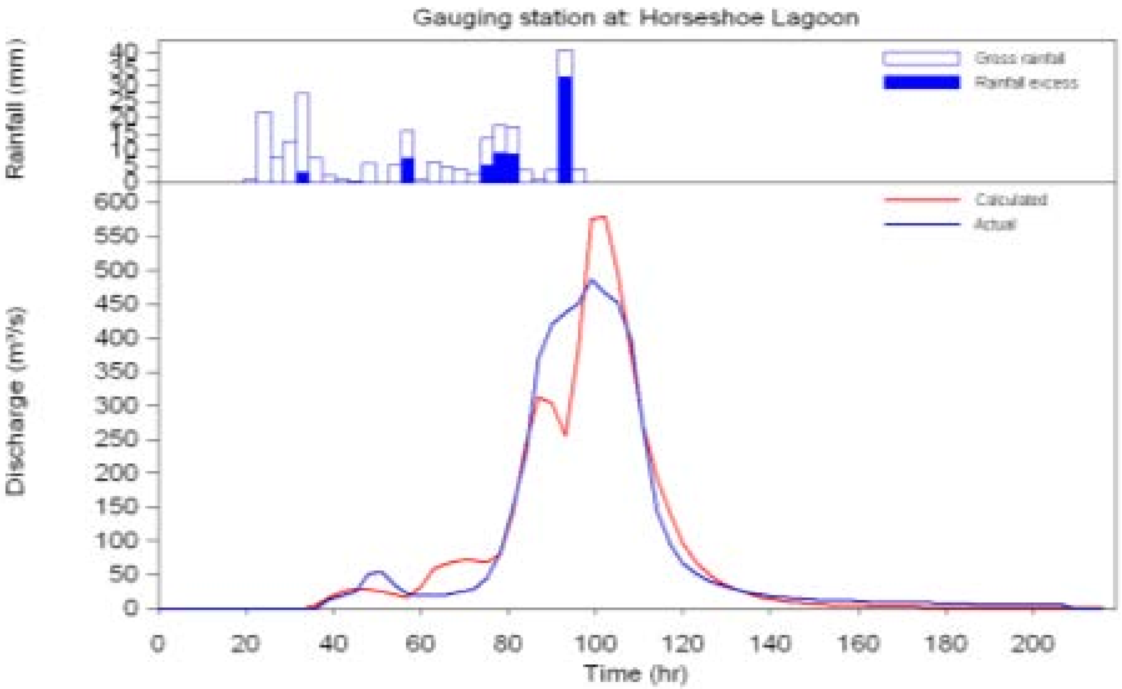


Figure A6.3: Hyetograph and calibrated hydrograph for the November 2011 flood event

December 2011

The December 2011 storm occurred over a week with over 100 mm of rain falling over the catchment. The storm commenced during the afternoon of 5th December and finished in the morning of 12 December. In the fortnight preceding this storm, there was over 230 mm of rainfall over the catchment. Consequently, the Tycannah Creek catchment was saturated prior to this storm event.

A baseflow of 2 m^3/s was present at the time of the storm event. This baseflow was subsequently removed for the hydrograph prior to the calibration process.

A time step of three hours was used for the calibration of the December 2011 event. The Moree pluviometer was the only station that was available for this event so daily rainfall totals at Bingara and Caroda were converted to three hourly data using the temporal pattern from the Moree Station. The model was constructed with a single rainfall burst. The sub-catchment rainfall depths and temporal patterns were assigned to the closest station to the centroid of the sub-catchment. Rainfall depths were theissen weighted and applied to each of the sub-catchments. The rainfall depths for the December 2011 storm are shown in Table A6.5.

Table A6.5: Rainfall depths and stations for December 2011 storm

Rainfall station	Station no.	Rainfall total (mm)
Moree Aero	053115	101
Bingara (Pallal)	054090	119
Caroda (Roseberry Park)	054125	151

Rainfall over the catchment was non-uniform over the catchment with daily rainfalls varying from approx.150 mm at Caroda to 100 mm to the west at Moree.

RORB is a rainfall run-off model that converts rainfall excess to run-off. For reason, it is necessary to remove any baseflow from the hydrograph prior to calibration. A baseflow of approx. 2.3 m^3/s was identified immediately before the commencement of this storm event. Hence, this baseflow was removed from the observed hydrograph prior to calibration.

An m value of 0.8 and kc value of 70.9 was selected to best fit the observe hydrograph shape. The catchment was saturated prior to the commencement of the December storm event and consequently, an initial loss of 0 mm/hr and continuing loss of 3.86 mm/hr was determined during the calibration process.

The rise and peak of the modelled hydrograph matched very well to the observed hydrograph. The timing of the hydrographs also matched well with the modelled peak occurring only 3.6 hr after the observed peak. The plot of the calibrated hydrograph is shown in Figure A6.4.

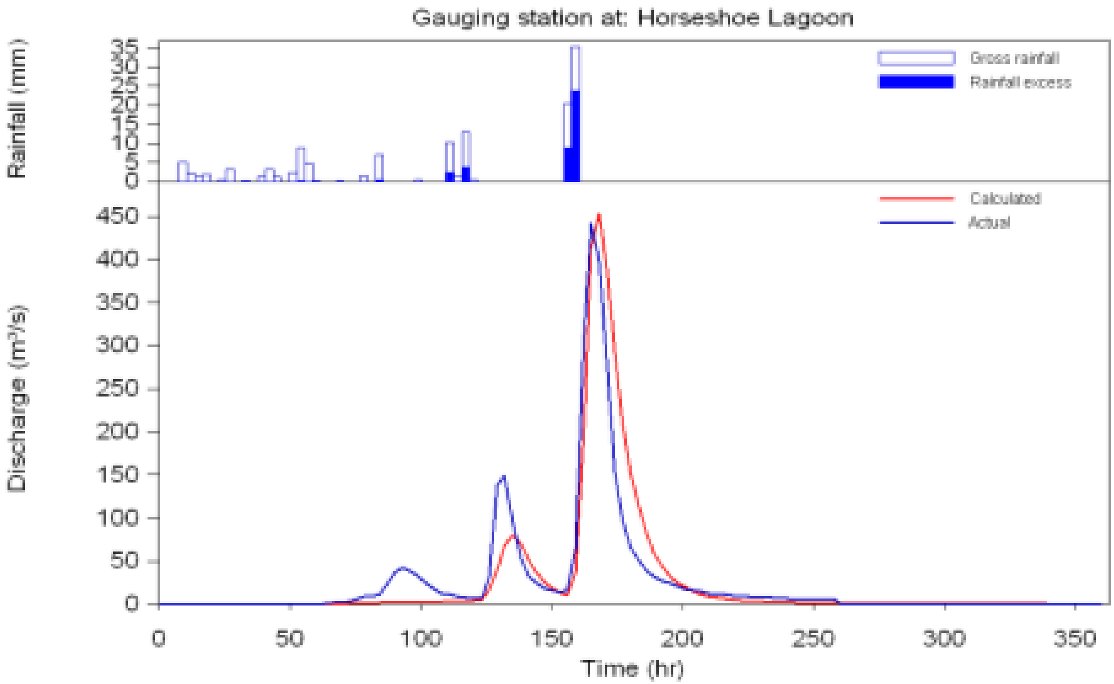


Figure A6.4: Plot of calibrated hydrograph

Appendix 7: Details of ungauged modelled inflows

Gil Gil Creek

Gil Gil Creek was divided into five separate areas (Figure A7.1). Each area was delineated into sub-catchments using the Shuttle Radar Topography Mission (SRTM) 30 m DEM. The catchment delineation was in accordance with the guidelines in the RORB user manual. Table A7.1 shows the number of sub-catchments and total areas.

