Department of Primary Industries
Water

Rural floodplain management plans

Water Management Act 2000

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

Volume 1

Publisher: NSW Department of Primary Industries, Water

Title: *Rural floodplain management plans: Background document to the floodplain management plan for the Gwydir Valley Floodplain 2015*

First published February 2015

ISBN number – 978-1-74256-821-8 vol.1

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JTN 13126

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Abbreviations

ABS	Australian Bureau of Statistics
AEP	annual exceedance probability
AHIMS	Aboriginal Heritage Information Management System
ASDST	Aboriginal Sites Decision Support Tool
ATWG	Aboriginal Technical Working Group
DPI	NSW Department of Primary Industries
Gwydir FMP	Floodplain management plan for the Gwydir Valley Floodplain 2015
FMP	floodplain management plan
HHIMS	Historic Heritage Information Management System
IRP	Interagency Regional Panel
MDB	Murray-Darling Basin
MZ	management zone
NV Act	*Native Vegetation Act 2003*
NSW	New South Wales
OEH	NSW Office of Environment and Heritage
TAG	Technical Advisory Group
WA 1912	*Water Act 1912*
WMA 2000	*Water Management Act 2000*
WSP	water sharing plan

Purpose

The purpose of this document is to inform local landholders and the wider community about how the rural floodplain management planning approach presented in the *Rural Floodplain Management Plans: Technical manual for plans developed under the* Water Management Act 2000 (the Technical Manual) has been applied across the Gwydir Valley Floodplain. This document should be read in conjunction with the Technical Manual and the draft *Floodplain Management Plan for the Gwydir Valley Floodplain 2015* (Gwydir FMP).

The Gwydir Valley Floodplain

The area that this document pertains to is the Gwydir Valley Floodplain as shown in Figure 1. The Gwydir Valley is bounded by the Great Dividing Range to the east, the Mastermans Range to the north, the Nandewar Range to the south and the Barwon-Darling River System to the west. The valley covers 2.66 million hectares or two per cent of the Murray-Darling Basin. The Gwydir Valley Floodplain covers 1.15 million hectares.

The main irrigation storage in the Gwydir Valley is Copeton Dam, which was built in 1976 in the upper catchment below the junction of the Gwydir River and Copes Creek. Copeton Dam has a capacity of 1354 gigalitres and partially controls Gwydir River flows. The floodplain's river system has been further regulated by weirs and other regulating structures that are used to store and distribute water. These structures were built mostly after the construction of Copeton Dam to allow water to be managed for irrigation delivery. Weirs now divert flow from the Gwydir River into the Mehi River, Carole Creek and Moomin Creek systems to supply irrigators with water.

East of the Gwydir Valley Floodplain, the upper valley is steep or undulating with relatively confined floodplain areas. The floodplain itself is very flat and flood flow velocities are generally slow. Floodwaters fan out in a delta-type drainage pattern to the southwest via the Mehi River, to the west via the Gingham Channel, and to the northwest via Carole Creek. The Mehi River is the largest effluent of the Gwydir River and Carole Creek is the second largest. The Gwydir River system is often termed a 'closed system' because under normal conditions, it discharges flow across the lower floodplain; however, during large flood events, floodwaters can extend and enter the Barwon River system to the west. Large floods inundate the entire floodplain and inundation can last for many weeks or even months in the lower reaches (McNamara 1981).

The Gwydir Valley Floodplain contains the Gwydir Raft, which is an immense obstruction of timber, sediment and debris that built up after the catchment was extensively cleared in the early 1900s (see Figure 1 for location) (McCosker 2001). The formation of the Gwydir Raft has significantly affected flows to the lower part of the Gwydir system by effectively damming the original main channel of the Gwydir River. As a result, upstream of the Raft at Tyreel Weir, the Gwydir River splits into the Gingham and Lower Gwydir channels. The impact of the Raft on river flows has since been largely accepted as part of the existing flooding regime.

The ecosystems that reside on this floodplain are unique and diverse with many being flood-dependent and requiring a particular frequency of inundation to remain viable. Floodplain water flows are therefore crucial to the structure and function and long-term survival of the flood-dependent ecological communities that comprise the Gwydir Valley Floodplain. The Gwydir Valley Floodplain includes the Gwydir Wetlands, which are formed on the very flat near-terminal floodplain of the Gwydir River and consist of a complex network of flow paths and floodways. The wetlands are located 60 kilometres west/northwest of Moree and are formed along the Gingham Watercourse, Lower Gwydir Watercourse and the Mehi River – Mallowa Creek – Moomin Creek system. Parts of these wetlands are listed under the Ramsar Convention (823 hectares) and the NSW reserve system (7069 hectares) (Figure 1). The Gwydir Wetlands are also listed in the Directory of Important Wetlands in Australia (Environment Australia 2001) (Figure 1). The Gwydir

Wetlands have high biodiversity values (DECCW NSW 2011). The Gamilaroi people are the traditional owners of the Gingham floodplain, Gwydir Wetlands and most of the length of the Gwydir River. The Gwydir Valley Floodplain contains many cultural sites and values that are important to the local Aboriginal community, including cultural modifications, such as coolamon scars to living trees that are flood-dependent species.

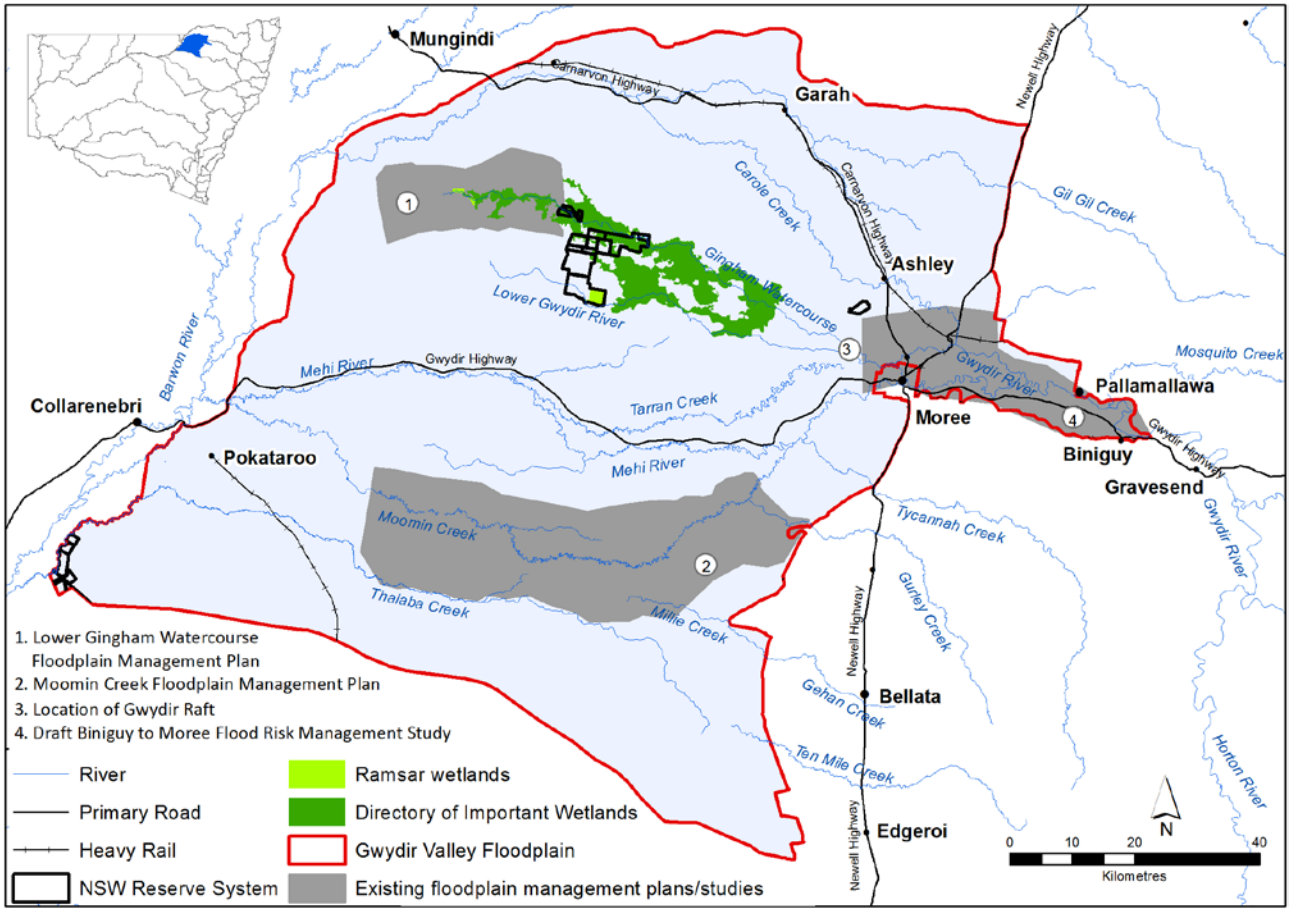

Figure 1: Key features of the Gwydir Valley Floodplain

Most of the land in the Gwydir Valley is used for agriculture. Following river regulation, there was a shift from grazing to cropping, including crops such as cotton, which is the dominant irrigated crop by area and value. The area of irrigated farming fluctuates each year primarily in response to water availability. Recreational fishing and the associated tourism is also considerable in the Murray-Darling Basin, including the Gwydir catchment.

Works have been built on the Gwydir Valley Floodplain to enhance agricultural productivity. Flood works, such as levees, earthworks, banks and channels have been built to protect crops, land, stock and properties from flooding; provide on-farm access; and to manage and store irrigation, stock and domestic water. Approximately 191,000 hectares of floodplain area is protected by flood works in the Gwydir Valley Floodplain. In many instances, flood works have contributed positively to the agricultural productivity of land in the Gwydir Valley Floodplain; however, when flood works are built in an uncoordinated way they can change traditional flood patterns.

The natural flooding regime has also been altered by changes to the carrying capacity of distributary channels (Gwydir River, Mehi River, Moomin Creek and Carole Creek) caused by channel modification (deepening and widening) for more efficient supply and management of allocated water. The flow carrying capacity of the rivers and channels has also been altered by

changes in riverbed morphology caused by the regulated delivery of water (i.e. constant flow instead of wet and dry periods) and regulators directing flows away from certain areas and towards others. Furthermore, there is usually less vegetation in floodways, which are often farmed or otherwise closely grazed. This can lead to increased flow velocities and possibly increased discharge in the floodways. More dense vegetation in other areas will slow velocities and increase depth of flow.

To coordinate flood-work development, the NSW Government has been responsible for rural floodplain management planning in the Gwydir Valley Floodplain since the 1970s. Planning has focused on areas with intensive irrigation development and areas where major flood events revealed changes to flooding behaviour caused by flood works. The outcomes of planning in the Gwydir Valley Floodplain to date are two existing and gazetted rural floodplain management plans, which are for the Moomin Creek and the Lower Gingham Watercourse (see Figure 1). There are also six sets of current floodplain development guidelines, including Carole Creek, Brageen Crossing, Boolcarrol to Bulyeroi, Moree Area and Mehi River, and one draft Biniguy to Moree Floodplain Risk Management Study.

To build on the floodplain management planning work done so far in the Gwydir Valley Floodplain, a Gwydir FMP has been prepared in accordance with the floodplain planning and environmental protection provisions under the *Water Management Act 2000* (WMA 2000). Existing floodplain management arrangements have been consolidated in the Gwydir FMP, which applies floodplain management principles consistently across the extent of major flooding. Similar to current management measures, the new plan aims to coordinate flood-work development to protect flooding behaviour while minimising risk to life and property from the effects of flooding. The Gwydir FMP provides management zones and transparent rules for the NSW DPI Water to use when determining flood-work development approvals for new flood works and amendments to existing flood works.

Flooding in the Gwydir Valley Floodplain

Gravesend to Moree

Flows in the Gwydir Valley are linked to rainfall and run-off in the upper catchment. Flows that produce flooding upstream of Gravesend rapidly rise and subside and have high flow velocities. Immediately downstream of Gravesend, water is largely contained in the Gwydir River. At the Slaughterhouse Creek confluence, channel capacity reduces and floodwaters spread to the north and south (McNamara 1982).

About 13 km downstream of Pallamallawa, the floodplain is six and a half kilometres wide. The floodplain then broadens to 15 km at the Newell Highway about 35 km downstream of Pallamallawa (McNamara 1982). Slaughterhouse Creek and Mosquito Creek have relatively wide floodplains that average over a kilometre wide due partly to backwater from the Gwydir River (McNamara 1982).

Flooding over the south bank of the Gwydir River between Gravesend and Moree occurs via the ‘Biniguy Break’. The Biniguy Break is located near Slaughterhouse Creek confluence, which is 27 km downstream of Gravesend. The feature is a high-level flood runner that cuts the Gwydir Highway and marks the beginning of widespread inundation due to diminishing bed slope and reduction in main channel capacity. Floodwaters are conveyed via the Biniguy Break to the Mehi River.

The Mehi River is the largest effluent of the Gwydir River and it leaves the Gwydir at Tareelaroi Regulator. The Mehi River rises more slowly than the Gwydir River during a flood. The distribution of floodwaters between the Gwydir River, the Mehi River and overbank flow varies significantly for

floods with different annual exceedance probabilities (AEPs)[1] (McNamara 1982). For example, while the floodwater distribution of a 50% (or 1 in 2) AEP flood event will be 85%, 15% and 0% for the Gwydir River, Mehi River and overbank flow, respectively, a 1% (or 1 in 100) AEP flood will have floodwater distribution of 30%, 27% and 43% for the Gwydir River, Mehi River and overbank flow. Flood discharge in the Mehi River is dependent on both peak discharge and volume of the flood in the Gwydir River. Biniguy Break is a major contributor of flood discharge to the Mehi River.

The Horton River, which is upstream of Gravesend, is the largest single tributary of the Gwydir River above the main floodplain. The Gwydir Wetlands receive unregulated flows from the Horton River which is a major contributor to flood flows in the Gwydir. Flooding that begins in the Horton River peaks faster than flooding from the upper Gwydir catchment, which must first pass through Copeton Dam.

West of Moree

The Gwydir River and its effluents progressively decrease in channel size with distance downstream. With reduced carrying capacity in the main channel, much of the flow of large flood events in the Lower Gwydir Valley is carried overbank and flows through a multitude of channels, swamps and natural depressions. Floods west of Moree can extend across the full width of the catchment and overbank durations can exceed 30 days (McNamara 1982). About 4000 km2 between the Mehi River and the southern boundary of the valley is subject to flooding (McNamara 1982).

South of Moree several creeks rise in the Nandewar Ranges and flow in a north-westerly and westerly direction to join the major watercourses of the flat western plains. Most of the creeks south of Moree, such as Halls, Tookey, Boggy, Little Bumble and Millie creeks, only flood narrow strips of country east of the Newell Highway and up to 10 km west of the highway. These creeks feed the Thalaba Creek section of the Gwydir catchment but not the floodplain. In large floods, some of the Tycannah Creek floodwaters spill north into the Gwydir, 15 km east of Moree. A smaller amount of floodwater spills south into Gurley Creek (McNamara 1982).

West of Moree the original main Gwydir River channel has been blocked by the Gwydir Raft, which is a 35 km long mass of timber and debris. The Raft began accumulating in the early 1900s, due to large-scale clearing of timber by settlers. Mechanical clearing prevents the Raft from advancing upstream. The Raft is thought to have caused more flooding to the north in large floods (WMA water 2008); however, the effect on major floods is less discernible (McNamara 1982). A natural levee bank has formed adjacent and parallel to most of the stream channels near the Raft. Once the natural levees are overtopped, floodwaters inundate hundreds of square kilometres of valuable farming and grazing land. Moderate to major floods continue over the Tyreel weir into the Gwydir Raft Pool. Major floods then divide; either breaking southwest across Terille Island to rejoin Gwydir River flows to the west, or breaking west and northwest into the Gingham Watercourse (Paterson Consultants Pty Ltd 2003). Since the establishment of the Raft, the Mehi Creek has carried the bulk of low-flow discharge. Numerous effluent and distributary streams exist along the Mehi River. The dominant effluent is Moomin Creek which parallels the Mehi for 85 km. From the Raft, flood flows split between the Lower Gwydir River and Gingham Watercourse in a delta-like drainage pattern. The lack of a high volume channel in the Gingham means even moderate flows spread over the floodplain and terminate in the watercourse.

Carole Creek is the second largest Gwydir effluent and is regulated by Boolooroo Weir, which is six kilometres upstream of the Yarraman Bridge on the Gwydir River. As floodwaters rise, Carole Creek and other distributary streams of the region, including the Gingham Watercourse, carry

[1] AEP is the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage (%) or a likelihood of 1 flood in x years. For example, a flood with an AEP of 5% means there is a 5% chance that a flood of the same size or larger will occur in any one year.

increasing volumes of water until their channel capacities are exceeded and cross country flow sets in (McNamara 1982). Carole Creek leaves the main channel five kilometres upstream of Moree and conveys a large volume of floodwater northwest to the Carole – Gil Gil Creek system. Before river regulation, Carole Creek was ephemeral and only flowed seven per cent of the time (Green & Bennett 1991). Since regulation, the creek facilitates large volumes of water for stock, domestic and irrigation use. During a flood, the Boolooroo Weir gates are raised to allow maximum flood flow and should have a minimal impact on floodwater in Carole Creek.