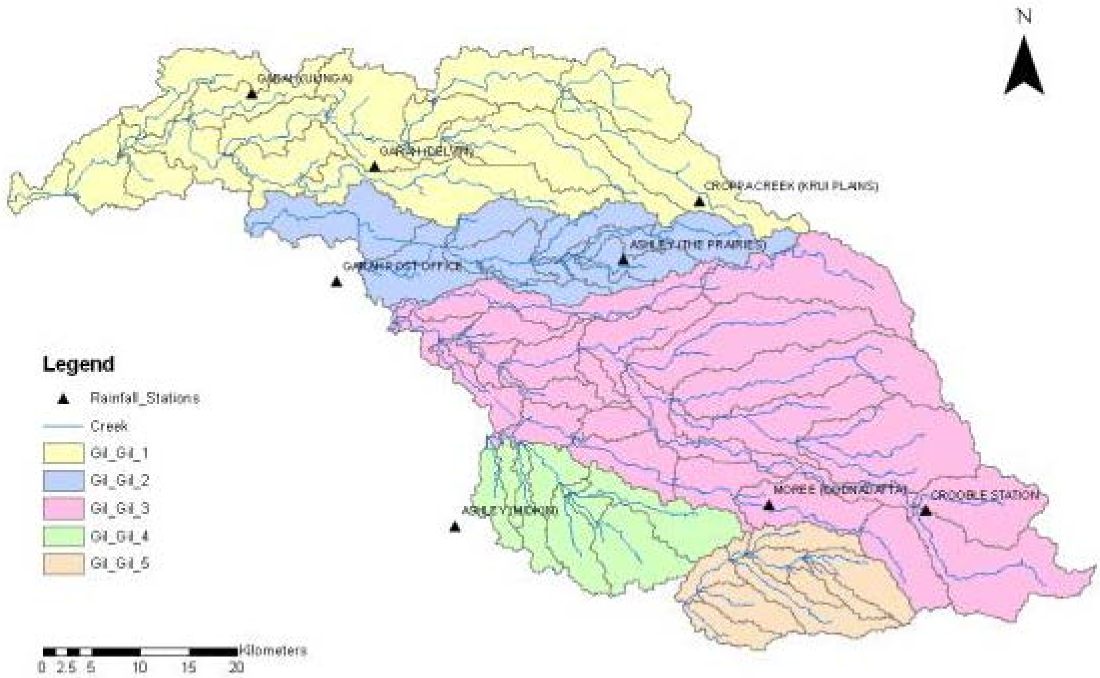


Figure A7.1: Gil Gil RORB sub-catchments and location of rainfall stations

Table A7.1: Details of sub-catchment areas used in models

Model	No. of sub-catchments	Area (km^2)
Gil Gil 1	17	934
Gil Gil 2	11	380
Gil Gil 3	24	1372
Gil Gil 4	8	261
Gil Gil 5	10	222

Table A7.2: Details of rainfall stations used in the Gil Gil Creek model

Model	Rainfall station	Station no.	Period of record
Gil Gil 1	Garah (Ulinga)	053042	1936 – 2012
	Garah (Delvin)	053085	1967 – 2012
	Croppa Creek (Krui Plains)	053018	1914 – 2013
Gil Gil 2	Garah PO	053011	1906 – 2013
	Ashley (The Prairies)	053040	1928 – 2011
Gil Gil 3	Croppa Creek (Krui Plains)	053018	1914 – 2013
	Crooble Station	054124	1967 – 2013
Gil Gil 4	Ashley (Midkin)	053020	1906 – 1978
	Moree (Oodnadatta)	053116	1994 – 2012
Gil Gil 5	Moree (Oodnadatta)	053116	1994 – 2012
	Crooble Station	054124	1967 – 2013

Thalaba Creek

Thalaba Creek has a catchment area of was delineated into 20 sub-catchments using the Shuttle Radar Topography Mission (SRTM) 30 m DEM (Figure A7.2). The catchment delineation was in accordance with the guidelines in the RORB user manual. Table A7.3 shows the area for each sub-catchment.

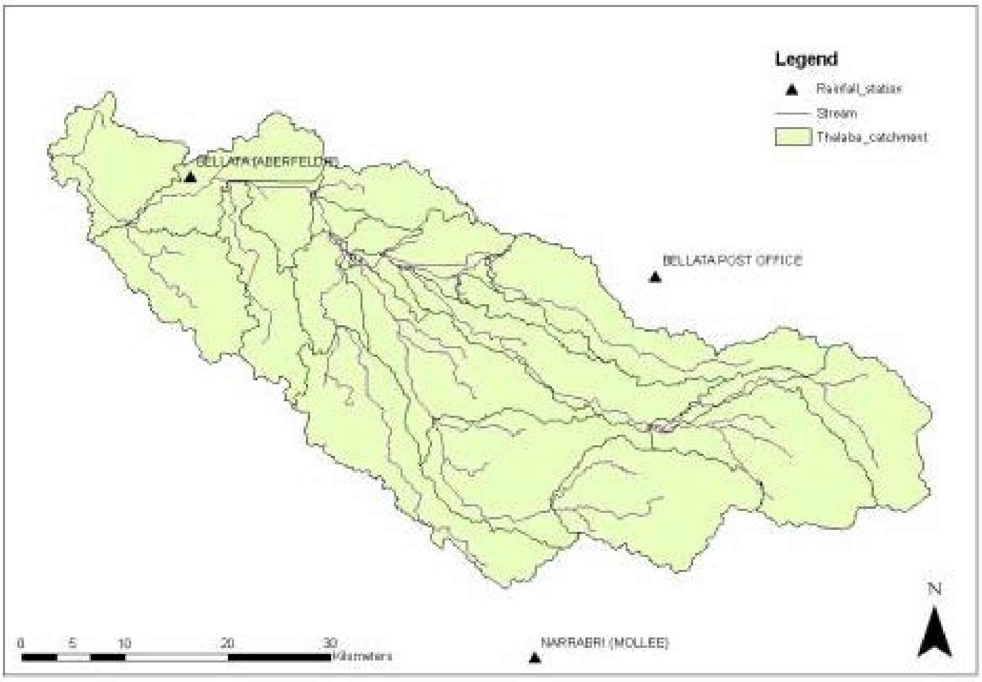


Figure A7.2: Thalaba RORB sub-catchments and location of rainfall stations

Table A7.3: Details of rainfall stations used to model Thalaba Creek

Rainfall station	Station no.	Period of record
Bellata (Aberfeldie)	053035	1902–2013
Bellata PO	053003	1912–2013
Narrabri (Molle)	053026	1926–2012

Appendix 8: Further detail on hydraulic modelling

The floodplain has been broken up into four sub-areas for hydraulic modelling purposes, this has been done for two main purposes:

- to ensure that each sub-area is represented with the resolution required
- limits to the extent of available topographic data sources

The four sub-areas are:

- **Upstream of Pallamallawa**: this area extends from the upstream end of the floodplain to the upstream extent of the LiDAR survey
- **Pallamallawa to Moree**: this area extends from the upstream extent of the LiDAR survey to just downstream of Moree
- **Downstream of Moree**: This area extends from just downstream of Moree to the downstream extent of the LiDAR around the Barwon River confluence, it includes the majority of the Marshalls Ponds, Carole, Gil Gil, Gingham, Gwydir, Mehi and Moomin Creek systems
- **Thalaba Creek**: This area covers the southern extent of the floodplain and covers the Thalaba Creek and Southern Moomin Creek systems.

Model network

The networks for existing models (Moomin Creek and Biniguy – Moree) were geo-referenced using aerial photography and other controls. Some other small changes were made to the Moomin Ck network to improve the flow distribution while the remaining existing networks were left as is.

For the new model areas the network was defined using existing watercourse layers, aerial photography and flood aerial photos to determine breakout locations and overland flow paths. Where a defined channel existed and was likely to carry a significant amount of flow, it was represented within the one-dimensional component of the model. Other areas, such as broad floodways or flood storage areas (e.g. Lower Gingham), were represented in the two dimensional grid.

Boundaries

The model boundaries were located at gauging locations where a suitable gauge was available, gauges provide a convenient place for either an inflow time series or an outflow stage discharge relationship. Where no gauging existed, inflows were estimated using hydrological modelling and outflow stage discharge relationships were estimated using the available cross-sections.

At boundary locations where two model areas intersect, the time series results from the upstream model was extracted and then used as the inflow to the downstream model.

Structures

Where structures within the existing models were stable, they were left as is, or otherwise modified to improve the model stability and results; however, it was assumed that the existing models included a representation of all significant structures, and so no new structures were added in the existing model areas.

For the new model areas an initial search of the model area using the ADS40 identified approximately 90 in channel structures, this included bridges, fords and weirs. Very limited information was available on the majority of these structures and it was assumed that many of these would have little to no impact on the flood conveyance. Examination was then made of all available flood aerial photography to identify those structures that had a visible, significant impact on the flood, typically where there was a change between the upstream and downstream flood extents. These structures were then implemented within the model using the best available data to approximate their dimensions. This varied from detailed survey to estimation based on the LiDAR DEM.

Hydrodynamic parameters

The main hydrodynamic parameter, roughness, was not altered for existing models, and was modified during calibration for the new models. Channel roughness ranged from 0.035 to 0.08 (Mannings 'n') which is within the normal range of roughness for open natural channels. The floodplain roughness varied much more significantly, between 0.03 and up to 1, this large variation is due to vegetation, where dense vegetation can impede the majority of flow.

For the new model areas, roughness values were estimated based on existing model values and extrapolated based on vegetation mapping. Vegetation was broadly classed into community types, such as forest, grasslands, crops etc. for roughness purposes.

Other parameters that control the model operation such as the solution scheme, time step, and delta value, were left as is for existing models and typical values were used for the new model areas.

Model calibration

All models, with the exception of Moomin Creek, have been calibrated using the 2012. Moomin Creek has been calibrated to the 2012 and 1974 events. The 2012 event has been selected as it has been used as the design flood.

The models have been calibrated against a range of data sources, particularly:

- Peak flood heights at gauge locations – All gauges with available flood heights for the event and have been reduced to the Australian Height Datum. Figure A8.1 below shows the spatial coverage of the gauges, notably there is a lack of gauge coverage on the Thalaba Creek.
- The flow distribution calculated for the development of the floodplain guidelines – These have been checked where available and where the flow paths have not significantly changed since the distribution was calculated.
- Flood extents from satellite imagery and aerial photography – These were checked to determine the width of the flow and compared to the peak width within the model section, or directly compared to 2D model results.

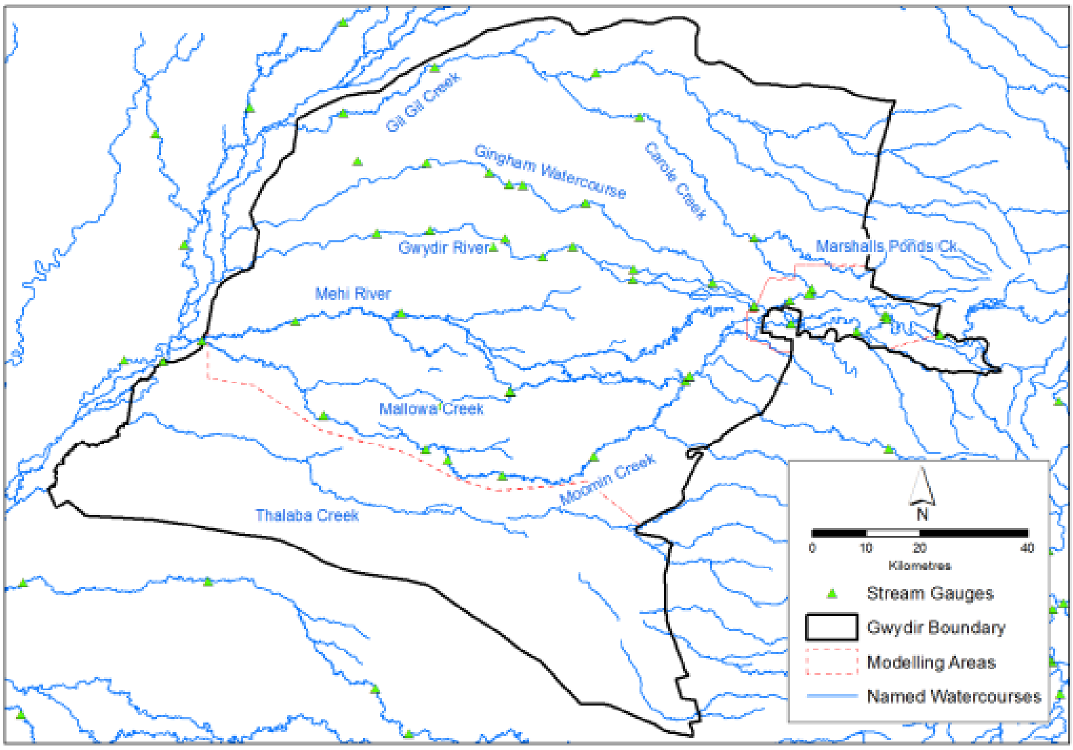


Figure A8.1: Spatial coverage of gauges in the Gwydir Valley Floodplain

The Table A8.1 below shows the calibration of the peak water surface to the major gauges within the system. Generally the model matches well with the gauge data (Difference < 0,2m).

For the Thalaba Creek, where no gauge data existed (that had been reduced to AHD), the model was analysed by undertaking sensitivity analysis, in particular:

- Varying inflows by plus or minus 20%
- Varying roughness by plus or minus 20%

It was found that the variations in parameters had little on the delineation of the management zones and therefore the model was considered fit for purpose.

Table A8.1: Calibration of peak water surface to major gauges in the system

Gauge	Sub-area	Recorded peak	Modelled peak	Difference
418042	Gwydir	222.06	222.04	-0.02
418087	Mehi	219.21	219.25	0.04
418002	Mehi	208.63	208.83	0.2
418011	Carole	210.53	210.57	0.04
418004	Gwydir	208.70	208.77	0.07
418063	Gwydir	204.66	204.59	-0.07
418086	Carole	199.60	199.61	0.01
418037	Mehi	193.18	193.04	-0.14
418060	Moomin	179.11	179.06	-0.05
418067	Moomin	170.37	170.46	0.09
418061	Moomin	163.73	163.63	-0.1
418049	Mallowa	171.83	171.91	0.08
418085	Mehi	171.70	171.72	0.02
418068	Mehi	159.74	159.55	-0.19
418058	Mehi	151.96	152.04	0.08
418078	Gwydir	178.31	178.35	0.04
418074	Gingham	197.30	197.19	-0.11
418076	Gingham	177.24	177.12	-0.12
418086	Carole	199.61	199.62	0.01
418052	Carole	178.71	178.54	-0.17
416027	Gil Gil	163.35	163.40	0.05
416052	Gil Gil	157.87	158.06	0.19

Appendix 9: Marxan prioritisation – planning units

Planning units grouped features of biodiversity in close proximity to each other to determine the relative importance of each unit. The Gwydir Valley Floodplain was divided into 50 hectare hexagonal planning units (*n* = 22,460) using the Qmarxan plugin (Apropus Information Systems Inc.) executed within Quantum GIS Version 1.8.0 software (QGIS Development Team 2013). Hexagonal-shaped planning units have been shown to produce more efficient and less-fragmented planning portfolios and were determined to be a suitable scale for the floodplain management planning process (Nhancale & Smith 2011).