Thalaba Creek runs along the southern limits of the catchment and drains into the Barwon River. Since river regulation, flows in the Mehi River and Carole Creek systems reach the Barwon River more regularly, whereas before river regulation, most high flows and floods dissipated in the Gingham and Big Leather watercourses (DECCW 2011). During large flood events, there is evidence of floodwaters from the Namoi Valley crossing into the Gwydir watershed near the headwaters of Thalaba Creek and Galathera Creek and continuing westwards. The southern catchment boundary is therefore ill-defined (McNamara 1982).

Key changes to the natural flooding regime

The construction of Copeton Dam, the coinciding river regulation, land-use changes and flood-work development have caused changes to the nature, frequency, extent and duration of flooding in the Gwydir Valley Floodplain.

In general, development in the Gwydir Valley and regulation of the river system has caused (CSIRO 2007):

- significant reductions in moderate to high flows in the Lower Gwydir
- large floods to be reduced in size and smaller events to be less frequent
- an increase in the average period between large flows
- a reduction in the average volume of large flows.

The flow regime has been substantially altered by the construction of Copeton Dam, which regulates 55 per cent of inflows to water users, and the weirs and regulators that allow water to be diverted into the Mehi/Moomin system and Carole Creek to supply irrigators (Keyte 1994).

The effect of Copeton Dam below Moree is moderated by other tributaries (including Tycannah Creek, Gurley Creek, Gil Gil Creek, Carole Creek and Horton River) that bring unregulated water into the floodplain. Between flooding from main river flows, the core wetlands receive small flows from localised rain in the catchments of tributaries downstream of Copeton Dam (Keyte 1994). Heavy rain in local catchments and wetland areas can also add flooding events.

Since river regulation, water from the Mehi River and to a lesser extent, the Gil Gil/Carole creeks reaches the Barwon River more frequently and in smaller river flows (WMA water 2008). Generally, flows get to the lower reaches of the floodplain faster since the construction of Copeton Dam.

Large floods still occur in the Gwydir floodplain and extend across the landscape as they would have done prior to river regulation and the construction of flood works; however, the frequency of flooding and flood extent on the floodplain has been modified by Copeton Dam. For instance, the 1955 flood was a 1.4% (1 in 70) AEP flood before the construction of Copeton Dam, but would have been considered a greater that 1% AEP flood after the dam's construction. Similarly, the 1971 flood was a 10% (1 in 10) AEP flood before Copeton Dam but would have been considered a 5% (1 in 20) AEP flood after the construction of Copeton Dam. The effects of Copeton Dam diminish below Moree where other factors are more important for the extent and frequency of flooding.

Infrastructure, including roads, railway lines and flood works, influences the direction and extent of floodwaters. The regulation of the Gwydir River, water harvesting by irrigators and the construction

of the Tareelaroi Weir and Mehi Regulator (which diverts water into the Mehi), and the Boolooroo Weir (which diverts water into Carole Creek) have all led to reduced volumes of water from smaller floods and freshes reaching the Gwydir wetlands (Keyte 1992).

Due to the very low gradient in the Gwydir Valley Floodplain, vegetation density in the floodways can significantly influence flood behaviour (McNamara 1982). There is usually less vegetation in floodways, which are often farmed or otherwise closely grazed in many areas. This can lead to increased flow velocities and possibly increased discharge. More dense vegetation in some areas will slow velocities and increase depth of flow. Where there is more dense vegetation, the effect of vegetation on flood behaviour tends to be highest for smaller floods and is drowned out during larger floods.

Most of the main rivers in the Gwydir floodplain have undergone channel modification (deepening and widening) for more efficient supply and management of allocated water. These modifications have had an impact on smaller floods by providing more flow capacity in creeks and rivers, leading to less flow onto the floodplain. Channel modification did not occur in the wetland areas, except for stock and domestic channels, which are minor and are mostly being filled in by the cap and pipeline projects.

Developing the plan

The Gwydir FMP was developed by the NSW Office of Environment and Heritage (OEH) and the DPI Water in consultation with the Gwydir Technical Advisory Group (TAG) and was based on consensus decision-making and technical methodologies. The draft FMP was developed through a 10 step process which is outlined in the following sections (see Figure 2). In addition to the 10 steps the draft FMP is assessed and reviewed:

- through targeted community consultation
- by an Interagency Regional Panel (IRP)
- through public exhibition.

Targeted community consultation on the draft management zones and rules in the draft Gwydir FMP occurred during March and April 2014. Outcomes from the targeted consultation are provided in this document in 'Consultation and review of the plan'.

In April 2014, the IRP reviewed and endorsed the draft Gwydir FMP management zones and rules for public exhibition. The IRP will also undertake review of submissions made during public exhibition and are responsible for endorsement of the final management zones and rules. Further details on the IRP review process are outlined in 'Consultation and review of the plan'.

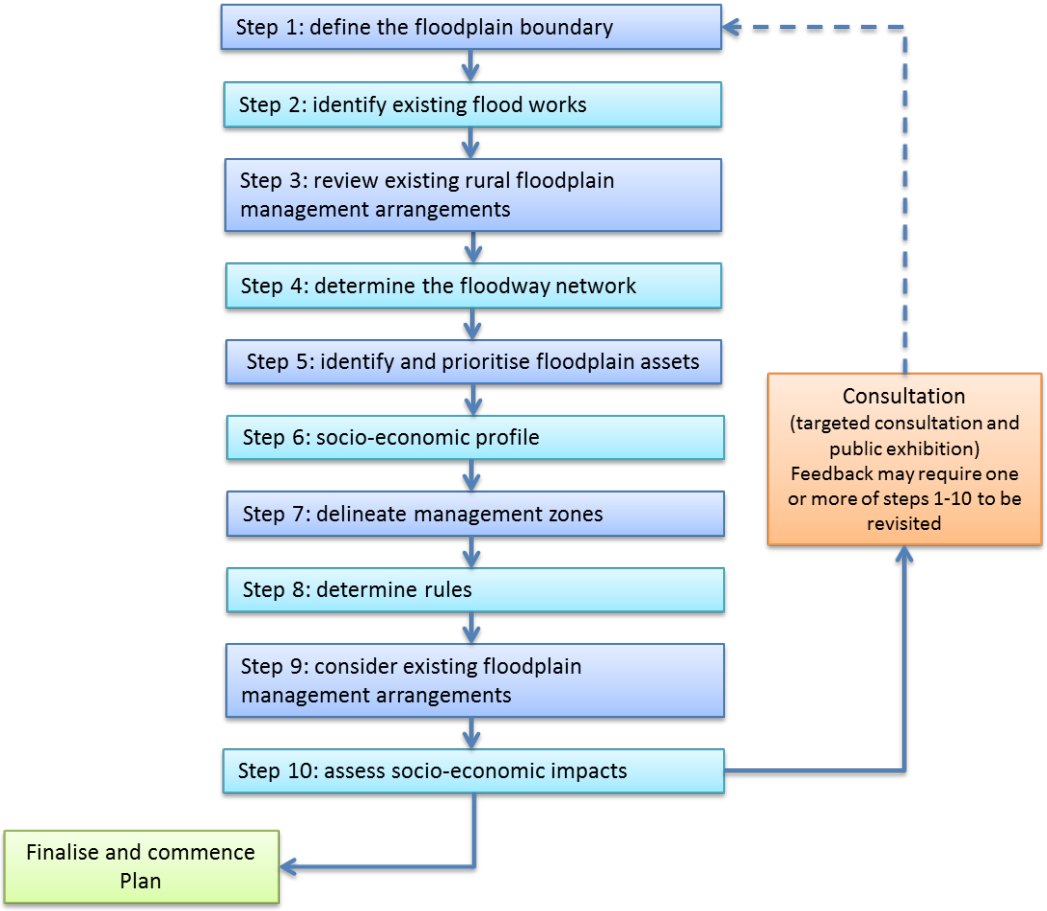

Figure 2: Ten steps used to develop rural floodplain management plans under the *Water Management Act 2000*

Appendix 1 contains a detailed flow diagram of the 10 steps including the input/process and output/outcome related to each step.

Step 1: Define the floodplain boundary

The designated Gwydir Valley Floodplain was based on the following:

- **Existing designated Lower Gwydir Floodplain boundary**

  The Lower Gwydir Floodplain was designated under section 166 Part 8 of the WA 1912 on 18 October 1984. This area includes the parts of the valley in which Part 8 of the WA 1912 currently applies. This area was the basis for capturing existing and potential floodplain developments within the floodplain.

- **Current rural floodplain management plan boundaries**

  Within the Gwydir Valley Floodplain, there are two current and gazetted rural floodplain management plans, one for the Moomin Creek and the other for the Lower Gingham Watercourse. There are also six sets of current floodplain development guidelines, including Carole Creek, Brageen Crossing, Boolcarrol to Bulyeroi, Moree Area, Mehi River and one draft Biniguy to Moree Floodplain Risk Management Study.

- **Hydraulic effects of development**

  The floodplain will include additional flood works that are outside the existing designated floodplain area to meet the objectives of the Gwydir FMP and to assist with the coordination of all flood works across the extent of major flooding.

- **Cadastral relevance**

  Where appropriate, the boundary will align with significant cadastral features to ease administration and to provide clarity to water users.

- **Planning legacy – unregulated water sharing plans (WSPs)**

  Where appropriate, the boundary will align with relevant unregulated water source boundaries. This is to ensure consistency with other boundaries for water management plans under the WMA 2000, ease of administration and increased clarity for water users.

- **Planning legacy – regulated WSPs**

  Where appropriate, the boundary will align with relevant floodplain harvesting boundaries contained in the regulated WSPs of the Barwon-Darling. The location of flood works used to capture water for floodplain harvesting is included within the boundary of the valley in which the point of take has been accounted for or the point of take is located within the valley in which the associated floodplain harvesting has been accounted for.

- **Floodplain harvesting**

  The boundary will be aligned to include areas identified through the Floodplain Harvesting Project's register of interest process and potential floodplain harvesting structures. This will ensure consistency with the NSW Floodplain Harvesting Policy (NSW DPI 2013), which only applies to floodplain harvesting activities on properties where all or part of that property lies within the designated floodplain.

Step 2: Identify existing flood works

Part 6 of the Gwydir FMP identifies existing flood works. Schedule 4 shows a map indicating the overall footprint of approved flood works using information current as of 30 November 2013. Approximately 193,400 hectares of floodplain area is bordered by flood works in the Gwydir Valley Floodplain.

Individual works are not shown in the footprint areas but include:

- infrastructure protection works
- levees
- private access roads
- storages
- below-ground and above-ground supply channels
- stock refuge works, and
- other earthworks and embankments.

Limited height works were also included in the developed areas. Instream works are not identified as flood works but are generally identified as controlled activities under the WMA 2000. Supply channels and storages may be identified as water supply works and flood works.

Step 3: Review existing rural floodplain management arrangements

Existing rural floodplain management arrangements in the Gwydir Valley Floodplain include (see Figure 3):

First generation rural floodplain development guidelines (non-statutory)

- *Guidelines for Mehi River flood plain development* (1971) NSW Water Resources Commission
- *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* (1981) NSW Water Resources Commission
- *Guidelines for Narrabri to Wee Waa* (1984) NSW Water Resources Commission
- *Guidelines for flood plain development Gwydir River downstream of Brageen Crossing* (1989) NSW Department of Water Resources

Second generation statutory rural floodplain management plans (WA 1912)

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

Outcomes from flood studies

- Draft Biniguy to Moree Flood Risk Management Study (prepared in 2005).

The Gwydir FMP will supersede all current plans and guidelines in the Gwydir floodplain when it is finalised and gazetted.

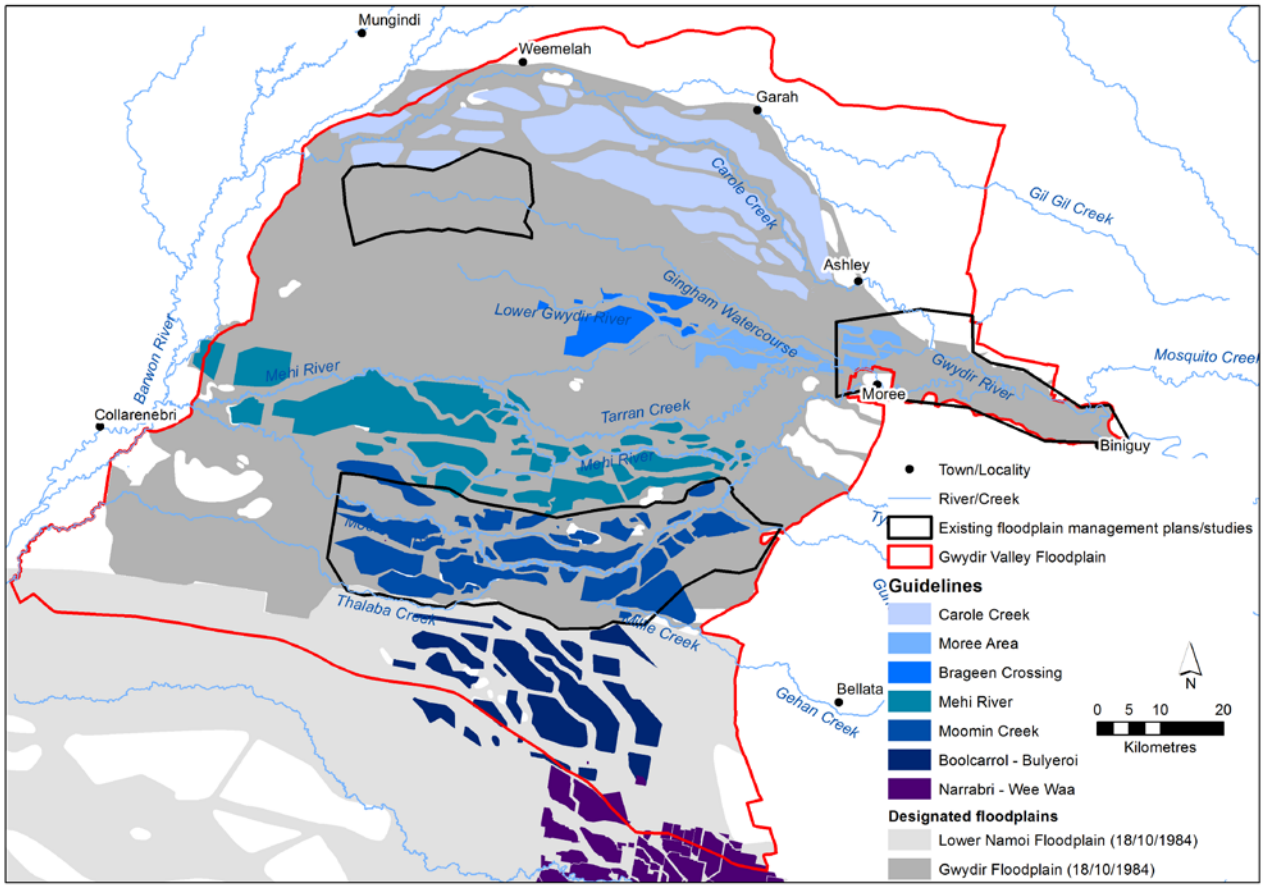

Figure 3: History of floodplain management in the Gwydir Valley Floodplain

A detailed history of floodplain management in the Gwydir Valley Floodplain is outlined in Appendix 2.

Existing rural floodplain management arrangements in the Gwydir Valley Floodplain were reviewed to determine their respective:

- flood management principles
- ecological and cultural heritage considerations
- floodway networks
- hydraulic models
- design flood events
- types of works considered for approval
- advertising requirements for applications
- assessment process for flood-work applications, including any assessment criteria used.

See Appendix 3 for the outcomes of this review process.

Step 4: Determine the floodway network

The Gwydir floodway network (see Figure 4) is comprised of two hydraulic categories:

- floodways, which are areas where a significant discharge of floodwater occurs
- inundation extent, which includes areas of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.