Appendix 10: Marxan prioritisation – targets for ecological surrogates

Floodplain landscapes are highly complex and there is a large diversity of plants, animals and microscopic organisms. To represent biodiversity patterns in the Gwydir Valley Floodplain, several key ecological surrogates were chosen for input into the Marxan process. Ecological features and datasets were recommended by specialists via Technical Advisory Group (TAG) workshops and were collated and prepared for use in Marxan. Ecological surrogates are spatially definable components of biodiversity patterns and may include mapped information such as vegetation, waterbird habitat and fish biodiversity hotspots. The chosen ecological surrogates were representative of biodiversity across the floodplain and hence had varying degrees of flood dependency.

Targets are conservation objectives that specify the amount of an ecological surrogate that would be needed to be conserved to ensure the persistence of that ecological surrogate (Margules & Pressey 2000). The targets were used to drive the selection of priority assets for protection in the Gwydir FMP and were set and revised at two TAG meetings.

Ecological surrogates can be divided into:

- area-based data sets for native vegetation and fauna: the primary ecological surrogate for the prioritisation
- point-based data records of fauna observations, as well as habitat suitability modelling at NSW fisheries sites.

Targets for area-based data sets

Area-based data for vegetation was the primary ecological surrogate for the Marxan prioritisation. Mapped vegetation was chosen if it was dependent on flooding and/or provided habitat to flood-dependent fauna.

The vegetation classes that comprised the hydro-ecological functional groups were used as ecological surrogates when prioritising ecological assets in the Gwydir floodplain and included nine vegetation groups (Figures A10.1 and A10.2):

Flood-dependent

- semi-permanent wetland (flooded less than once per year)
- floodplain wetland (flooded every one to one in five years)
- flood-dependent forest (flooded every one to three years to every two to four years)
- coolibah – river cooba – lignum (flooded up to once in 10 years)
- coolibah open woodland (flooded up to once in 10 years)
- black box woodlands (flooded up to once in 10 years)

Non-flood-dependent

- belah woodlands
- windmill grass
- native millet/cup grass grasslands.

Waterbodies derived from the vegetation mapping were included as an ecological value of the in-stream landscape position, floodplain watercourses.

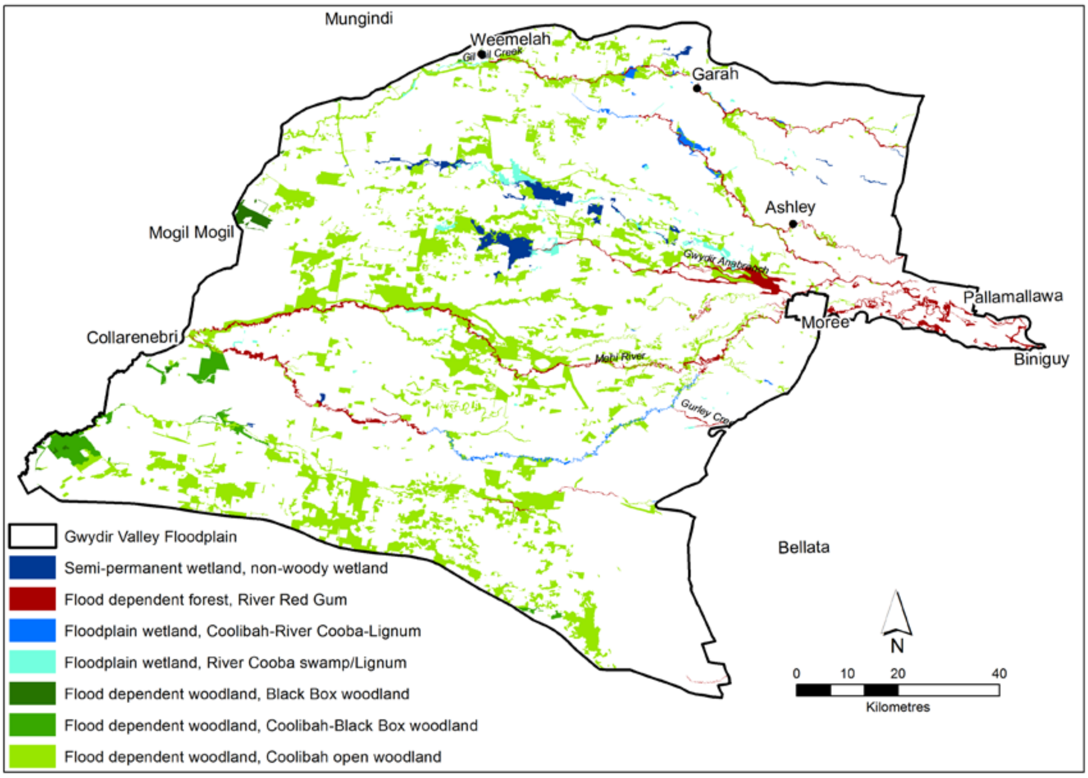


Figure A10.1: Flood-dependent vegetation groups used as ecological surrogates in the Marxan prioritisation process. Vegetation types are simplified to represent the dominant species for the purposes of this map.

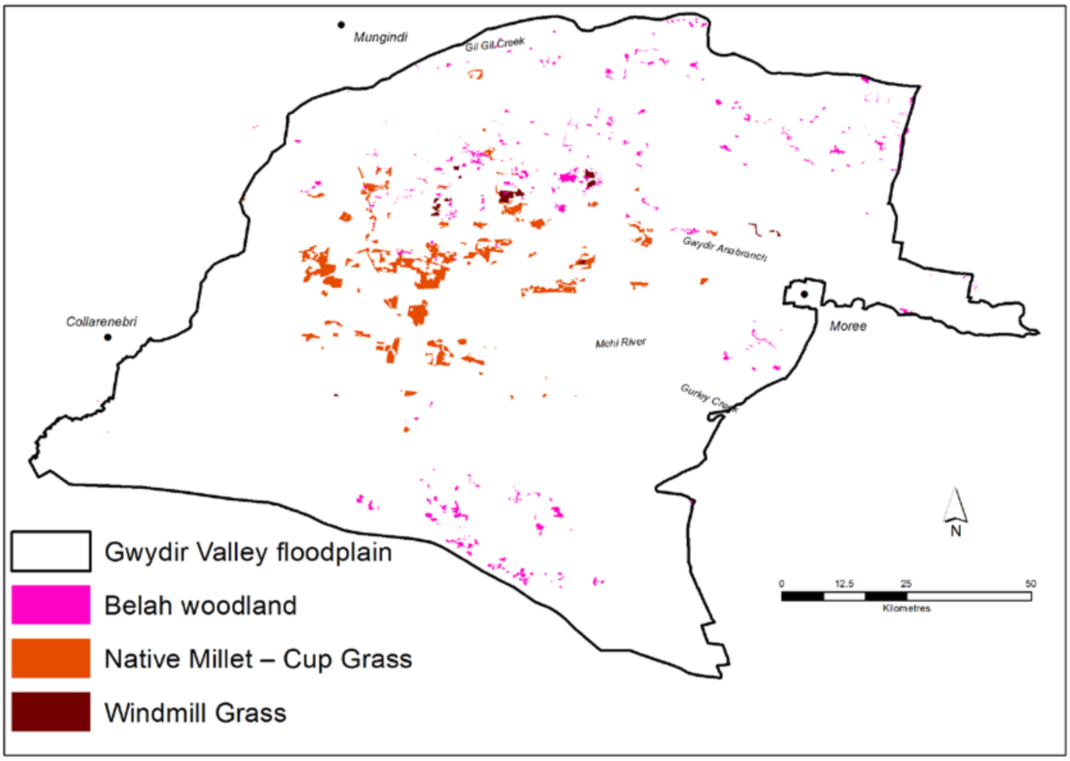


Figure A10.2: Non-flood-dependent vegetation groups used as ecological assets in the Marxan prioritisation process

Area-based ecological surrogates for floodplain fauna included:

- a mapped layer of colonial waterbird nesting sites
- modelled waterbird breeding habitat
- species distribution models for two frog species and a habitat assemblage of the three turtle species found in the area.

See Appendix 12 for further detail on the mapping of area-based data for fauna.

Target setting for area-based targets was initiated at 30% of the pre-development area, below which there is a steep drop off in biodiversity (Ausseil et al. 2011). The 30% habitat area has also been recommended by the World Conservation Union (IUCN 2003). Generally, targets for vegetation surrogates were set high as the Gwydir floodplain is a highly-cleared landscape and all remaining vegetation is of conservation significance (Table A10.1).

To determine the percentage area of vegetation surrogates remaining in the Gwydir floodplain, a pre-1750 vegetation reconstruction map (White 2002) was compared to the map of vegetation surrogates. Some of the vegetation surrogates were merged and assessed as a group because the White (2002) map contained very broad classes of vegetation. The two grassland surrogates were not considered because the grassland classes used in the reconstruction were too broad to undertake a meaningful analysis.

Flood-dependent forest (river red gum) was found to have 36% of the pre-development area remaining. The target was set at 80% for this vegetation surrogate to approximately meet the requirement of protecting 30% of the pre-development area.

The Gwydir floodplain is a highly-cleared landscape and it was found that some surrogates have been cleared below 30% of the pre-development area. The targets were set at 100% of this remaining vegetation for the following vegetation ecological values:

- coolibah/river cooba/lignum (27% of the pre-development area remains)
- coolibah (27% of the pre-development area remains)
- black box (27% of the pre-development area remains)
- belah woodland (15% of the pre-development area remains).

Flood-dependent woodlands (coolibah and black box), initially set at 100% failed to achieve the target so was dropped to 90% (Table A10.1).

Although semi-permanent wetland and floodplain wetland were found to have 60% of the pre-development area remaining, the target was set to 100% by experts who recognised the ecological and cultural significance of these areas. These surrogates form part of the areas where there is considerable effort to preserve the core wetland (inner floodplain), especially in the Gingham and Gwydir through efforts of the environmental water manager and documents such as the Gwydir Adaptive Environmental Management Plan (DECCW 2011).

Marxan can be parameterised to fix or exclude planning units into the final solution through the use of status codes. Wetlands of international importance, including Windella, Crinolyn, Goddard's Lease and Old Dromana Ramsar sites and area with pre-existing commitments to watering were fixed into the solution (i.e. the planning unit is forced into the final solution).

Table A10.1: Targets for area-based ecological surrogates

Ecological surrogate	Total area (ha)	Target (% of area)	Fixed in solution	Justification
Areas of state and international conservation significance				
Ramsar sites	823	100	Yes	Internationally important areas
Wetlands identified in the Lower Gingham FMP	775	100	Yes	Focus of protection in previous floodplain management plans
Wetlands identified in the Moomin Ck FMP	16	100	Yes	Focus of protection in previous floodplain management plans
Watering commitments identified in the Moomin Creek FMP	681	100	Yes	Focus of protection in previous floodplain management plans
Waterbodies	148	100	Yes	Important areas for fish and other fauna. May provide drought refuge
Habitat for flood-dependent fauna (mapped)				
Waterbird colony sites	1,096	100	No	>60% of mapped area fell within the semi-permanent and floodplain wetland vegetation ecological values. Such sites have high environmental importance
Semi-permanent wetland	8,866	100	Yes	Ecologically and culturally significant areas
Floodplain wetland (river cooba/lignum)	4,668	100	Yes	Cleared below 30% of the pre-development area. Ecologically and culturally significant areas
Floodplain wetland (coolibah/river cooba/lignum)	4,674	100	Yes	Cleared below 30% of the pre-development area. Ecologically and culturally significant areas
Flood-dependent forest (river red gum)	17,682	80	No	To meet the requirement of protecting 30% of the pre-development area
Flood-dependent woodland (coolibah)	144,714	90	No	Cleared below 30% of the pre-development area. Initially set at 100% but failed to achieve the target so it was dropped to 90%
Flood-dependent woodland (black box)	13,202	90	No	Cleared below 30% of the pre-development area. Initially set at 100% but failed to achieve the target so it was dropped to 90%
Non flood-dependent vegetation (belah)	9,670	100	No	Cleared below 30% of the pre-development area
Non flood-dependent vegetation (windmill grass)	1,691	50	No	Non flood-dependent
Non flood-dependent vegetation (native millet/cup grass)	19,370	50	No	Non flood-dependent

Ecological surrogate	Total area (ha)	Target (% of area)	Fixed in solution	Justification
Habitat for flood-dependent fauna (modelled breeding waterbird assemblage habitat suitability)				
High	2,412	100	No	Ecologically and socially significant function
High–moderate	15,712	60	No	Decreasing targets set with decreasing habitat values
Moderate	48,488	30	No	Decreasing targets set with decreasing habitat values
Threatened fauna species (modelled species distribution)				
Barking frog – high value	55,021	50	No	The realised niche is likely to be a subset of the modelled areas
Eastern sign-bearing froglet – moderate value	56,124	50	No	The realised niche is likely to be a subset of the modelled areas
Turtle assemblage – moderate value	49,559	40	No	The realised niche is likely to be a subset of the modelled areas
Turtle assemblage – high value	4,905	60	No	The realised niche is likely to be a subset of the modelled areas

The mapped waterbird colonies largely fell within the semi-permanent and floodplain wetland vegetation ecological values (>60% of mapped area), and were considered to be environmentally important, hence had their target set to 100%. High-value modelled waterbird breeding habitat was similarly valued, with decreasing targets set with decreasing habitat values. Modelled species distributions due to the potential of false negative high values had lower target levels (Table A10.1).

Targets for point-based occurrence data

Ecological surrogates derived from point-based data for fauna included:

- 12 species of fish
- three species of frogs
- four species of amphibious reptiles
- one species of mammal[1].

These fauna species and assemblages were selected because they have a high dependence on floodwater and lower mobility. Low mobility species were less likely to be opportunistically recorded sightings of movement between areas of core habitat.

A score for presence or absence for the species was assigned to all planning units. If the point record was within a planning unit, the species was considered present.