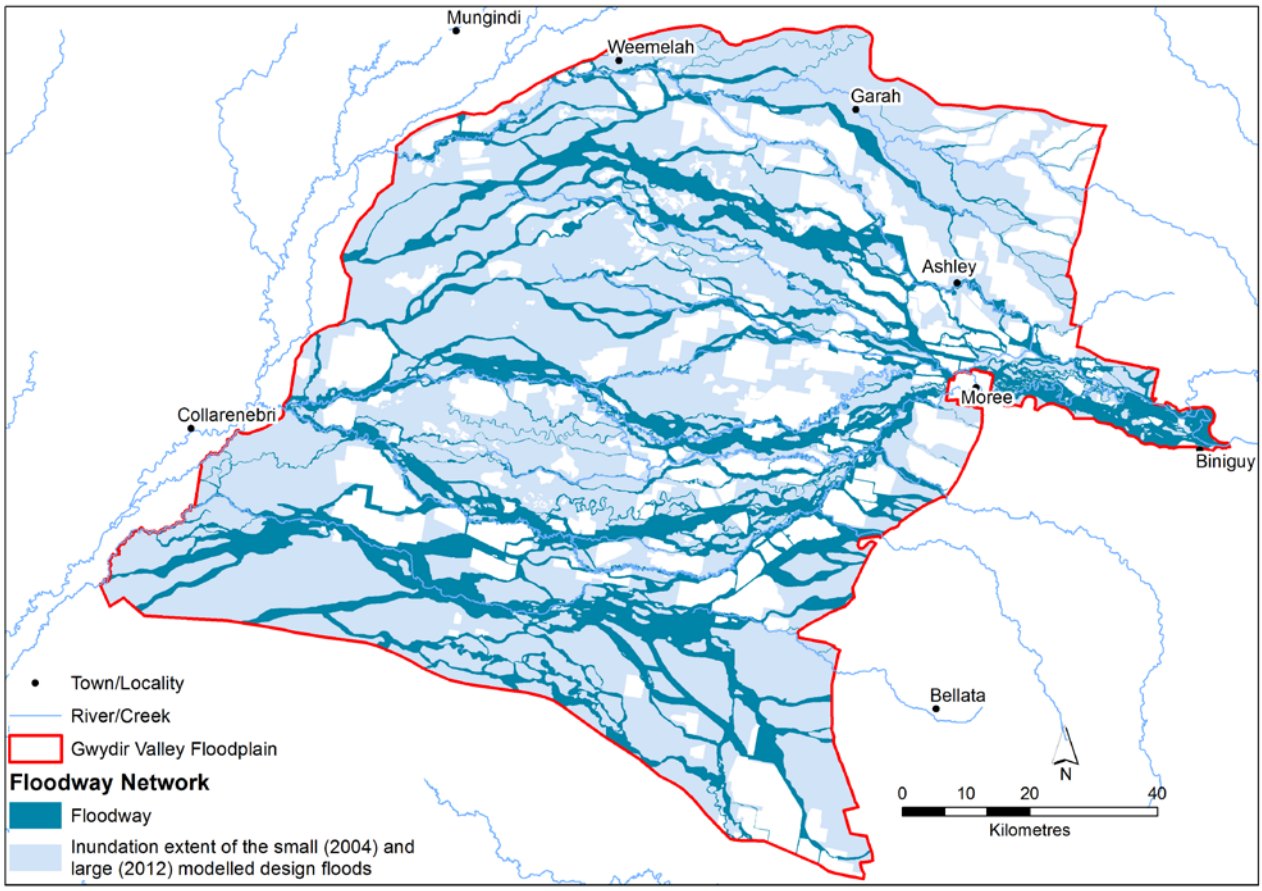

Figure 4: The floodway network for the Gwydir FMP

The floodway network was the hydraulic basis for determining the management zones and rules of the Gwydir FMP. Step 4 involved selecting floods of different magnitudes (design floods) and constructing hydrologic and hydraulic models to simulate the movement of those floods through the river channels and floodplain. This modelling data as well as additional data, such as flood imagery, was used to map the floodway network.

Design floods

Two design floods were selected for the Gwydir FMP:

- large design flood – February 2012 (4% AEP @ Gravesend)
- small design flood – January 2004 (10% AEP @ Gravesend).

A flood frequency analysis was undertaken to assist with the selection of the design floods (Table 1). The flood frequency analysis was used to determine the relationship between peak flood discharge at a location of interest and the likelihood that a flood event of that size or greater would occur (see Appendix 4 for more details on how the flood frequency analysis results were obtained).

Table 1: Annual exceedance probability (AEP) for historic flood events at selected locations in the Gwydir Valley

Reason for selecting a gauging station for analysis	Location (Gauging station number)	% AEP				
		1955	1976	2004	2011	2012
Located in the upper part of the study area Long period of record	Gravesend (GS 418013)	1[a]	3	10	8	4
Located in upper part of study area Downstream of the major tributaries of the Gwydir River and upstream of the first major distributary Long period of record	Pallamallawa (GS 418001)	n/a	10	14	10	9
Measures inflows to the Gwydir wetlands	Yarraman (GS 418004)	n/a	13	33	20	4
Measures inflows to the Gwydir wetlands	Moree (GS 418002)	n/a	n/a	14	5	3
Captures flows from Gurley Creek	Moomin Creek (GS 418067)	n/a	n/a	33	5	3
Located in the lower portion of the wetlands	Gingham Channel (GS 418079)	n/a	n/a	20	11	9
Measures a major unregulated inflow to Moomin Creek	Tycannah Creek (GS 418032)	n/a	14	20	6	3

[a] Based on post-Copeton Dam conditions.

The large design flood (February 2012) was used to determine the extent of the floodway network as well as to delineate the floodway areas. The large design flood was selected because:

- it is the most recent large flood and therefore likely to be in the collective memory of floodplain users
- it is representative of large floods in the valley
- there is a significant amount of information available for the event.

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. Neither of these floods were used for the Gwydir FMP because an analysis of available stream flow data shows that the new large design flood (February 2012) has a larger maximum flood level (15.88 m) at Gravesend gauging station than either the 1971 or 1974 floods (see Table 2). Appendix 5 shows the availability of stream flow data.

Although the 1976 flood had a higher peak height (16.02 m) than the 2012 flood at Gravesend, the 1976 flood was not selected as the large design flood because the February 2012 flood had a higher peak height on the Gwydir River at Moree. The increased levels at Moree were likely due to inflow from the local tributaries, which experienced significant flooding during this flood (OEH 2012).

Table 2: Comparison of floods at Gravesend from 1955 to 2012

Year	Peak height (m)[a]	Peak discharge (ML/d)[a]	Volume (ML)[b]
1955	17.50	570,000	1,036,000
1964	13.87	218,000	564,000
1971	15.54	315,000	1,772,000
1974	15.46	305,000	393,000
1976	16.02	358,000	692,000
1984	14.14	230,000	292,000
1998	12.87	178,000	426,000
2000	11.20	123,000	556,000
2004	13.67	195,000	454,000
2012	15.88	327,000	978,000

[a] Information from OEH, 2012

[b] Information from DWR, 1988

The small design flood (January 2004) is a 10% AEP flood event at Gravesend gauge and 14% AEP flood event at Pallamallawa gauge. This smaller event was selected to ensure that critical flow paths to floodplain assets are identified in the floodway network.

The small design flood was selected because it:

- approximated a 13% AEP flood, which was selected in the Sustainable Rivers Audit to protect ecologically significant areas
- exceeded all the environmental flow rules at Yarraman (MDBA 2010), including:
    - peaking at 6500 ML/d
    - maintaining a flow of 52,500 ML/d for two days
    - exceeding a flow of 150 ML/d for more than 45 days.[2]

Although not a design flood per se, the 1% AEP flood was also selected to provide additional hydraulic information. This additional information will be used to assess the hydraulic impacts of proposed flood works located in floodplain areas outside the inundation extent of the large design flood. The 1% AEP flood extent is an estimate only to assist the hydraulic analysis of flood works and was not mapped for rural floodplain planning purposes or used to design the floodway network. This information is retained by DPI Water and made available to landholders where additional supporting information such as hydraulic modelling is required to support applications for flood works.

Hydrologic models

Hydrologic models simulate rainfall run-off on a catchment by converting storm rainfall to flow hydrographs. This is done using a procedure known as run-off routing, which subtracts losses, such as from soil infiltration, from the total rainfall. The rainfall excess is then routed through the catchment storage to produce discharge hydrographs at specified locations (Laurenson et al. 2010).

[2] The 2004 flood did not meet the environmental requirements at Mallowa as it maintained a flow of 120 ML/d for only five days.

For the development of the Gwydir FMP, hydrological modelling using RORB (RORBWin Version 6.15, 2010) was used to estimate peak flood discharges and hydrographs in 15 ungauged catchments where there is no rainfall data (see Table 3 for a list of the ungauged catchments grouped into sub-floodplain areas).

Hydrological modelling was also undertaken in one gauged catchment (Tycannah Creek), to estimate the four parameters of RORB to be used in the ungauged catchments (see Table 4 for a description of RORB parameters). The Tycannah Creek gauged model was calibrated using the three largest floods that have data available:

- February 2012 (peak discharge of 51,840 ML/day)
- November 2011 (peak discharge of 42,336 ML/day)
- December 2011 (peak discharge of 36,288 ML/day).

Table 3: Hydrological models within each sub-catchment

Sub-floodplain	Sub-catchment hydrological model	
Biniguy to Moree	Mosquito Creek Deadmans Creek Creamin Creek Bell Creek Spring Creek Slaughterhouse Creek	Eatons Creek Mia Mia Creek North East[a] South East[a] West*
Gil Gil and Carole Creeks	Gil Gil 1 to 5	
Mehi River and Moomin Creek	Gurley Creek Millie Creek	Thalaba Creek Tycannah Creek

[a] Inflow based on pluviograph data, catchment area and negligible losses

When calibrating the Tycannah Creek RORB model, the values for k_c were based on the default equation in the RORB manual and catchment area (Laurenson et al. 2010) and m was maintained at the recommended value of 0.8 (see Table 4).

The calibration aimed to achieve a consistent k_c and continuing loss for the model. The initial loss varied for each individual storm, for instance the December 2011 flood event had an initial loss of 0 because the catchment was saturated prior to the storm event (see Table 4). The parameter values used to calibrate the RORB Tycannah Creek model are summarised in Table 4. See Appendix 6 for more details on model building and calibration.

The average values for m, initial loss and continuing loss from the calibrated Tycannah Creek RORB were used to simulate the flows for the 1976, 2004 and 2012 floods in the ungauged catchments. The parameter, k_c was adjusted for the area of each model's sub-catchment.

Table 4: Tycannah Creek RORB calibrated parameter values

Parameter	Description	Flood event			Average
		Nov 2011	Dec 2011	Feb 2012	
k_c	Dimensional coefficient related to the time delay of flood routing	70.9	70.9	70.9	70.9
m	Dimensionless exponent defines the non-linearity of the catchment	0.8	0.8	0.8	0.8
Initial loss (mm)	Used to determines the rainfall excess of the storm	59	0	25	28
Continuing loss (mm/hr)	Used to determine the rainfall excess of the storm	2.8	3.9	2.3	3.0

The simulated flows from the 16 RORB models were used as inputs to the hydraulic models (see Appendix 7 for more detail).

Hydraulic models

The hydraulic models built for the Gwydir FMP were a combination of one-dimensional (1D) river systems which model channel flow and two-dimensional (2D) grids which simulate water flowing over floodplains.

Hydraulic model outputs used in the Gwydir FMP were:

- a depth velocity product map from the large design flood
- inundation extents of the small and large design floods.

These outputs were used to determine the appropriate width of each floodway in the floodway network. The location of flow paths in the models were determined using digital elevation models, flood aerial photography, satellite imagery, watercourse layers, flood marks and local knowledge.

The overall footprint of constructed works was identified in Step 2. For the purposes of hydraulic modelling, these floodplain areas enclosed by existing flood works that are not limited height works were assumed to not be overtopped by floodwater and were excluded from the models' computational grid. Areas protected by limited height works (as indicated by licence files) were assumed to be overtopped by floodwater and were represented in the models as indicated by their licence files.

The hydraulic models used to develop the Gwydir FMP are outlined in Table 5. For information on hydraulic model networks, boundaries, structures, hydraulic parameters and model calibration, see Appendix 8.

Table 5: Hydraulic models in each sub-floodplain

Sub-floodplain/ models	Model description
Upstream of Pallamallawa	The MIKE11 model constructed in 1992 and then updated in 2000 for the draft Biniguy to Moree FMP was utilised for this reach. The model was updated to the 2012 version of the software and the calibration confirmed.
Pallamallawa to Yarraman	A new coupled 1D/2D MIKE Flood model was created. The model utilises inflows from the Biniguy to Moree model at Pallamallawa and extends downstream past Moree to the Gwydir River gauge at Yarraman. The model utilises a 20 m computational grid and the crest level of major features such as roads and railway embankments has been implemented.
Downstream of Yarraman	A new coupled 1D/2D MIKE Flood model was created, utilising some components of the existing 2008 MIKE Flood model, created for the Rivers Environmental Restoration Program. The model extends from Yarraman downstream to the Barwon River and stretches as far north as the Gil Gil Creek floodplain and as far south as the Moomin Creek floodplain. The model utilises a 50 m computational grid and the crest levels of major features such as roads and railway embankments has been implemented.
Thalaba Creek and Southern Floodplain	A new coupled 1D/2D MIKE Flood model was created covering the southern area of the floodplain, particularly Thalaba Creek and its tributaries. It extends from just downstream of the Newell Highway to the confluence with the Barwon, it includes some areas of the Moomin Ck and as far south as the Galathera Creek and inflows from the Namoi River. The model utilises a 50 m computational grid. For the boundary area between the downstream of Yarraman and the Thalaba Creek models, the MIKE11 model constructed in 2002 for the Moomin Creek Floodplain Management Plan has been utilised. This model has been updated and the calibration confirmed.

Model calibration

Hydraulic models were calibrated using selected historic flood events that are around the design flood magnitude and that activate all likely flow paths. The models were calibrated against a range of data sources, which are listed in the Technical Manual.

Mapping the floodway network

Hydraulic model outputs used to map the floodway network included:

- depth velocity product maps for the large design flood (February 2012)
- discharge and velocity values along flow paths
- inundation extents for small (January 2004) and large (February 2012) design floods.

These outputs were used to determine the appropriate width of each floodway and the overall extent of the floodway network. Additional data was used to ensure that the floodway network represents on-ground conditions, including:

- flood aerial photography and satellite imagery from 2004 and 2012 floods
- spatial watercourse layers and topographical mapping – hydrolines
- previous floodplain management plans (Lower Gingham, Moomin Creek) and development guidelines (Biniguy to Moree)
- local knowledge obtained from floodplain communities, and floodplain and environmental managers.

The criteria for delineating the hydraulic categories are summarised in Table 6 and the methods for determining the criteria are outlined in detail below.

Table 6: Summary of criteria used to delineate the hydraulic categories in the floodway network

Hydraulic category	Criteria
Floodways	Areas that have a depth velocity product >0.1 m^2/sec for the large design flood (Feb 2012) Parts of the small design flood extent (Jan 2004) that ensure continuity of floodways
Inundation extent	Flood extent up to the large design flood (Feb 2012) Does not include areas categorised as floodways
Areas outside floodway network	Flood fringe area outside large design flood (Feb 2012) extent Floodplain areas enclosed by existing flood works that were assumed to not be overtopped by floodwater

Mapping floodways

The expected velocity variation with depth for a wide flat floodplain channel with the average slope found across the Gwydir floodplain was investigated to determine an appropriate threshold for identifying floodways (see Figure 5). Figure 6 shows that a depth velocity product of 0.1 would require a depth of approximately 0.45 m which would have a velocity of approximately 0.23 m/s. The areas where these conditions are met will likely be the major rivers and creeks as well as areas along floodways where there is significant conveyance. These areas are also likely to include the main drainage lines and carry the initial flow and smaller flows to floodplain assets. Floodways were therefore identified as any areas with a depth velocity product greater than 0.1 m/s during the 2012 design flood.

The location and size of floodways in the floodway network is strongly reflected in the design of the management zones. Therefore, the socio-economic impacts of the depth velocity product threshold selected were also a consideration. This is discussed further in Step 10: Phase 1.