Point-based records of fauna observations were available through the NSW Wildlife Atlas and the Atlas of Living Australia. All species recorded in the Gwydir valley plan area were examined for flood dependency. Data from two surveys (Wilson 2009; Spencer et al. 2010) not available in the Atlas databases was also used. These datasets gave reliable recent observations of fauna species and

[1] Waterbird observations were excluded from the prioritisation. Due to their high mobility some observations are likely transitions between areas of core habitat. Colonial waterbird breeding habitat, both mapped and modelled was used instead of point data to include this important wetland group.

included spatial accuracy and information about the site of each observation. Any data with a spatial accuracy of less than 100 metres or an association with a human artefact, such as a farm dam, was removed from the analysis. See Appendix 13 for further information on point-based data for fauna.

All point-based occurrence surrogates were given 100% targets (Table A10.2) as the number of records did not cover a large part of the landscape. It was decided that it was important to try to include the small number of sites where these wetland indicator species where known to occur.

Table A10.2: Targets for point-based ecological surrogates

Ecological surrogate	No.	Target (% of sites)
Observed fish		
Unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*)	13	100
Australian smelt (*Retropinnia semoni*)	24	100
Bony bream (*Nematalosa erebi*)	24	100
Carp gudgeon (*Hypseleotris* spp)	33	100
Midgeleys carp gudgeon (*Hypseleotris* sp)	7	100
Firetail gudgeon (*Hypseleotris galii*)	7	100
Western carp gudgeon (*Hypseleotris klunzingeri*)	13	100
Silver perch (*Bidyanus bidyanus*)	1	100
Golden perch (*Macquaria ambigua*)	22	100
Murray cod (*Maccullochella peelii*)	16	100
Murray-Darling rainbowfish (*Melanotaenia fluviatilis*)	21	100
Spangled perch (*Leiopotherapon unicolor*)	36	100
Freshwater catfish (*Tandanus tandanus*)	16	100
Observed amphibious fauna		
Eastern barking froglet (*Crinia parinsignifera*)	8	100
Barking marsh frog (*Limnodynastes fletcheri*)	22	100
Broad-palmed frog (*Litoria latopalmata*)	16	100
Eastern long-necked turtle (*Chelodina longicollis*)	13	100
Broad-shelled turtle *(Chelodina expansa)*	1	100
Macquarie turtle *(Emydura macquarii)*	1	100
Water dragon (*Physignathus lesueurii)*	1	100
Water rat (*Hydromys chrysogaster)*	4	100
Modelled fish biodiversity		
High	7	100
Moderate	13	100
Low	7	100

Appendix 11: Constraint surface for use in Marxan

The constraint surface represented the ability to physically connect water to floodplain assets and was used to constrain the selection of planning units in the Marxan solution. NSW land capability classes were used as a surrogate for inundation likelihood to derive the constraint surface for the Gwydir valley plan (Emery 1986). The eight-class classification was based on an assessment of the biophysical characteristics of the land, the extent to which these will limit a particular type of land use and the technology available for land management (Emery 1986).

The land capability classes were fitted to the planning unit layer to create the constraint surface. This was done using an area-weighted average value of land capability to give each planning unit a single value (Figure A11.1).

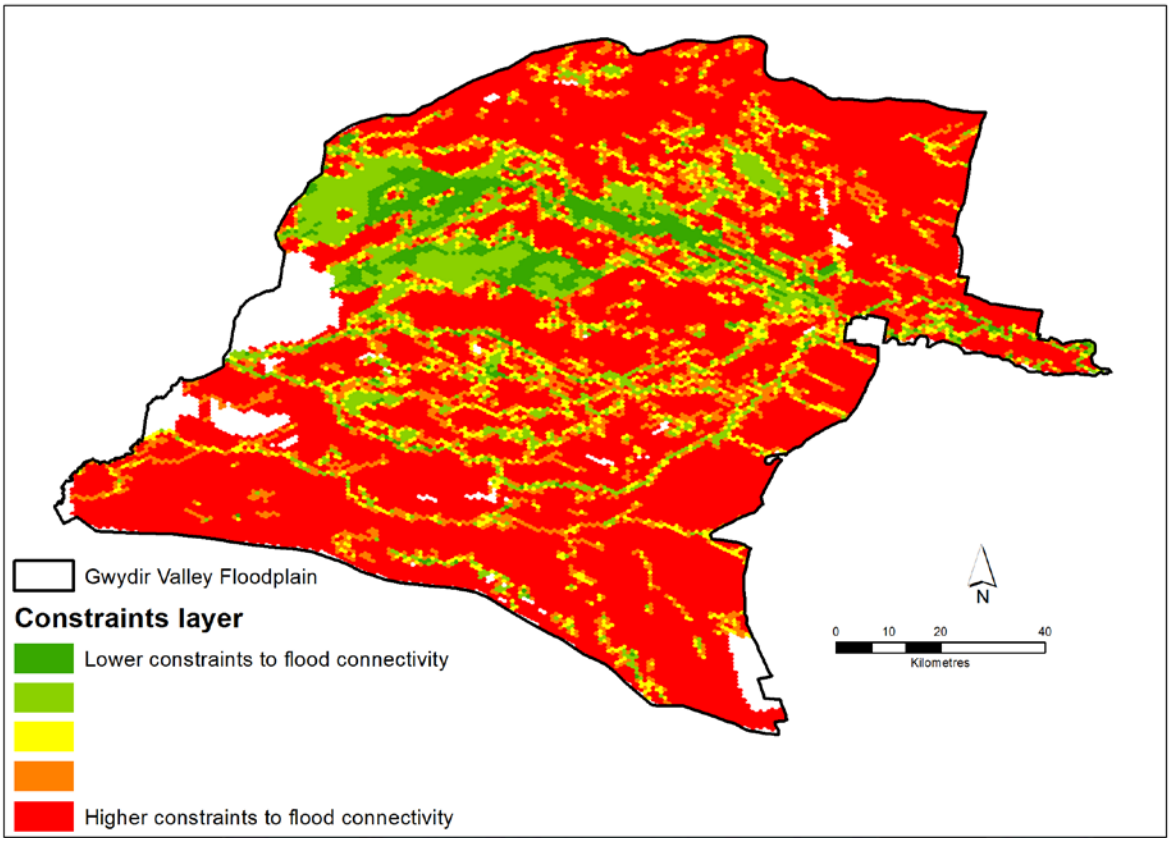


Figure A11.1: Constraint surface

The history of flooding on floodplains has made these areas some of the most fertile and productive in Australia. The fertile soils and water resources make floodplains highly-values commercial sites suitable for agricultural production. Visual comparison of an inundation likelihood product created by Thomas et al. 2010 with the NSW land capability mapping showed an initial similarity in pattern (Figure A11.2). Low constraint classes were much more likely to be associated with high inundation frequency, the central constraint class was more likely to fall in moderate inundation likelihood and the high constraint class was associated with a low likelihood of inundation. The inundation likelihood product could not be used as the constraint surface because it did not cover the entire Gwydir floodplain. Five land capability constraint classes were associated with inundation likelihood and given low to high constraint values for use in Marxan.

Table A11.1: Land capability classes (Emery 1986) and their constraint rankings

NSW land capability class	Land capability codes	Constraint value in Marxan
Other – land best protected by green timber, cliffs, lakes or swamps and other lands unsuitable for agricultural and pastoral production	7, 8	0.50
Land suitable for grazing but no cultivation: least opportunity cost	6	0.65
Land suitable for grazing with occasional cultivation	4,5	0.75
Land suitable for regular cultivation	1,2,3	0.85
Flood irrigation	FI	1
Urban area	U	1

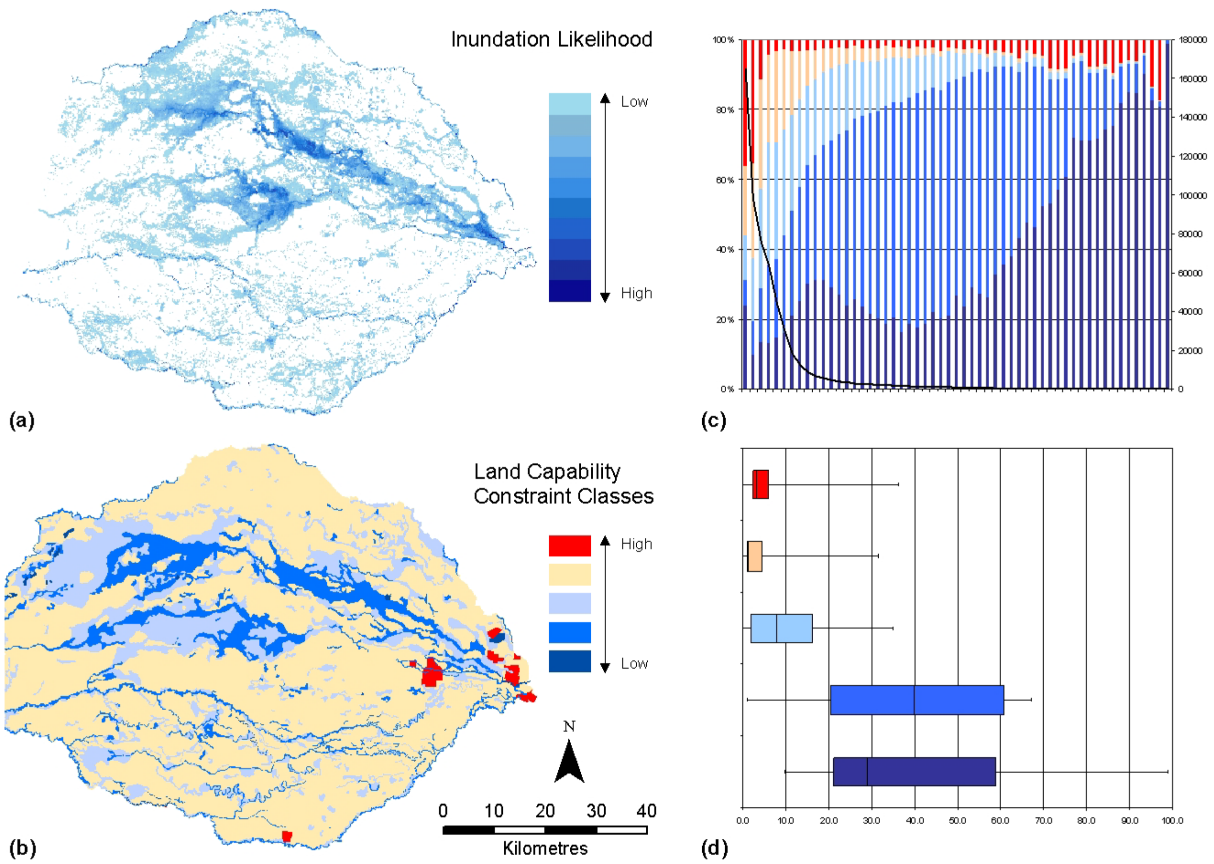


Figure A11.2: Comparison of inundation likelihood with land capability: (a) the extent of the inundation mapping by Thomas et al. (2010) showing light blue to dark blue with increasing likelihood of inundation; (b) amalgamated land capability classes clipped to the boundary of the Thomas etal (2010) product – the lowest value (blue – 50) being the easiest to deliver water to, through to red (100) the most difficult; (c) the percentage make up of each of the 51 inundation likelihood classes by the five land capability classes

The black line is the area in ha of each inundation likelihood class (right hand axis). (d) box plots showing the spread of inundation likelihood in each of the five land capability classes (as a percentage of the inundation likelihood class). In (c) and (d) inundation likelihood increases from left to right on the x-axis.

Appendix 12: Fauna mapping (area-based data)

Colonial waterbird nesting sites

Colonial waterbird breeding habitat was mapped for the summer flood event of 2011–12 (Spencer et al. in prep). The habitat was mapped using visual analysis of high resolution digital aerial photography of the colonial waterbird nesting sites. This information is sensitive and therefore not displayed in this document.

Modelled waterbird breeding habitat

Modelling of waterbird breeding habitat was undertaken by the NSW National Parks and Wildlife Service using unpublished data. The modelling used expert knowledge to assign waterbird breeding habitat value to vegetation types. The modelling method was based on habitat modelling for the Southern Mallee (Ellis et al. 2007). For the Gwydir valley plan, thresholds based on natural breaks in the data were used to divide the waterbird breeding habitat data into three suitability classes; high, moderate – high and moderate.

Species distribution models

Species distribution models can make inferences of the likelihood of finding a species in areas where reliable observations do not occur (Hernandez et al. 2006). They take recorded locations of the species and extrapolate using a set of environmental variables (Phillips et al. 2006). These models have been used in other systematic conservation planning studies in riverine ecosystems using Marxan (Esselman & Allan 2011; Linke et al. 2012).

Species distribution models were created for the:

- the eastern sign-bearing froglet (*Crinia parinsignifera*)
- the barking marsh frog (*Limnodynastes fletcheri*)
- a turtle assemblage from the Ellis et al. (2007) habitat modelling comprised of three turtle species that share habitat and have dietary overlap (Meathrel et al. 2002):
    - eastern long-necked turtle (*Chelodina longicollis*)
    - broad-shelled turtle (*Chelodina expansa*)
    - Macquarie turtle (*Emydura macquarii*)) have been noted as sharing habitat and having dietary overlap.

Fourteen environmental variables based on derivatives of digital elevation models, climatic variables and geographic features were used for the species distribution models.

Species distribution models may overestimate the likelihood of a species occurring. It can be difficult to evaluate overestimation in species distribution models that use presence data only (Hernandez et al. 2006). The species distribution models for this project where evaluated using the Receiver Operating Characteristic (ROC) which evaluates overall fit and incorporates omission and commission error (Hernandez et al. 2006). In the three species distribution models the area under the ROC curve was used to evaluate the models. The area under the ROC curve for all models on reserved test data was above 0.75, which was an acceptable value. Nevertheless, the models were weighted lower than other mapped surrogates in the Marxan analysis to acknowledge that the actual distribution of species may be a subset of the modelled distribution.

Thresholds were applied to the median and quartile values of the likelihood surface to create areas of high to moderate value to input into the prioritisation. The thresholds were weighted higher for higher likelihood (see targets below). Species distribution models were generally weighted lower compared to other mapped data.

Species selected for species distribution models were chosen for the same reasons as the point-based species observations data.

Appendix 13: Fauna mapping (point-based data)

Fish

There have been anecdotal reports of severe declines in native fish populations in the Gwydir (Spencer et al. 2010); however, fish were historically abundant (Green & Bennett 1991). All available native fish records were therefore used in the prioritisation.

Fish records were sourced from the NSW Fisheries Database and surveys completed as part of the Wetland Recovery Plan (Wilson 2009; Spencer et al. 2010). A total of 56 sites and 12 native species were used in the Marxan prioritisation.

Freshwater fish biodiversity hotspots were modelled by Fisheries NSW using species diversity and abundance from existing sites, as well as relationships to neighbouring values (Fisheries 2012). The biodiversity hotspot modelling was used as a surrogate for in-stream fish habitat. The modelled data was thresholded into high, medium and low value based on in the accompanying metadata.