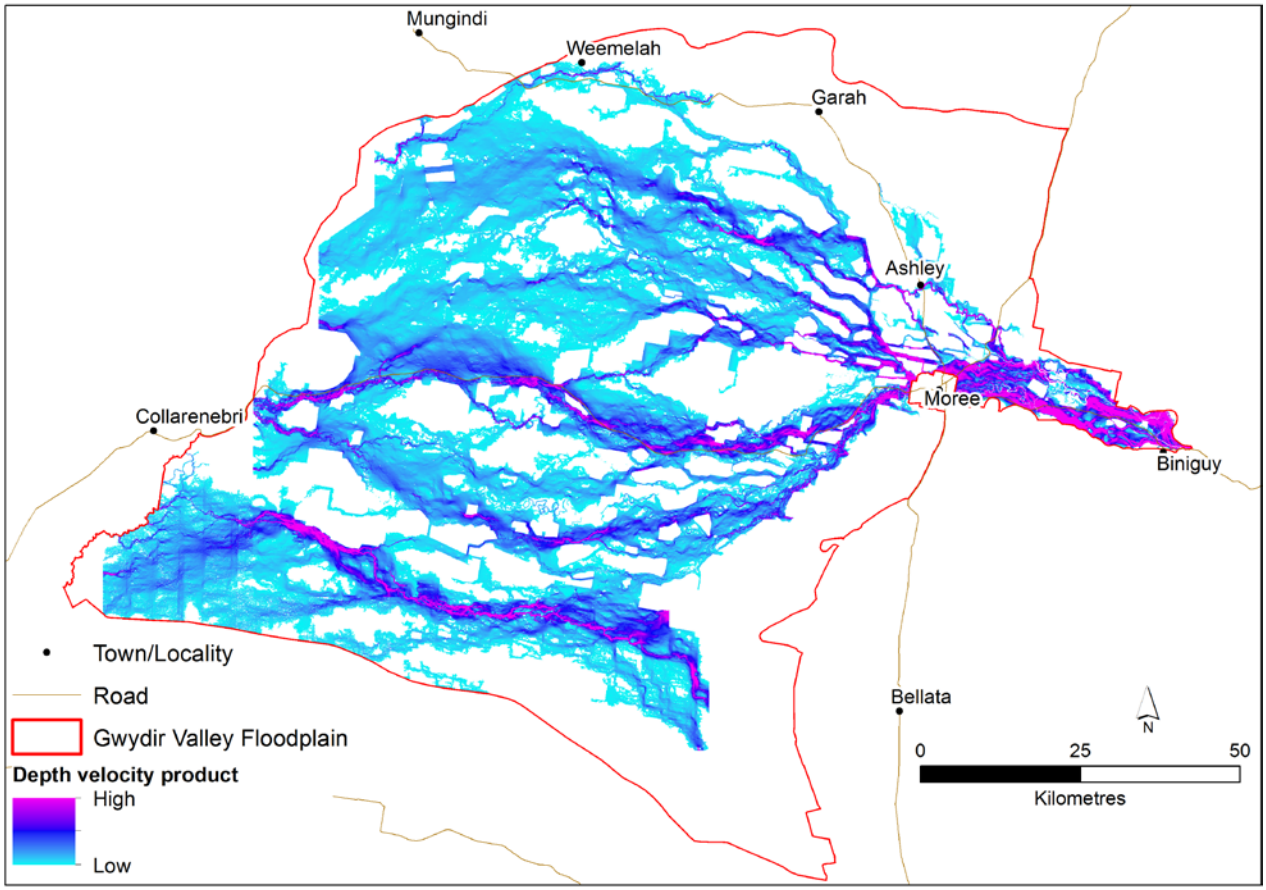

Figure 5: Depth velocity product map

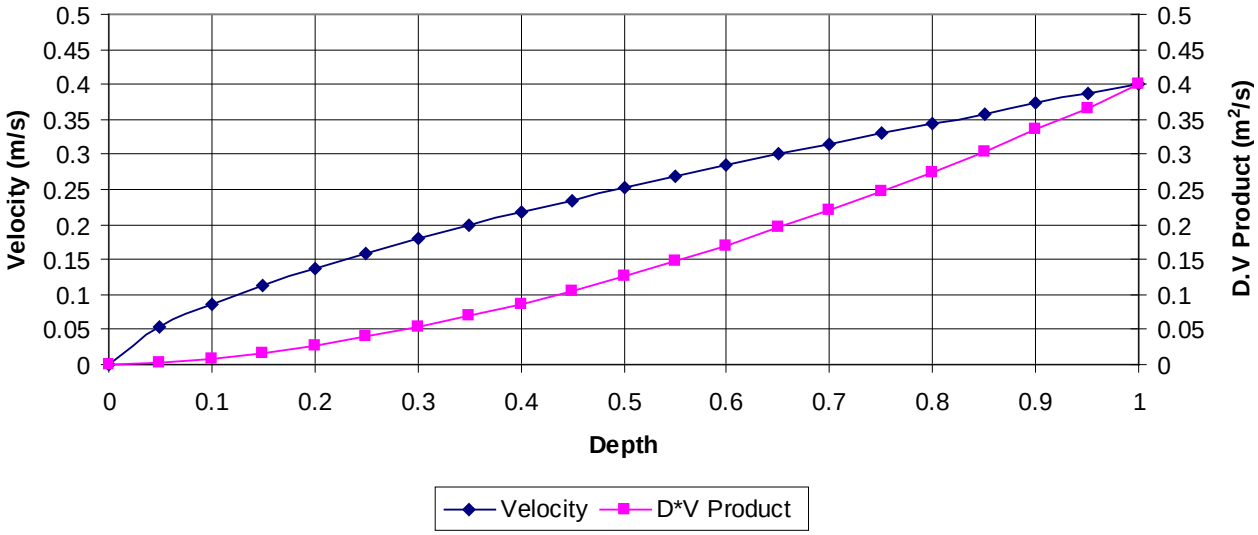

Figure 6: Depth velocity relationship for a general floodplain channel (Mannings formula, n=0.06)

In large flat floodplains such as the Gwydir, the depth velocity product is dominated by depth. Floodways identified by applying a threshold of >0.1 m^2/s to the depth velocity product map were refined by considering the depth velocity product in tandem with flow velocity. In this way, the floodway network also included areas where:

- flow velocity was relatively higher than in other areas of the floodplain regardless of depth
- there was significant depth but relatively low velocity.

The depth velocity product has limitations associated with the resolution of hydraulic models. For instance, in 2D models each cell averages the area that is underneath it, which may be a combination of deeper flood runners and higher ground; however, comparisons of areas modelled in both 1D and 2D models, and comparisons of gaugings made during floods showed that these limitations were not a significant issue for delineating floodways.

The floodways identified from the depth velocity product map of the large design flood were compared with the inundation extent of the small design flood. The comparison was undertaken to ensure that areas of the floodplain activated during small floods were incorporated into the floodway network as floodways, irrespective of whether they reached the selected depth velocity product threshold of >0.1 m^2/s. Such areas are also likely to be the first floodways activated during large flood events. For instance, Figure 7 shows that although the large design flood would activate both floodway A and B, only floodway B would be identified as a floodway using the depth velocity product map. By considering the inundation extent of the small design flood, floodway A would be picked up in the floodway network as a floodway. Such floodways may be important for connecting flood-dependent assets to floodwater during smaller floods.

The inundation extent of the small design flood was automatically generated within the 2D modelled areas and created within the 1D modelled areas using the LiDAR digital elevation models where it was available.

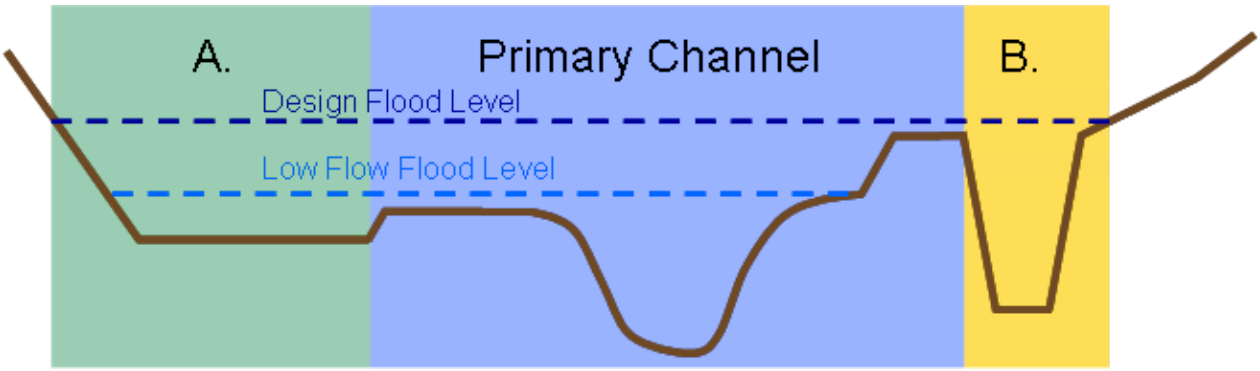

Figure 7: Identification of floodways using the depth velocity product map versus inundation extent

Floodways A and B are both activated during a large design flood; however, only B would meet the threshold for being identified as a floodway in the floodway network according to the depth velocity product map. By considering the low flood level, the significance of Floodway A is also represented in the floodway network.

Mapping inundation extent

Hydraulic modelling produced the inundation extent of the large design flood across the floodplain. Where the flood extent was reliable, its outer limits were used to determine the extent of the floodway network; however, where topographic data was not sufficient to accurately map the extent of the flood, the limits to the floodway network were determined by using aerial and satellite flood imagery that was captured for the design event.

Areas within the extent of the design event are considered important for providing temporary pondage during large floods. Areas beyond the extent of the design flood may also be flood-prone, but would only become inundated during larger floods including extreme events, and would generally have low conveyance or pondage capacity.

Step 5: Identify and prioritise floodplain assets

Step 5 was undertaken to identify and prioritise the many unique and diverse floodplain assets found on the Gwydir Valley Floodplain to inform the design of the management zones and rules.

Ecological assets

The Gwydir FMP considered three types of ecological asset (see Figure 8):

- wetlands
- other floodplain ecosystems
- areas of groundwater recharge (the nature of groundwater recharge is complex and due to data limitations is not shown in Figure 8).

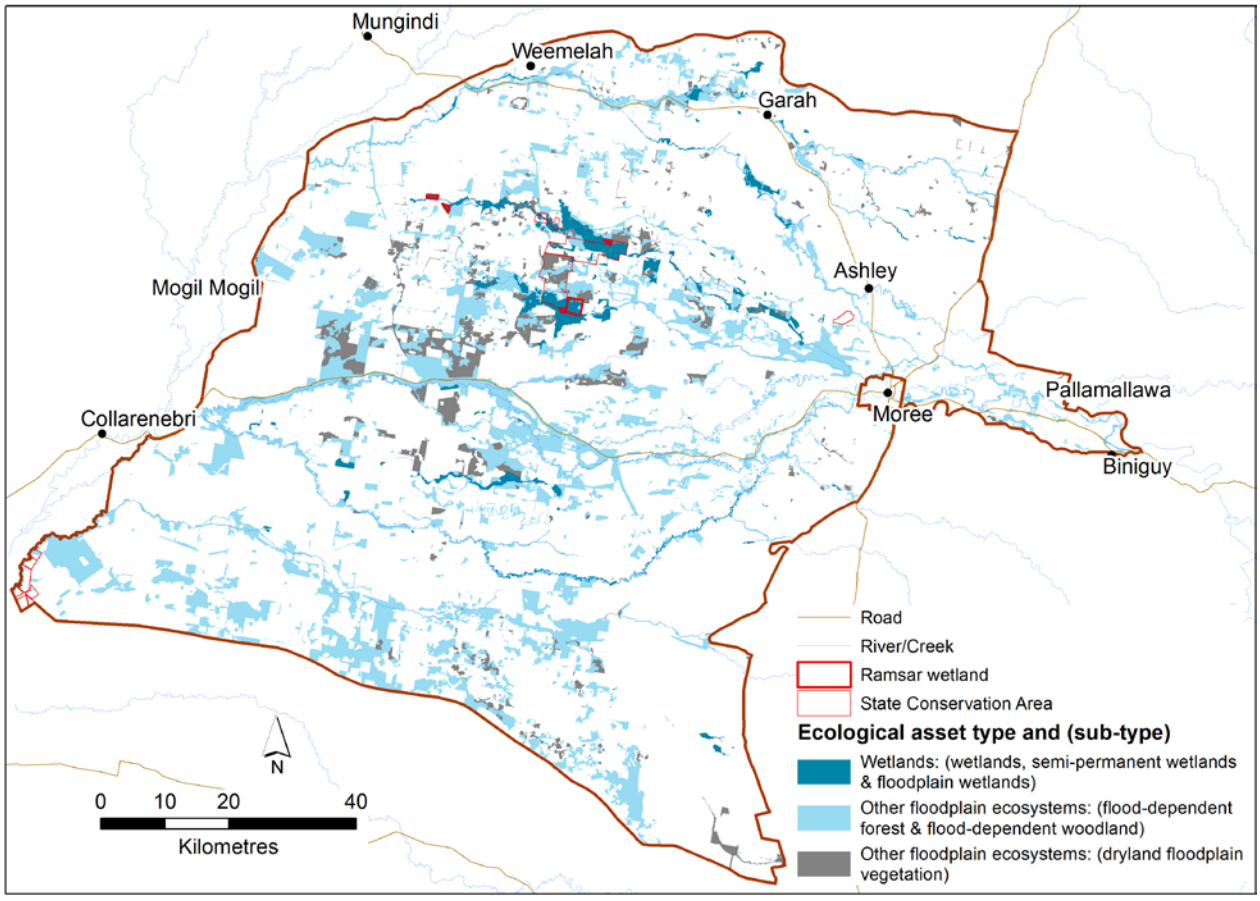

Figure 8: Ecological assets identified on the Gwydir Valley Floodplain for the purposes of the Gwydir FMP

Ecological asset type – wetlands

The ecological asset, *wetlands*, is comprised of floodplain watercourses, semi-permanent wetlands and floodplain wetlands (see Figure 9).

Floodplain watercourses include:

- permanent flowing rivers and creeks[3], including those where the flow is modified by upstream dam(s), to the top of the natural bank regardless of whether the channel has been physically modified
- intermittent flowing rivers and creeks that retain water in a series of disconnected pools after flow ceases[3], including those where the flow is modified by upstream dam(s), to the top of the natural bank regardless of whether the channel has been physically modified

[3] These floodplain watercourses were picked up in the floodway network and were not re-identified in the ecological assessment.

- flood channels or flood runners that run across or along floodplains during high-flow events[4]
- billabongs, lakes and lagoons that are fed by floodwater.

Semi-permanent wetlands require annual or a higher frequency of inundation to maintain structure and community composition. Semi-permanent wetlands contain the vegetation types (Bowen & Simpson 2010; Bowen et al. 2012):

- water couch (*Paspalum distichum*)
- ribbed spike rush (*Eleocharis plana*)
- marsh club rush (*Bolboschoenus fluviatilis*)
- Juncus species
- common reed (*Phragmites australis*)
- cumbungi (*Typha dominensis*)
- mapped waterbird rookeries.

Floodplain wetlands require flooding at intervals of one to five years. Floodplain wetlands contain the vegetation types (Bowen & Simpson 2010):

- river cooba (*Acacia stenophylla*) swamp (PCT ID 241)
- lignum shrubland (*Duma florulenta*) (PCT ID 247).

Wetlands can provide habitat for flood-dependent fauna such as nesting waterbirds, fish, amphibians and turtles.

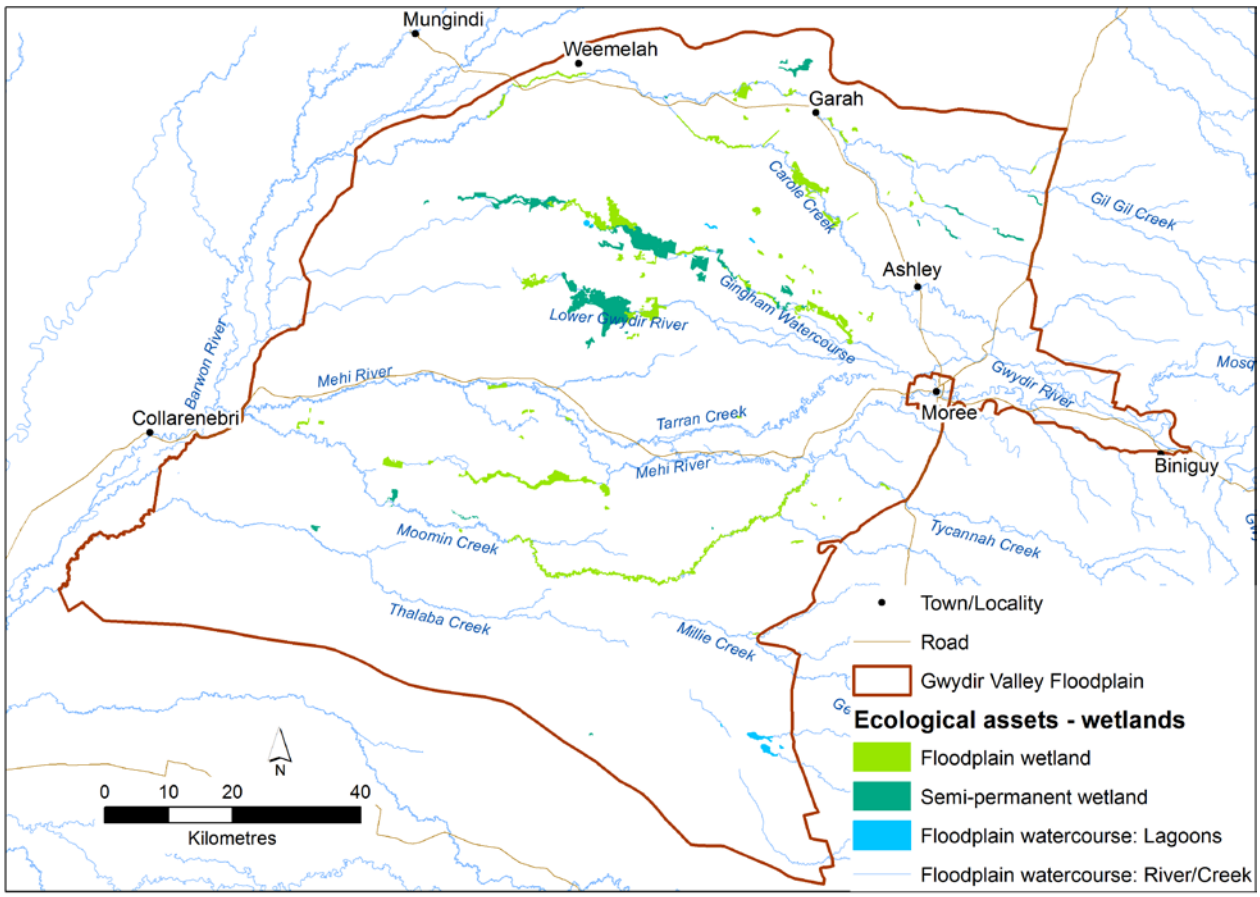

Figure 9: Location and type of wetlands identified as ecological assets

[4] These floodplain watercourses were picked up in the floodway network and were not re-identified in the ecological assessment.