Frogs

The Gwydir Wetlands are characterised by diverse and abundant frog populations, with 14 species reported to occur (Holmes et al. 2009; Wilson 2009).

Frogs are periodically very abundant, responding to flows and floods (Ng et al. 2011). Frogs and tadpoles play an important role in the food web of the Gwydir Wetlands as an important food source for waterbirds and snakes (DECCW 2011b; Holmes et al. 2009; Wassens & Maher 2010).

Frogs have been identified as species and communities of special significance in the Gwydir (DECCW 2011b). Found in most wetland habitats, frogs require standing water at all or some of their life cycle stages, which makes them appropriate for use as surrogates of wetlands (OEH 2012; Jansen & Healey 2003; Wassens 2010a).

Frogs selected as surrogates included:

- plains froglet or eastern sign-bearing froglet (*Crinia parinsignifera*)
- broad-palmed frog (*Litoria latopalmata*)
- barking marsh frog (*Limnodynastes fletcheri*).

These frog species were chosen because there are records of them occurring in the Gwydir floodplain and they are species that are reliant on seasonal floodwater inundation and not just local rainfall as is the case for some burrowing frogs (Wassens 2010b).

In particular, flooding is essential to:

- maintain their wetland habitat
- initiate breeding
- facilitate the successful metamorphosis of tadpoles
- provide food (algal growth for tadpoles).

The three species selected are all widespread in the Northern Murray-Darling Basin and are associated with wetlands and floodplain waterbodies (Anstis 2002; Wassens 2010b). All show a preference for vegetated wetland sites (Wassens & Maher 2010). *Crinia parinsignifera* favours water couch habitat, and *Limnodynastes fletcheri* spike rush beds (OEH 2012); however, they can also be associated with man-made waterbodies such as farm dams. Sites associated with human development were removed from the data. The three frog species were recorded at 30 sites in the Gwydir floodplain of which one was unsuitable for use in the prioritisation and for input into the species distribution models.

Amphibious reptiles

Reptiles are an important indicator species in wetlands (Holmes et al. 2009). The three turtle species are likely to occur in permanent pools and lagoons and so represent in-stream and the semi-permanent wetlands (Wilson 2009).

Amphibious reptiles selected as surrogate species for prioritisation included:

- eastern longed-necked turtle (*Chelodina longicollis*)
- broad-shelled turtle (*Chelodina expansa*)
- Macquarie turtle (*Emydura macquarii*)
- eastern water dragon (*Itellagama lesueurii*) (formerly *Physignathus lesueurii*).

The three species of turtle are found throughout the Murray-Darling Basin and have similar distributions and occupy similar wetland environments, such as lagoons lakes, rivers, and swamps (Cann 1998). They can also be found in dams; however, any records of this nature were removed from the data set.

The turtles fulfil different but overlapping roles in the food chain from obligate carnivore (*Chelodina expansa*) to opportunistic omnivore *Emydura macquarii* (Meathrel et al. 2002; Chessman 1986; Cann 1998; Cogger 2000). *Chelodina longicollis* is the most common in the Gwydir floodplain with 13 usable records compared to one each for the other two species.

The water dragon, *Itellagama lesueurii*, found on the slopes and ranges of Eastern Australia is at the western extent of its range in the Gwydir floodplain with only one record occurring in the east of the study area (Cogger 2000). It is a semi-aquatic arboreal lizard, occupying vegetation that overhangs rivers and creeks and preys on a variety of aquatic and terrestrial organisms as well as foraging on berries and fruit (Cogger 2000; Hosking 2013).

Mammals

The water rat, *Hydromys chrysogaster*, inhabits streams, rivers and wetlands throughout the Murray-Darling Basin (Scott & Grant 1997). Water rats can occur in high numbers by permanent wetlands and prefer slower moving waters and dense vegetation cover (Scott & Grant 1997; CSIRO 2004). The water rat is often associated with irrigation infrastructure and two records were removed from the data set accordingly (Scott & Grant 1997) (Table A13.1).

Table A13.1: Fauna observations (sites): total and cleaned

Group	Common name	Scientific name	Total sites	Sites used	Sites discarded
Fish	Australian smelt	*Retropinna semoni*	26	25	1
	Bony bream	*Nematalosa erebi*	27	25	2
	Freshwater catfish	*Tandanus tandanus*	16	16	0
	Golden perch	*Macquaria ambigua*	27	26	1
	Carp gudgeon	*Hypseleotris spp.*	42	42	0
	Firetail gudgeon	*Hypseleotris galii*	7	7	0
	Murray cod	*Maccullochella peelii peelii*	17	17	0
	Murray-Darling rainbowfish	*Melanotaenia fluviatilis*	24	22	2
	Silver perch	*Bidyanus bidyanus*	1	1	0
	Spangled perch	*Leiopotherapon unicolor*	39	38	1
	Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	14	13	1
	Western carp gudgeon	*Hypseleotris klunzingeri*	14	13	1

Group	Common name	Scientific name	Total sites	Sites used	Sites discarded
Frogs	Barking marsh frog	*Limnodynastes fletcheri*	26	25	1
	Broad-palmed frog	*Litoria latopalmata*	17	17	0
	Plains froglet	*Crinia parinsignifera*	8	8	0
Reptiles	Broad-shelled river turtle	*Chelodina expansa*	1	1	0
	Eastern snake-necked turtle	*Chelodina longicollis*	16	13	3
	Murray turtle	*Emydura macquarii*	1	1	0
	Eastern water dragon	*Itellagama lesueurii*	1	1	0
Mammals	Water rat	*Hydromys chrysogaster*	6	4	2

Appendix 14: Aboriginal Sites Decision Support Tool

The Aboriginal Sites Decision Support Tool (ASDST) was developed to meet a critical need in regional planning: whole-of-landscape data describing Aboriginal site issues. There are two key components of the ASDST: landscape visualisation through the provision of visual products (GIS layers) that fill in data gaps in the Aboriginal Heritage Information Management System (AHIMS) data; and analysis, by generating information products designed to meet the need of incorporating Aboriginal site heritage information into regional, park, land and natural resource management planning.

The tool is based on and a leader in international best practice in archaeological site predictive modelling and has been successfully applied as part of a variety of projects across NSW (see further information the ASDST website (www.environment.nsw.gov.au/licences/AboriginalSitesDecisionSupportTool.htm).

Landscape visualisation tool

A suite of statewide products (GIS layers) of the ASDST have been developed to support regional scale context setting and strategic planning. These layers provide users with landscape context about:

- the original (pre-colonisation) potential distribution of AHIMS features
- the current potential distribution of AHIMS features
- the accumulated impact on AHIMS features across the landscape
- the reliability and validation priority of the ASDST products, and
- a classification of the landscape into areas with similar AHIMS feature profiles.

Analytical tool

The analytical component of the ASDST generates information products (GIS layers, numerical reports and interpretive documents) that can be used to support regional planning for Aboriginal site heritage. The tool utilises modelled information about:

- accumulated impacts
- gap analysis, and
- representativeness.

In turn, this information can be used to report on issues including:

- degree of loss of different AHIMS features in the landscape
- assessment priority and developing survey strategies, and
- conservation priority.

For the Gwydir FMP, the ASDST was used as a context-setting tool, to inform where there may be areas of potential flood-dependent sites, and where there are significant knowledge gaps arising from gaps in the systematic survey for flood-dependent Aboriginal sites. The ASDST data products were used to inform the identification of priority conservation areas for Aboriginal values.