Ecological asset type – other floodplain ecosystems

The ecological asset, *other floodplain ecosystems*, is comprised of flood-dependent forest, flood-dependent woodlands and non-flood-dependent vegetation (see Figure 10).

Flood-dependent forest requires flooding at intervals of between one and three years (Roberts & Marston 2011) or up to every five years (Bowen et al. 2012). Flood-dependent forest contains the vegetation type river red gum (*Eucalyptus camaldulensis*) open forest of the Darling Riverine Plain (PCT ID 36).

Flood-dependent woodland requires flooding at least once every ten years (Bowen et al. 2012). Flood-dependent woodland contains the vegetation types (Bowen & Simpson 2010):

- coolibah (*Eucalyptus coolabah*) woodland (PCT ID's 39 & 40)
- black box (*Eucalyptus largiflorens*) woodlands on floodplains of the NSW central and northern wheatbelt (PCT ID 37).

The flood-dependent forests and woodland provide habitat for flood-dependent fauna including waterbirds and frogs. Turtles were recorded as present in flood-dependent forest, but not flood-dependent woodland.

Non-flood-dependent vegetation or dryland species of vegetation such as belah (*Casuarina cristata*) may occur adjacent to flood-dependent vegetation in response to rainfall events and may tolerate infrequent small floods. This vegetation is also documented to be essential habitat for waterbird feeding and breeding (Bowen et al. 2012). The non-flood-dependent vegetation types that were identified as part of this ecological asset were:

- belah (*Casuarina cristata*) woodland
- native millet/ cup grass (*Panicum decompositum/ Eriochloa crebra*) grassland
- windmill grass (*Chloris truncate*) – copperburr alluvial plains shrubby partly derived grasslands (PCT ID 49).

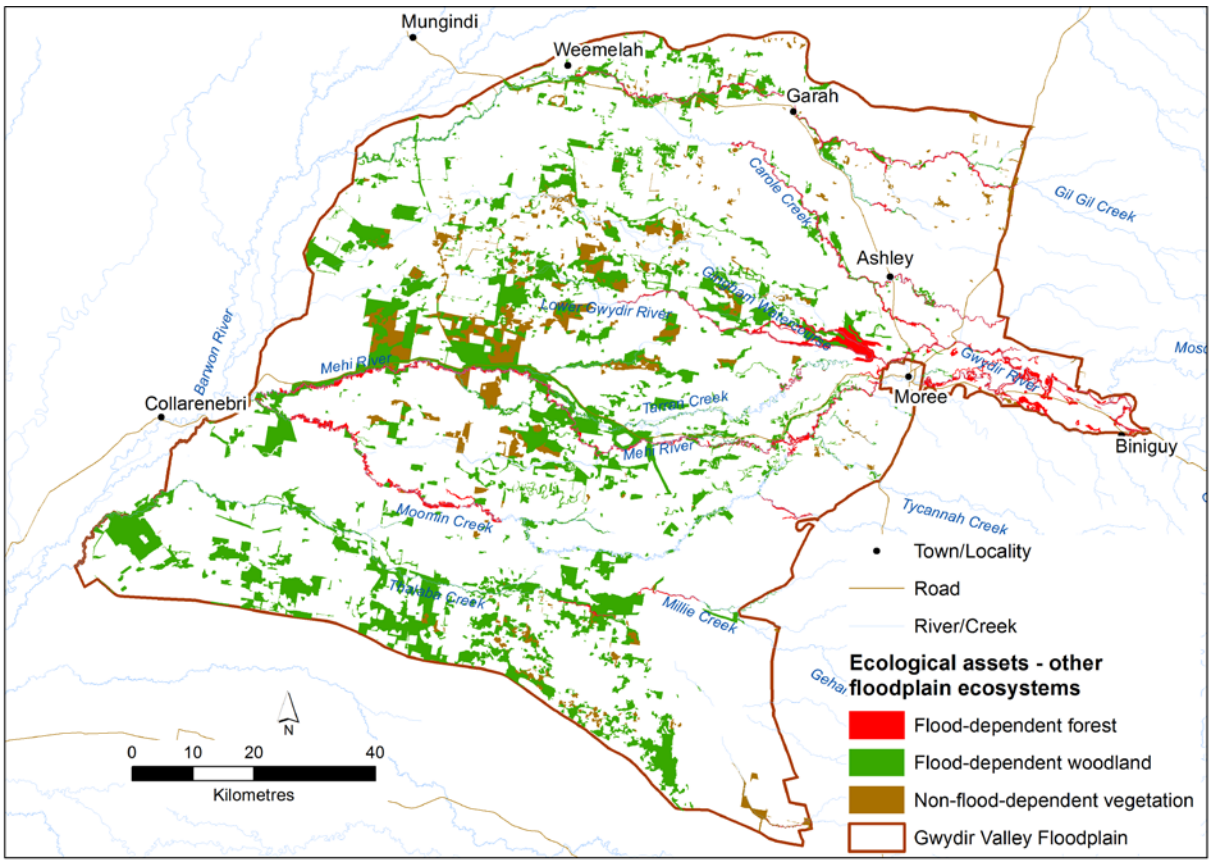

Figure 10: Location and type of other floodplain ecosystems identified as ecological assets

Ecological asset type – groundwater recharge

Groundwater recharge areas are areas where water from a flood event leaks through the soil profile into the underlying aquifers. The whole of the Lower Gwydir alluvium is a recharge zone and the dominant recharge source is leakage from the rivers and watercourses.

The alluvial sediments are in direct hydraulic connection with the watercourses upstream of Moree. This enables direct recharge from the river into the aquifer system. During years of average stream flow, the areas upstream of Moree and those located near rivers and creeks that have regulated flow could expect minimal recharge; however, recharge pulses will occur after major flood events when large volumes of water are available to recharge the aquifer system (Barrett 2009). In average years, the greatest proportion of recharge is expected to come from direct vertical infiltration from the regulated streams (Kalaitzis 1999).

Some additional recharge is also expected from rainfall, weir pools, on-farm storages, irrigation losses and groundwater inflows from the east (Barrett 2009). Hydrographs also indicate that leakage from the upper aquifer to the lower aquifer is occurring (Barrett 2009). Extraction from the lower aquifer will result in induced leakage from the upper aquifer, in some cases resulting in dewatering of the upper aquifer (Barrett 2009).

Flood-sourced groundwater recharge sites have not been previously mapped for most of the Gwydir floodplain. For the purposes of the Gwydir FMP, indicative groundwater recharge sites were inferred from mapping of alluvial soil types, the Great Artesian Basin Surat Shallow Groundwater Source and the Surat Groundwater Source.

The Gwydir FMP also considered vegetation communities that are associated with groundwater recharge, including:

- poplar box (*Eucalyptus populnea*) and white cypress pine (*Callitris glaucophylla*) woodlands on sandy loam soils
- dirty gum (*Eucalyptus chloroclada*) and white cypress pine (*Callitris glaucophylla*) woodlands on alluvial sand lenses.

The Gwydir FMP will assist in maintaining flood-sourced groundwater recharge by protecting as natural a flood-flow distribution as practicable and maintaining core floodplain inundation. This will improve the likelihood and duration of natural groundwater recharge areas being subjected to natural flood inundation. If further information on flood-sourced groundwater recharge areas becomes available, the Gwydir FMP may need to be reviewed to ensure that they are adequately considered in the design of the management zones and rules.

Flood dependency of wetlands and other floodplain ecosystems

Broad vegetation groups of the Gwydir floodplain are distributed across the landscape according to their relative water requirements. In particular, the distribution of vegetation in the floodplain can be related to flooding patterns at two time scales; in the short term (months) driven by individual flood events and in the long term (decades) driven by inundation frequency (Thomas et al. 2010).

The level of flood dependency of assets was a key consideration when making management decisions. The level of flood dependency is described in terms of annual exceedance probability (AEP) (see Table 7). Once identified, wetlands and other floodplain ecosystems were categorised into hydro-ecological functional groups according to the flooding requirements of the dominant or canopy species in a vegetation community (Bowen et al. 2012) and the high level of flood dependency of watercourses to maintain their ecological character. The ecological assets were then described using these hydro-ecological functional groups (see Table 7).

Table 7: Hydro-ecological functional groups that comprise wetlands and other floodplain ecosystems in the Gwydir floodplain and their flooding frequency requirements

Ecological asset	Description (hydro-ecological functional groups)	Vegetation/watercourse class	AEP required
Wetlands	Floodplain watercourses	Drainage lines Lagoons Billabongs Waterholes Lakes	<1 in 1
	Semi-permanent wetland	Semi-permanent wetland	<1 in 1
	Floodplain wetland	River cooba swamp Lignum shrubland Coolibah – river cooba – lignum	1 in 1 to 1 in 5
Other floodplain ecosystems	Flood-dependent forest	River red gum	1 in 3 to 1 in 5
	Flood-dependent woodland	Coolibah woodland Black box woodland	1 in <10
	Non flood-dependent vegetation	Belah woodlands Windmill grass Native millet/cup grass	N/A

The vegetation map used was a composite of three maps:

- Gwydir Wetland and Floodplain vegetation mapping (Bowen & Simpson 2010) (400,000 ha)
- Border Rivers-Gwydir CMA vegetation composite (Eco Logical Australia 2008) (690,000 ha)
- Greater Namoi vegetation mapping (Roff et al. 2012) (23,500 ha).

Vegetation classes were either combined or, where that was not possible, simplified into broader flood-dependent functional groups (Table 7) (Bowen & Simpson 2010). For instance, the Eco Logical Australia 2008 map was a composite of multiple existing maps and included broad regional vegetation communities. It was therefore possible to break the classes down using the primary, secondary and tertiary species included in the attributes. For example, the vegetation class coolibah – poplar box – belah could be subdivided into coolibah open woodland and belah woodland on the basis of the primary species. Any mapped classes that were described as cultivated (i.e. understory removed to allow cropping) were discarded from the analysis as they were assumed to be in very poor condition. Furthermore, datasets were refined through desk-top and on-ground analysis to reflect the current vegetation extent.

Prioritisation of ecological assets

Identification of priority ecological assets was carried out using conservation planning decision-support software, hereafter Marxan (Ball & Possingham 2000; Possingham et al. 2000; Ball et al. 2009). The role of Marxan was to assist the determination of areas of high conservation significance where floodplain connectivity should be secured. These areas were then afforded protection through their inclusion in the appropriate management zone, depending on their flooding requirements.

The prioritisation method involved:

- partitioning the floodplain into *planning units* (see Appendix 9)
- using local and expert knowledge to set *targets for ecological surrogates* (see Appendix 10). Ecological surrogates are referred to in the Gwydir FMP as ecological values

- developing a spatial layer (*constraint surface*) that represents the ability to physically connect floodwater to ecological assets to constrain the selection of priority planning units (see Appendix 11)
- running Marxan to *identify priority ecological assets* and *selection frequency scores*.

Ecological assets were prioritised using mapping of:

- fauna habitat (see Appendix 12), including:
    - colonial waterbird nesting sites
    - modelled waterbird breeding habitat
    - species distribution models for frogs and turtles
- vegetation species distribution (see ecological assets) for species, comprising:
    - wetlands
    - other floodplain ecosystems
- fauna observations (see Appendix 13) for:
    - fish, including biodiversity hotspots
    - frogs
    - amphibious reptiles
    - mammals
- areas of state and international conservation significance, including:
    - Ramsar sites
    - wetlands identified in current floodplain management plans.

Priority ecological assets

For the Gwydir floodplain, the decision-support software was run with one million iterations across 100 runs using a simulated annealing optimisation method[5] (Ball & Possingham 2000). The best solution from the 100 runs was chosen to identify the high-priority planning units (Figure 11). Thirty-five per cent of the planning units (*n*=7432) were assessed as a priority.

The ecological assets were then prioritised by relating the high-priority planning units to the natural landscape patterns, which for the Gwydir FMP, were mapped vegetation boundaries. The final product was a map of high-priority ecological assets (Figure 12). Almost all (>99%) of the vegetation-based ecological assets were identified as a priority asset, which is mainly due to the fragmented landscape of the Gwydir floodplain.

[5] a way of finding an optimal solution to a problem by comparing many possible solutions

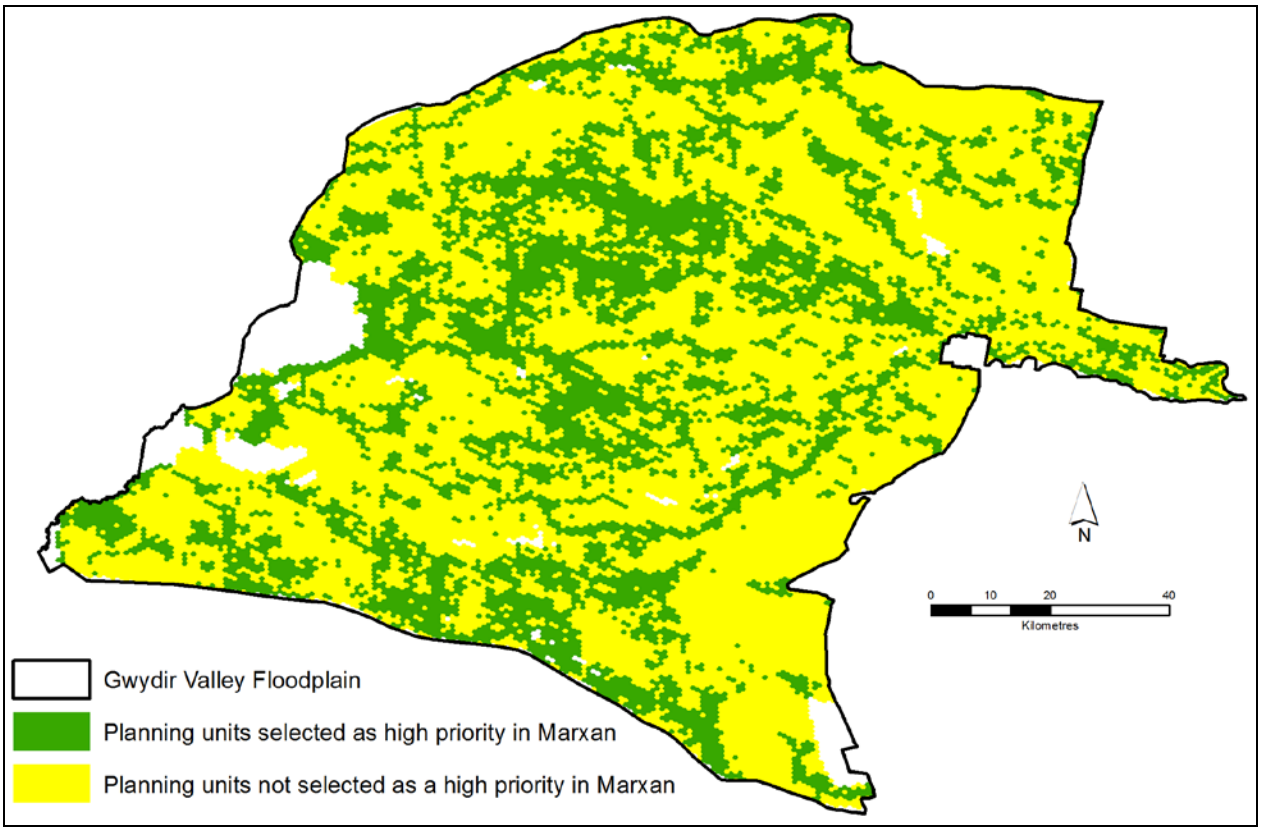

Figure 11: High-priority planning units selected in Marxan

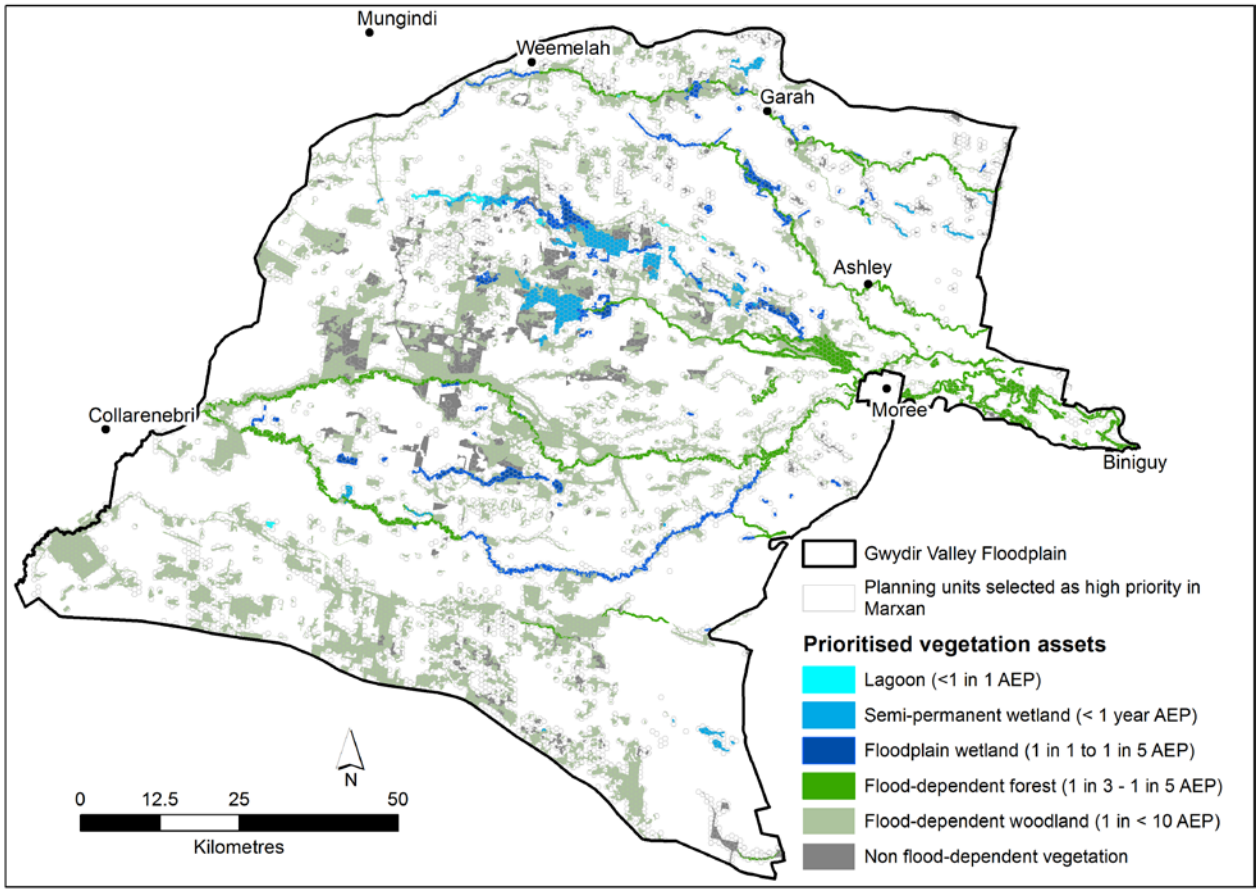

Figure 12: Prioritised assets identified by relating high-priority planning units to the natural landscape patterns, which are mapped vegetation boundaries

Selection frequency score

Another output of the software runs is the selection frequency score (Figure 13).The number of times a planning unit was selected in each of the 100 runs was counted to measure the relative importance of planning units. The selection frequency score provides feedback on how likely it is a specific area will be included in an efficient solution. When a planning unit is never selected it is attributed with a frequency score of 0, while those that are always selected will have a selection frequency equal to the maximum number of runs of the Marxan software (e.g. the highest possible frequency score for a planning unit is 100, based on 100 runs). Areas with a high frequency score are consistently important in the solutions. They are highly irreplaceable and have fewer substitutes if conservation objectives are to be achieved efficiently. This information was used to assist with justifying the adjustment of management zones to better protect flood connectivity to ecological assets in Step 7.

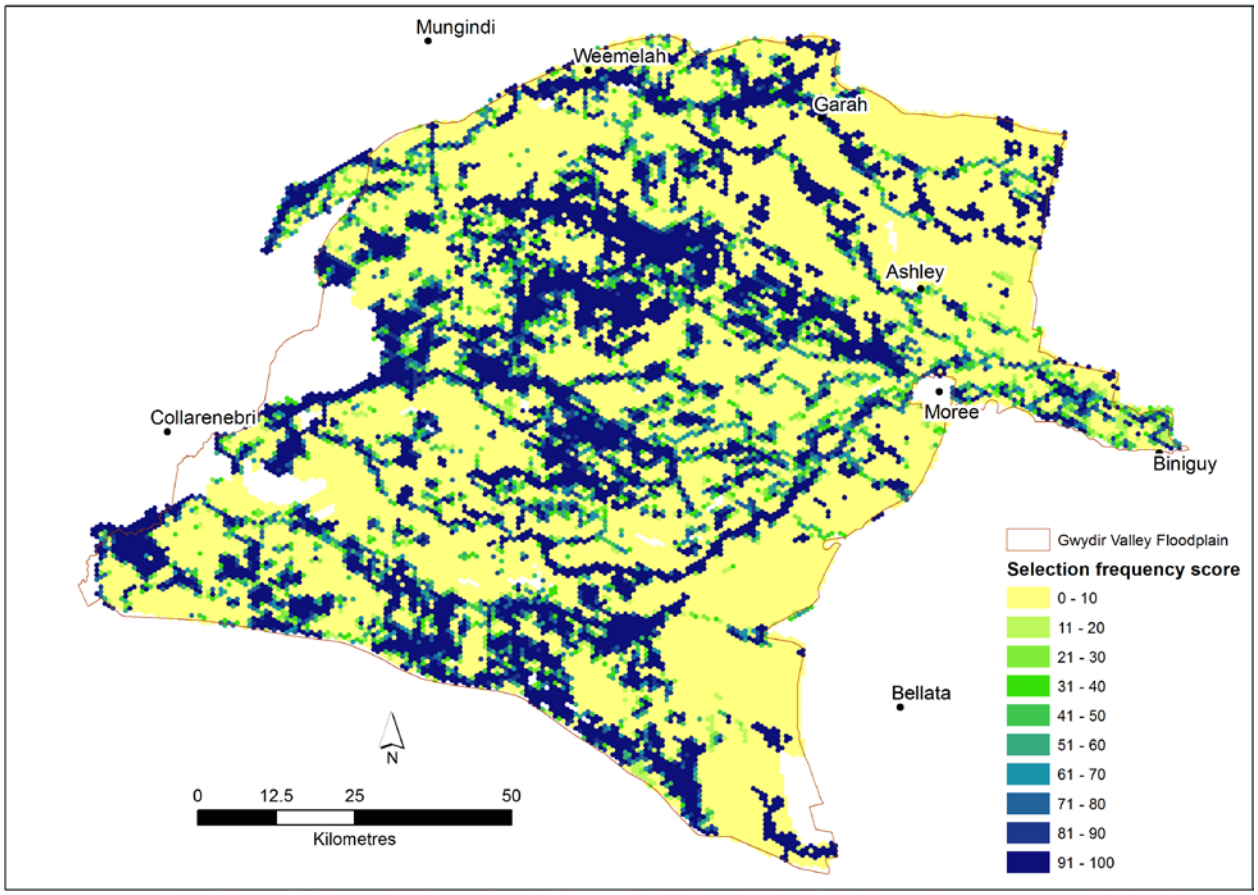

Figure 13: Selection frequency scores of planning units

Cultural assets

The Gwydir Valley Floodplain contains assets that have Aboriginal and cultural heritage value (cultural assets). The Gwydir FMP identified and prioritised two types of cultural assets:

- Aboriginal values
- heritage sites.

Cultural asset type – Aboriginal values

Aboriginal values are sites, objects, landscapes, resources and beliefs that are important to Aboriginal people as part of their continuing culture.

The Gamilaroi[6] people are the traditional owners of the Gingham floodplain, Gwydir Wetlands and most of the length of the Gwydir River. Today, the Gwydir floodplain contains many cultural sites and values that are important to the local Aboriginal community. Due to the sensitive nature of the data, specific Aboriginal values cannot be listed or mapped in published documents; however, Aboriginal values were generally found to include:

- wetlands and river channels, which were an important focus of settlement
- locations of Bora (initiation) ceremonies
- core semi-permanent wetlands with iconic plants (e.g. cumbungi and nardoo)
- riverine forests, woodland and grassland areas with iconic plants (e.g. river cooba, river red gum, coolabah, Mitchell grass and native millet)
- sites with scarred trees
- long-lasting waterholes of swamps in wetland areas that may have been a focus of settlement
- semi-permanent waterholes and channels on the floodplain that may have been a focus of settlement.

For the Gwydir FMP, Aboriginal values were identified at a regional scale by:

- reviewing previous studies that had investigated cultural values in the floodplain
- consulting with various NSW Government agencies involved with landscape management within the valley (e.g. Local Land Services, National Parks and Wildlife Service, DPI Water and OEH)
- reviewing the values recorded in the Aboriginal Heritage Information Management System (AHIMS)
- targeted consultation with members of the Aboriginal community with knowledge of values connected with the floodplain
- consultation with the Aboriginal Technical Working Group (ATWG), which was comprised of Aboriginal people with cultural connection to the floodplain
- context setting using existing spatial information about the potential distribution of unidentified values using the Aboriginal Sites Decision Support Tool (ASDST) (Appendix 14).

Cultural asset type – heritage sites

Heritage sites are cultural heritage objects and places as listed on Commonwealth, state and local government heritage registers. Some Aboriginal values may also be heritage sites and for the purposes of the Gwydir FMP, heritage sites were divided into historic heritage sites and Aboriginal heritage sites.

Commonwealth, state and local government heritage registers include:

- the State Heritage Inventory (see www.environment.nsw.gov.au/heritageapp/heritagesearch.aspx)
- the Historic Heritage Information Management System (HHIMS) (see www.environment.nsw.gov.au/licences/)
- AHIMS (see www.environment.nsw.gov.au/licences/).

Heritage sites are identified by conducting a search of these registers.

Flood dependency of Aboriginal values and heritage sites

During the development of the Gwydir FMP, flood dependency of cultural assets was established so that consideration could be given to how changes to the flooding regime may impact the assets across the floodplain.

[6] Also known as Kamilaroi.

Flood dependency – Aboriginal values

Flood dependency of the Aboriginal values nominated by the Aboriginal community was determined in direct discussion with knowledge holders about the nature of the value, and how it is connected with floodwater. The places nominated as having significant Aboriginal value were all found to have a strong connection or dependency on flooding.

Flood-dependent Aboriginal values included sites that are not necessarily flood-dependent, but where the purpose or location of the site is flood-dependent; for instance, ceremonial locations connected with intact flood-dependent vegetation and camp sites near wetlands that may persist regardless of flooding, but may not be utilised until the landscape is flooded, and resources only abundant during flood events.

Flood dependency – historic heritage sites

Flood dependency was assessed by reviewing the heritage listing records to establish the nature of the heritage theme and value of the site and determine if this was dependent on, or connected with floodwater. In the Gwydir floodplain, none of the listed floodplain historic assets that were reviewed were found to have flood-dependent values.

Flood dependency – Aboriginal heritage sites

Through consultation with the ATWG, the following Aboriginal site types occurring within the region were identified as having flood-dependent values associated with them:

- cultural modifications (e.g. coolamon scars) to living trees that were flood-dependent species
- fish traps
- ceremony sites located within or surrounded by floodplain vegetation[7].

Some Aboriginal sites were identified as being sensitive to the effect of erosion associated with the redistribution of flood flow or to ground disturbance caused by the construction of new flood works or the modification of existing flood works. For instance, thin elevated ridges known as ‘red country’, which were inhabited in floods when ‘black country’ (floodplains and wetlands) was too wet to live in, contain stone artefact sites and plants with cultural values. Such plants include belah, quandong and boobialla that may be vulnerable to changes in flood flows.

The specific flood dependency of cultural assets in the Gwydir floodplain is outlined in Table 8.

Table 8: Flood dependency of cultural assets in the Gwydir floodplain

Asset	Type	Flood dependency
Aboriginal values	Scarred trees	Dependent on the flood dependency of the living vegetation
	Places identified by the community	Nine areas that are dependent on frequent flooding
	Fish traps	No fish traps were recorded; if found, dependent on frequent flooding
Heritage sites	Bridge	Not flood-dependent

Prioritisation of cultural assets

High-priority cultural assets that are dependent on flooding were considered in the design of the management zones to protect their flood connectivity. The process for identifying these high-priority cultural assets is outlined below.

[7] While it is recognised the ceremony site itself may not be flood-dependent, based on advice received from the ATWG, it was noted that many ceremonies were connected with the surrounding flood-dependent landscape, and were undertaken when many floodplain resources were abundant.

Cultural assets vulnerable to the effect of erosion associated with the redistribution of flood flow or vulnerable to the direct impacts of the installation of new flood works or the modification of current works are not dealt with in the design of the management zones. Therefore, these cultural assets were not prioritised. Where identified, these cultural assets will be an additional consideration for licensing staff when assessing flood-work applications.

Prioritisation of Aboriginal heritage sites

Scarred trees

Scarred trees were investigated using AHIMS records and by inspecting the original site cards. Those scarred trees where it was clear that the tree was dead at the time of the recording, were excluded from the prioritisation. The location of each tree was also compared to current 2009 SPOT imagery to ensure that there was a reasonable likelihood the tree still existed (some recordings were over 30 years old). As a result of the comparison with SPOT, some recordings were found to have locations recorded that were inconsistent with information in the original site card and were corrected when found.

Fish traps

There are no records of fish traps within the study region; however, the possibility of them being used was noted by the ATWG.

Ceremonial sites

A search of the AHIMS database identified several ceremony sites recorded in the region. Based on the records and comparison with SPOT 2009 imagery, there was little remaining physically of these sites. The exception was AHIMS site 10–2–0014. The ceremonial site and associated carved trees were originally recorded by Etheridge in the late 19th century (Etheridge 1918), and when the AHIMS site was recorded in the 1980s, there was still evidence of the carved trees in situ. Given the rarity of sites remaining intact, this is a highly significant place, and was included as an Aboriginal value.

Prioritisation of Aboriginal values

Targeted consultation was undertaken with members of the Aboriginal community throughout the region who have knowledge about flood-dependent Aboriginal values. Given available timeframes, this was not an exhaustive consultation process, and the incorporation of Aboriginal values into the plan should be considered an ongoing process.

Discussions were had in person with community members with printed maps that they could annotate. The maps were left with the community members to give them a chance to consider the requirements of the plans, and follow-up discussions were held a week or so later.

The consultation process identified nine areas where the significance of Aboriginal values warranted an exclusion of further flood works. In some cases, this was because of the sensitivity of important and largely intact ceremony grounds. In other cases, this was due to the occurrence of relatively intact land that was rich with sites associated with living in the floodplain.

The nine areas were digitised and used to inform the design of the zones of the plan. The areas identified and their associated values will be stored in a database of flood-dependent Aboriginal values being established by DPI Water. The database will be used by DPI Water staff when implementing the plan.

Step 6: Prepare a socio-economic profile

To develop options for future floodplain management, the floodplain area must be understood and the ability of the community to absorb change appreciated. A socio-economic profile of the Gwydir Valley Floodplain was determined in this step to effectively consider the social and economic impact of development controls in the floodplain and flood risk to life and property from the effects of flooding.

The profile is an assembly of existing key socio-economic data which provide a general picture of the catchment in terms of its socio-demographic and economic structures. Key socio-economic data that informs the baseline profile include:

- geographies that are relevant to the socio-economic discussion of water use on the floodplain
- demographic profiles
- employment by industry
- income statistics
- economic wellbeing indicators
- production statistics.

Information from this assessment is used in the socio-economic impact analysis of the proposed plan, which is outlined in Step 10. The socio-economic impact analysis is undertaken in coordination with the development of management zones and rules for a valley and informs Steps 7, 8 and 9 of this process.

Study area geographies

There are three geographies that are relevant to the socio-economic discussion of water use on the Gwydir floodplain (see Table 9 for a description).

Table 9: Description of study area geographies used in socio-economic profile

Geography	Size (hectares)	Description
Gwydir Floodplain Economy	2,257,613	Most goods and services consumed in the Gwydir area are sourced from Moree or the small townships in this area
Gwydir Rural Floodplain	1,089,800	The residents who live and work in this area are predominantly agricultural based, but the community does include people who live in small rural towns. There are limited community services and infrastructure provided in this area; consequently most of the required farm inputs and outputs and human services are provided from the local towns and regional centres.
Gwydir Urban Floodplain	n/a	Constitutes the regional centre of Moree and the townships of Ashley and Pallamallawa. Floodwater management is provided under the Local Government Act. The communities that live in these towns are reliant upon the surrounding rural floodplain areas both as a source of employment and as a provider of services. A significant socio-economic component of all these areas is agricultural production derived from the floodplain.

The ABS Agricultural Census 2011 (ABS 2012) is a comprehensive source of data on both dry land and irrigated agricultural production. The ABS Agricultural Census 2011 is available for four regions that partially cover the Gwydir floodplain: Moree, Moree Region, Narrabri Region and Walgett-Lightning Ridge region. As the Moree and Moree Region as a whole better represent the area of the Gwydir FMP, we have used that data and scaled it back to the area of the Gwydir Valley Floodplain.

Demographic profiles

Demographic information is provided in Table 10 and includes information on the population, percentage of the population living in towns, percentage of the community who are Indigenous, gender ratio and the dependency ratio for each geography and the state average.

Table 10: Demographic information per socio-economic geography

Geography	Popn	Percentage living in towns	Indigenous community (%)	Gender ratio (women to men)	Dependency ratio (proportion of the population not working vs those working)
Gwydir Floodplain Economy[a]	13,730	72	18	96	56[b]
Gwydir Rural Floodplain	1,245[c]	n/a	4.3	81	55[b]
Gwydir Urban Floodplain	8,980	n/a	21.7	101	57
State average	n/a	n/a	2.5	103	52

[a] The information about population is based on ABS collection district (CD) boundaries that do not match the boundary of the Gwydir floodplain economic areas (rural and urban floodplains). Therefore the total of the Gwydir rural and urban populations do not equal the overall Gwydir Floodplain Economy.

[b] may be overstated.

[c] based on 11.42 people per 100 square kilometres based on the ABS Census 2011

The dependency ratio of the Gwydir Rural Floodplain and Gwydir Floodplain Economy is higher than the NSW ratio of 52, indicating that there are proportionally more people under 15 and over 65 in these areas compared to the total NSW community; however, there are a considerable number of farmers over the age of 65 working in the agricultural sector. The population pyramid (age by gender) displays an 'hour glass' shape indicating a lower than expected proportion of the population in the 10–29 age groups. This is likely to be related to the inaccessibility of secondary and tertiary education opportunities in this area. The Gwydir Urban Floodplain community does not reflect the same degree of under-representation in the 10–29 age groups as observed in the rural community.

Employment by industry

Employment in the Gwydir Floodplain Economy and Gwydir Rural Floodplain is predominantly in the agricultural, forestry and fishing sector, with 29 per cent and 70 per cent, respectively. This sector is also the most significant employer in the Gwydir Urban Floodplain, with 12 per cent of the workforce employed in the agricultural, forestry and fishing sector. This is in sharp contrast to the NSW state agriculture sector which engages only two per cent of the workforce.

Income

The weekly household income in the Gwydir Floodplain Economy closely correlates with that of the Gwydir Urban Floodplain, which is reasonably close to the NSW state proportions. The Gwydir Rural Floodplain households in 2011 are reasonably prosperous compared to their NSW state counterparts, with less than half as many households in the low income category. The Rural Floodplain proportion of households in the medium income range ($600–2499 per week) at 69 per cent is considerably above the NSW state value of 56 per cent. The high income proportion of 20 per cent is similar to the state proportion of 22 per cent.

Economic wellbeing indicators

The Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) ranks areas in terms of relative socio-economic advantage and disadvantage, using 25 variables. An area with a high score on this index has a relatively high incidence of advantage.

The IRSAD scores for key regions are:

- Moree Region – fourth decile – marginally disadvantaged
- township area of Moree – first decile – significantly disadvantaged
- majority of other floodplain areas – range from fourth to eighth decile – neither advantaged nor disadvantaged.

Production

Agricultural production occupies 84 per cent of the Gwydir Valley Floodplain area. Agricultural production is predominantly cropping, and cropping activities are dominated by cotton and to a lesser extent, wheat. The regional economy is structured to process the inputs and outputs of these industries and the services they require. The performance of the regional economy responds in large part to the fortunes of the cotton and wheat industries.

The Gross Value of Agricultural Production (GVAP) in 2010–2011, using 920,600 hectares, is estimated to be $544 million for this region or five per cent of total NSW GVAP. Broadacre cropping constitutes 95 per cent of the GVAP ($515 million), using 569,500 hectares or 62 per cent of the area. Livestock and livestock products account for five per cent of GVAP while using most of the remaining 38 per cent of the area. Horticultural products account for the remaining 0.3 per cent of GVAP, using minimal area. The highest value producing individual broadacre crops are cotton, yielding $274 million or 50 per cent, and wheat, yielding $128 million or 23 per cent of the total GVAP.

According to the ABS Census data there were 43,100 hectares of irrigated land in the Gwydir Valley Floodplain area in 2010–2011, mostly situated in the Gwydir Rural Floodplain area (ABS 2012). This is about four per cent of the area of Gwydir Rural Floodplain. The area irrigated each year depends principally upon the amount of water available, which can fluctuate widely. Irrigation on the Gwydir Valley Floodplain is dominated by irrigated cotton production. The ABS Agricultural Census 2010–2011 estimated that 244,200 megalitres of the water used in agricultural irrigation is extracted from various surface water and groundwater sources (ABS 2012). Surface water sources include the regulated rivers, various unregulated rivers and streams and floodplain harvesting. The majority of the irrigation water used in 2010–2011 was applied to cotton (237,100 megalitres, 97 per cent) using 40,800 hectares or 95 per cent of the irrigated area and applied at an estimated average rate of 5.81 megalitres per hectare.

Step 7: Delineate management zones

Types of management zone

The Gwydir FMP contains four different management zones, including:

- Management Zone A – major flood discharge zone
- Management Zone B – flood storage and secondary flood discharge zone
- Management Zone C – flood fringe and floodplain development areas zone
- Management Zone D – special environmental protection zone (refer to Step 9 under ecological and cultural considerations).

A map of all four management zones is shown in Figure 14 and a summary description is provided below.

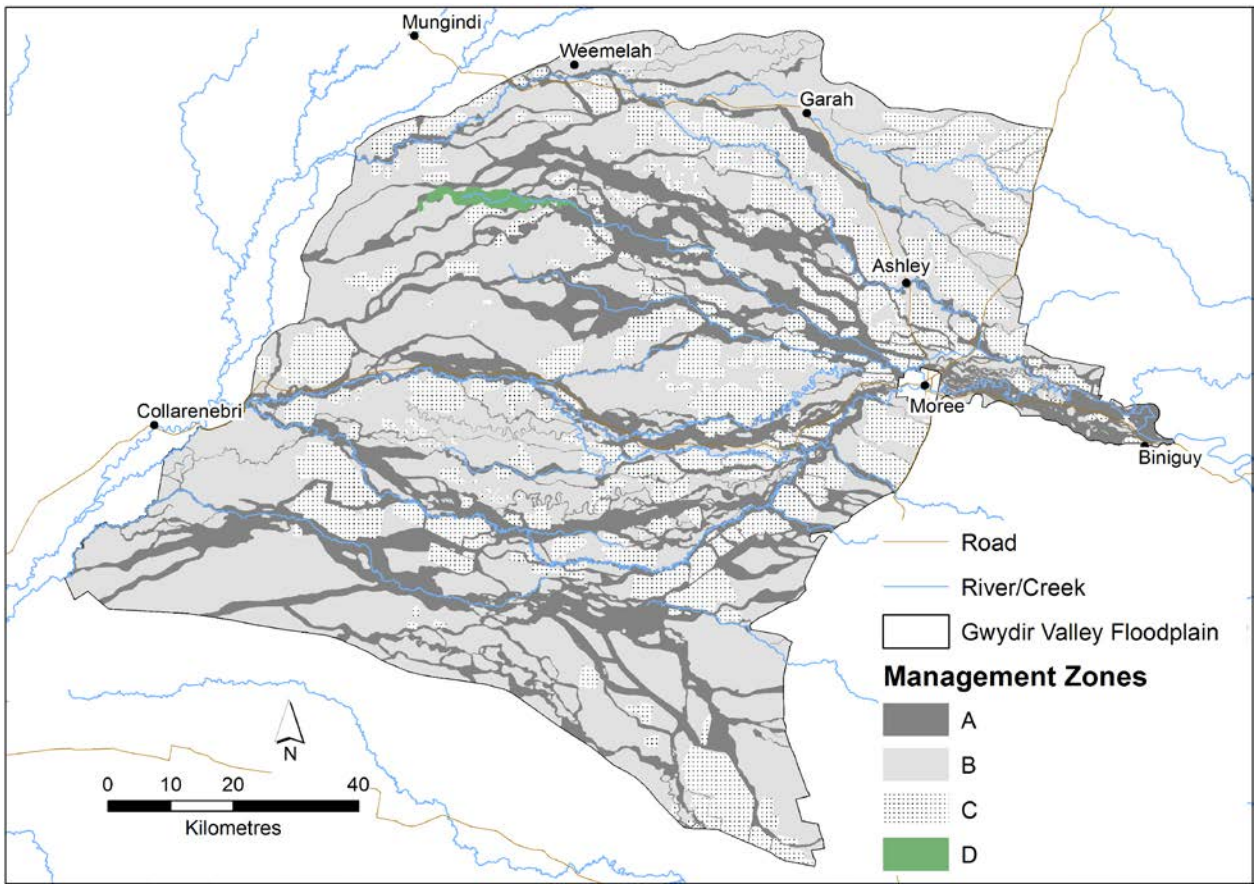

Figure 14: Map of the management zones in the Gwydir Valley Floodplain

Management Zone A – major flood discharge areas for design floods

Management Zone A:

- includes floodways that convey significant floodwater discharge during the small (2004) and large (2012) design floods
- is important for the conveyance of floodwater to floodplain assets during large and small flood events, including environmental flow releases and along ecological flood flow corridors
- includes areas where uncoordinated flood-work development may have a high adverse impact on flood behaviour
- ensures a reduction in the risk to life and property by limiting flood-work developments to prevent flood flow redistribution, increased flood velocities and flood levels which may adversely impact on life and property
- ensures there is continuity of flow and flow paths and assists in maintaining the overall flow distribution on the floodplain.

Management Zone B – flood storage and discharge areas for design floods

Management Zone B:

- includes areas of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood
- has an outer boundary defined by the modelled inundation extent of the large design flood
- is important for the conveyance of floodwater to floodplain assets during larger flood events
- includes areas where coordinating flood-work development is important to manage the cumulative and local impact of works on flood behaviour.

Management Zone C – flood fringe areas for floods greater than design floods and existing developed areas

Management Zone C:

- includes existing developed areas and areas that are outside the inundation extent of the large design flood
- includes areas where flood-work development in the flood fringe areas is unlikely to have a significant effect on flood behaviour
- includes areas where flood works still require an assessment and approval to protect the health of the floodplain environment.

Management Zone D – special environmental protection zone

Management Zone D:

- is an environmental protection zone taken from the Lower Gingham Watercourse Floodplain Management Plan (2006)
- includes a core wetland area with high-biodiversity values
- was included in the Gwydir FMP to ensure consistency with the existing floodplain management planning arrangements
- was included to ensure flood connectivity to this area is maintained and protected.

Staged approach to delineating management zones

A four-stage approach was implemented to determine the nature and location of the four management zones in the Gwydir floodplain. These stages included:

- establish preliminary management zones based on *hydraulic criteria* used to develop the floodway network
- determine *ecological criteria* to adjust management zones to maintain flood connectivity to ecological assets
- determine *cultural criteria* to adjust management zones to maintain flood connectivity to cultural assets that are dependent on flooding
- if required, determine *criteria to better reflect current floodplain management arrangements*.

The four-stage approach for developing the management zones considered the impact of existing and future development on flooding in rivers and floodplains; the flood risk to life and property; the flood connectivity of floodplain assets and the social and economic impacts of restricting flood-work development.

Stage 1: Hydraulic criteria

Preliminary management zones were established based on hydraulic criteria, which were developed from information on flood behaviour contained in the floodway network.

In the Gwydir floodplain, three primary hydraulic categories were identified from the floodway network:

- floodways – areas where a significant discharge of floodwater occurs during small and large design floods. This zone is usually located in active river channels, adjacent floodplain flood runners and major overland flow paths
- flood extent up to the large design flood – areas of the floodplain that are important for the temporary pondage of floodwaters during the passage of a flood. The zone's outer boundary is defined by the inundation extent of the large design flood
- flood fringe and developed areas – areas outside of the floodway network that are typically outside the extent of the design floods and include the flood fringe as well as existing licensed developed areas.

The preliminary management zones were founded on these three categories so that:

- the floodways became the most restrictive zone in terms of coordinating flood works (Management Zone A)
- the flood extent up to the large design event became the zone that would require detailed assessment to determine the potential impacts of flood works but would be less restrictive than Management Zone A (Management Zone B)
- the flood fringe and developed area became the least restrictive in terms of coordinating flood works (Management Zone C).

Figure 15 illustrates the proposed management zones based on hydraulic criteria.

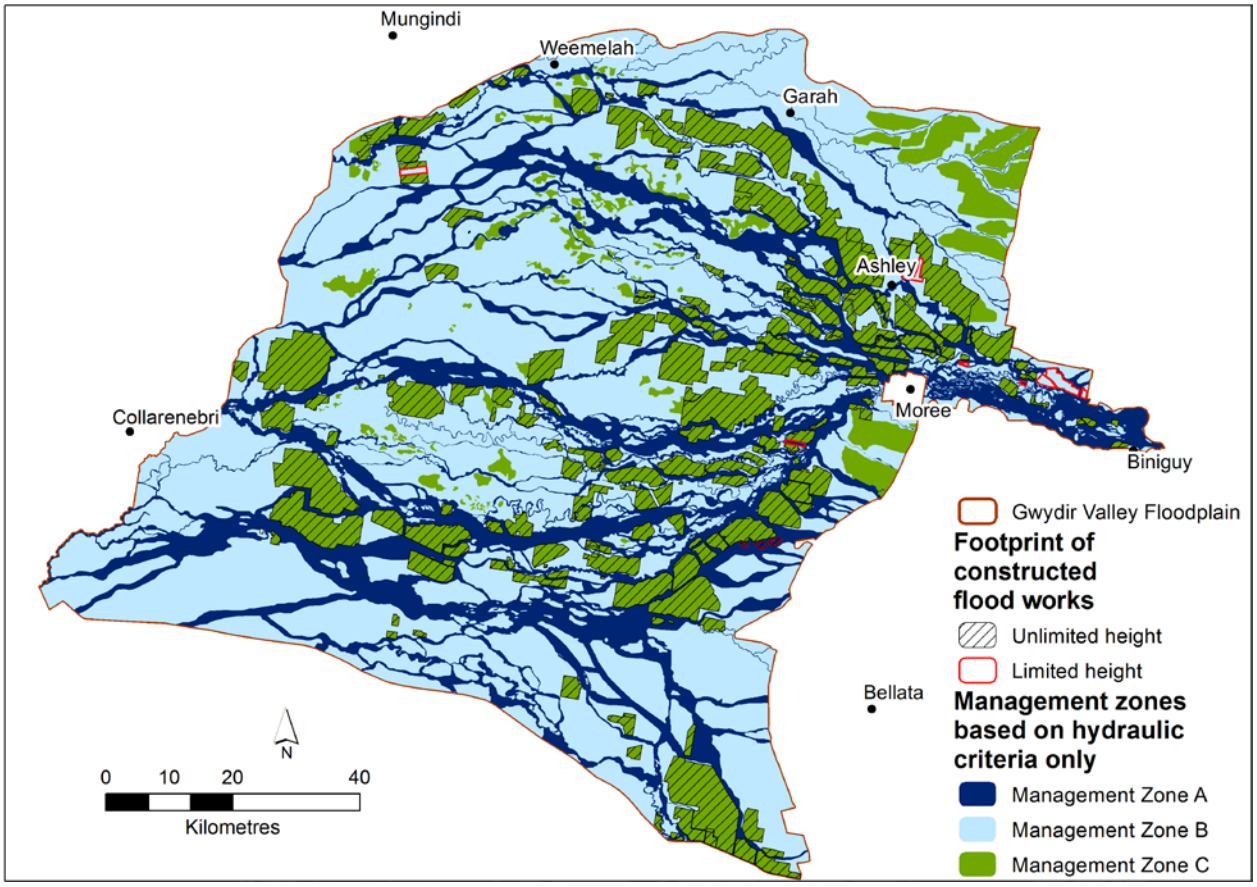

Figure 15: Management zones based on hydraulic criteria only

The delineation of the hydraulic categories as defined by the floodway networks is described in Step 4.

Stage 2: Ecological criteria

The purpose of this stage was to ensure that wetlands, watercourses, floodplain ecosystems and areas of groundwater recharge are not impacted by changes to the passage of floodwater caused by new flood works or amendments to existing flood works. This stage used assessment outputs from identifying and prioritising floodplain assets in Step 5.

Refinements were made to management zones based on:

- ecological water flow corridors
- ecological asset mapping recommendations for management zones.

If the management zones could not be amended then there were opportunities for developing management rules to protect flood connectivity to the asset (Step 8).

Ecological water flow corridors

The Gwydir River system is often termed a 'closed system' because under normal conditions it discharges flow across the lower floodplain of the catchment; however, during large flood events, floodwaters can extend and enter the Barwon River system to the west.

The ecosystems that reside on this floodplain are unique and diverse with many being flood-dependent and requiring a particular frequency of inundation to remain viable. Floodplain water flows are therefore crucial to the structure and function and long-term survival of the flood-dependent communities that comprise the Gwydir Valley Floodplain.

Ecological water flow corridors are tracts of floodplain land that have been identified as important for conveying significant floodwater discharge during smaller flood events (less than 1 in 8 AEP) through the floodplain and for watering connected flood-dependent communities.

The purpose of identifying the ecological water flow corridors was to include the corridors in Management Zone A to protect the passage of water during smaller flood events. The ecological water flow corridors are consistent with the efforts of OEH to implement environmental watering plans and consider ecological assets and values identified in the *Gwydir Wetlands Adaptive Environmental Management Plan* (OEH 2011).

The majority of all flood events that are likely to flow through the ecological water flow corridors will be derived from natural and regulated river flow; however, this corridor will also protect the passage of floodwater actively managed by licensed environmental water deliveries to identified flood-dependent ecological assets. It is the intention of the OEH Regional Water Team that the flow rates of delivered environmental water will be such that the delivered flow will be contained within the ecological water flow corridor. The Gwydir FMP does not control flow volumes or timing, but coordinates the development of flood works to protect the passage of water by identifying ecological water flow corridors.

Parts of the Gwydir Wetlands are listed under the Ramsar Convention (823 ha) and the NSW reserve system (7069 ha). The Gwydir Wetlands are also listed in the Directory of Important Wetlands in Australia and have high biodiversity values (Environment Australia 2001; DECCW NSW 2011).

The small design flood event (January 2004) considered during the hydraulic design of the management zones was a 1 in 10 AEP flood at Gravesend gauge. The 2004 small design flood event was selected because it was the most recent flood event that best matched the 1 in 8 AEP, which was the flood size selected by the Sustainable Rivers Audit as important for protecting ecologically sensitive areas; however, the flood frequency of the 2004 flood event increases as the flood moves through the ecologically-important Gwydir Wetlands. For instance, the 2004 flood has:

- a 1 in 3 AEP at Yarraman gauge, which measures inflows to the Gwydir Wetlands
- a 1 in 5 AEP at Gingham Channel gauge, which is located in the lower western portion of the wetlands.

Furthermore, there is a complex network of flow paths and pathways running through the Gwydir and Mallowa wetlands, which may be under-represented in the hydrodynamic model or may not have satisfied the selected hydraulic depth velocity product threshold for delineating Management Zone A.

To address these issues, additional assessment was undertaken to ensure that important ecological water flow corridors would be captured for inclusion in Management Zone A. These corridors were devised in consultation with the OEH Regional Water Team using information:

- from a video flyover of remnant water from the 2012–13 flood flows in the Gwydir Wetlands. The flyover was undertaken along known flood flow paths. The water levels of the remnant water approximated a 1 in 8 AEP flood event
- on state and Commonwealth priority assets that are actively managed with environmental water.

Figure 16 shows the location and extent of the ecological flow corridors identified in the Gwydir Valley Floodplain.

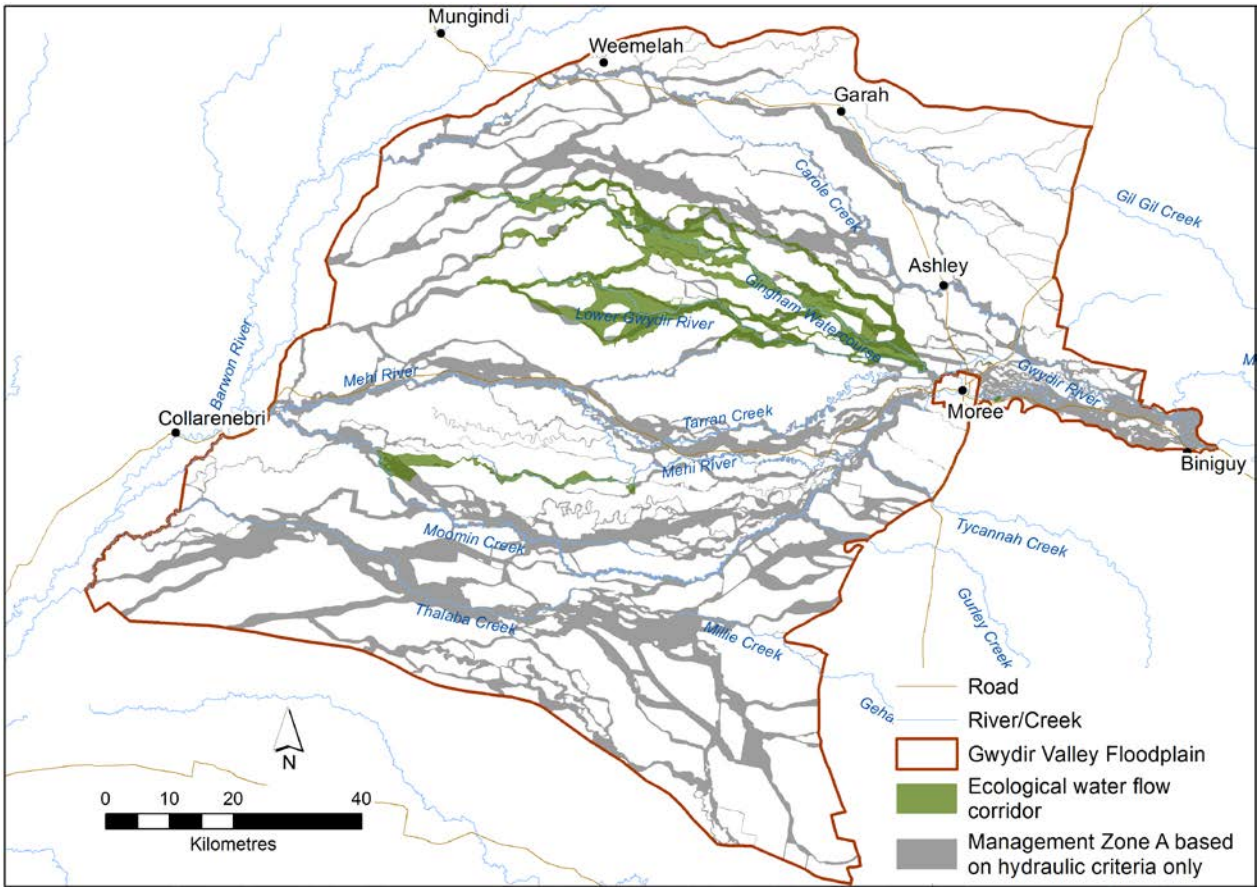

Figure 16: The location and extent of the ecological flow corridors identified in Gwydir Valley Floodplain

Ecological asset mapping recommendations

In Step 5, wetlands and other floodplain ecosystems were categorised according to the level of flood dependency of vegetation communities and watercourses, which was inferred by how frequently they are required to be flooded to maintain their ecological character. This information was a key consideration when designing the extent and location of management zones to protect the passage of floodwater to ecological assets.

Hydro-ecological functional groups were the basis for describing wetlands and other floodplain ecosystems. The vegetation and watercourse classes that comprised the hydro-ecological functional groups were used when allocating the ecological assets to management zones on the Gwydir floodplain.

In this step, the flood dependency of ecological assets was used as justification to recommend a management zone with the flood behaviour appropriate to reduce the risk of flood-work development adversely impacting on the frequency of flooding by blocking or diverting flows. Agency experts also determined the watering requirement of state-priority assets and ecological assets identified in existing FMPs. Ecological assets were then allocated to the management zone most likely to provide temporally and spatially appropriate flooding for the asset (Table 11, Figure 17).

Table 11: Management zone recommendations for ecological assets with justification for the selected management zone

Asset	Description	Management Zone recommendation	Zone justification
Wetland	Watercourses	Management Zone A	Requires regular in bank freshes to floods up to 1 in 5 AEP
	Semi-permanent wetland	Management Zone A	Requires regular flooding of at least every year
	Floodplain wetland	Management Zone A	Requires floods every year to 1 in 5 AEP
Other floodplain ecosystems	Flood-dependent forest	Management Zone A	Requires floods of 1 in 3 to 1 in 5 AEP
	Flood-dependent woodland	Management Zone B	Requires floods of 1 in <10 AEP
Areas of groundwater recharge	Likely recharge	Management Zone A or B	Area of core floodplain inundation

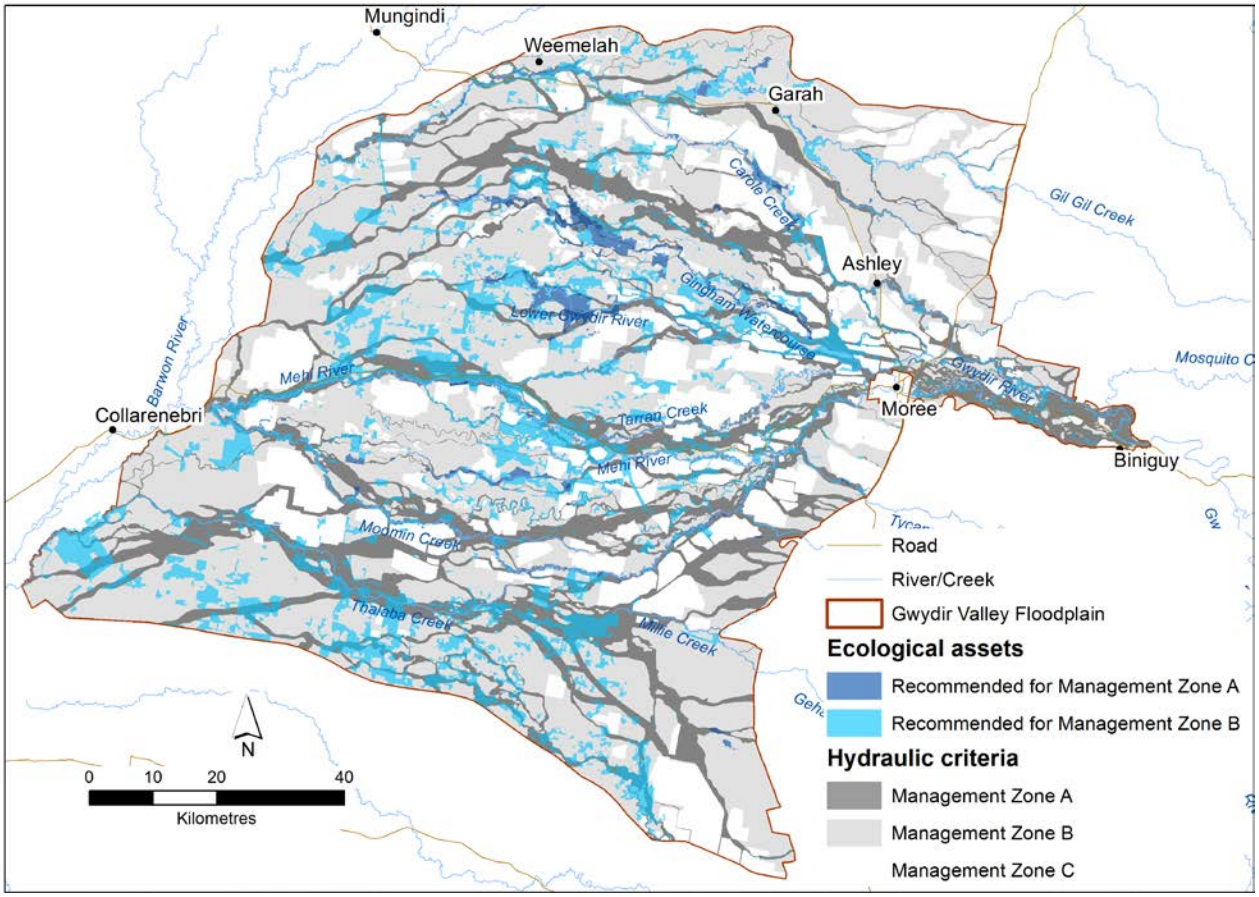

Figure 17: Management zone recommendations based on ecological assets

Once recommendations were made, a spatial analysis was undertaken to determine if the assets were captured in the recommended zone. Where assets were not captured in the recommended zone, criteria for management zone inclusion was determined based on (see Table 12):

- expert recommendations
- Marxan selection frequency score (see Step 5)
- canopy density
- data accuracy and confidence.

Table 12: Criteria to include assets in recommended management zones

Asset	Description	Criteria for management zone (MZ) inclusion
Wetland	Watercourses	Include whole of mapped area in MZ A.
	Semi-permanent wetland	Include whole of mapped area in MZ A.
	Floodplain wetland	Modify MZ A to include asset when: • Marxan selection frequency (SF) is >71 • canopy density is >40%. Ensure that the vegetation is connected to MZ A if not wholly within MZ A.
Other floodplain ecosystems	Flood-dependent forest	Modify MZ A to include asset when: • Marxan selection frequency (SF) is >71 • canopy density is >40%. Ensure that the vegetation is connected to MZ A if not wholly within MZ A.
	Flood-dependent woodland	Extend MZ B areas into MZ C areas (unless an existing licensed flood works area) to include the asset if the SF is >71. Do not extend MZ B area into MZ A.
Areas of groundwater recharge	Likely recharge	No modification required due to limited accuracy of data. Determine approximate groundwater recharge area covered by MZ A.

The high-priority ecological assets such as inner floodplain semi-permanent wetlands were found to occur within channels or depressions in close proximity to floodways (Management Zone A) as these vegetation communities depend on frequent flooding to survive and maintain their condition. Similarly, ecological assets such as flood-dependant forest – river red gum (*Eucalyptus camaldulensis*) are inner floodplain vegetation types predominately found along or adjacent to the banks of watercourses and primary channels, and the majority of these ecological assets were identified as already having connection to floodways (Management Zone A).

Outer floodplain vegetation, such as flood-dependent woodlands – the coolibah and black box (*Eucalyptus largiflorens*) woodlands were found to extend from the inner floodplains across the landscape into Management Zone B, which are parts of the floodplain that experience a wide range of inundation frequency and duration.

Stage 3: Cultural criteria

In Step 5, Aboriginal values and heritage sites were identified and their flood dependency established. Flood-dependent cultural assets were prioritised to assist with the design of the extent and location of management zones.

High-value Aboriginal values identified by the community and assessed as flood-dependent were recommended for Management Zone A (Table 13). Scarred trees, which are also high-priority Aboriginal values and associated with living flood-dependent vegetation, were referred to a management zone based on the level of flood dependency of the associated vegetation (see Table 13 for more information).

A spatial analysis was undertaken to determine if the assets were captured in the recommended zone. Where assets were not captured in the recommended zone, criteria for management zone inclusion was determined based on (see Table 13):

- expert recommendations
- criteria established for ecological assets
- data accuracy and confidence.

Table 13: Criteria to include cultural assets in recommended management zones

Asset	Type	Description	Management zone (MZ) recommendation	Criteria for management zone inclusion
Aboriginal values	Scarred trees	Living/flood-dependent vegetation	Variable – refer to vegetation	Include area in recommended MZ if within 200 m
	Places identified by the community	Nine areas that are dependent on frequent flooding	MZ A	Include whole of mapped area in MZ A
	Fish traps	None recorded	If found – MZ A	Include whole of mapped area in MZ A
Heritage sites	Bridge	Not flood-dependent	n/a	n/a

Cultural assets vulnerable to the effect of erosion associated with the redistribution of flood flow or vulnerable to the direct impacts of the installation of new flood works or the modification of current works are not dealt with in the design of the management zones. Where identified, these cultural assets will be an additional consideration for licensing staff when assessing flood-work applications.

Stage 4: Criteria to better reflect current floodplain management arrangements

The purpose of this stage was, if required, to amend management zones to better reflect current floodplain management arrangements.

After consideration of the *Lower Gingham Watercourse Floodplain Management Plan* (2006), it was decided to recommend that the core wetland area become an additional management zone. This was done so that specific rules that applied to that area in the current plan could be transitioned across to the new plan with minor changes. The additional management zone is known as Management Zone D, which is a special environmental protection zone (see Figure 18).

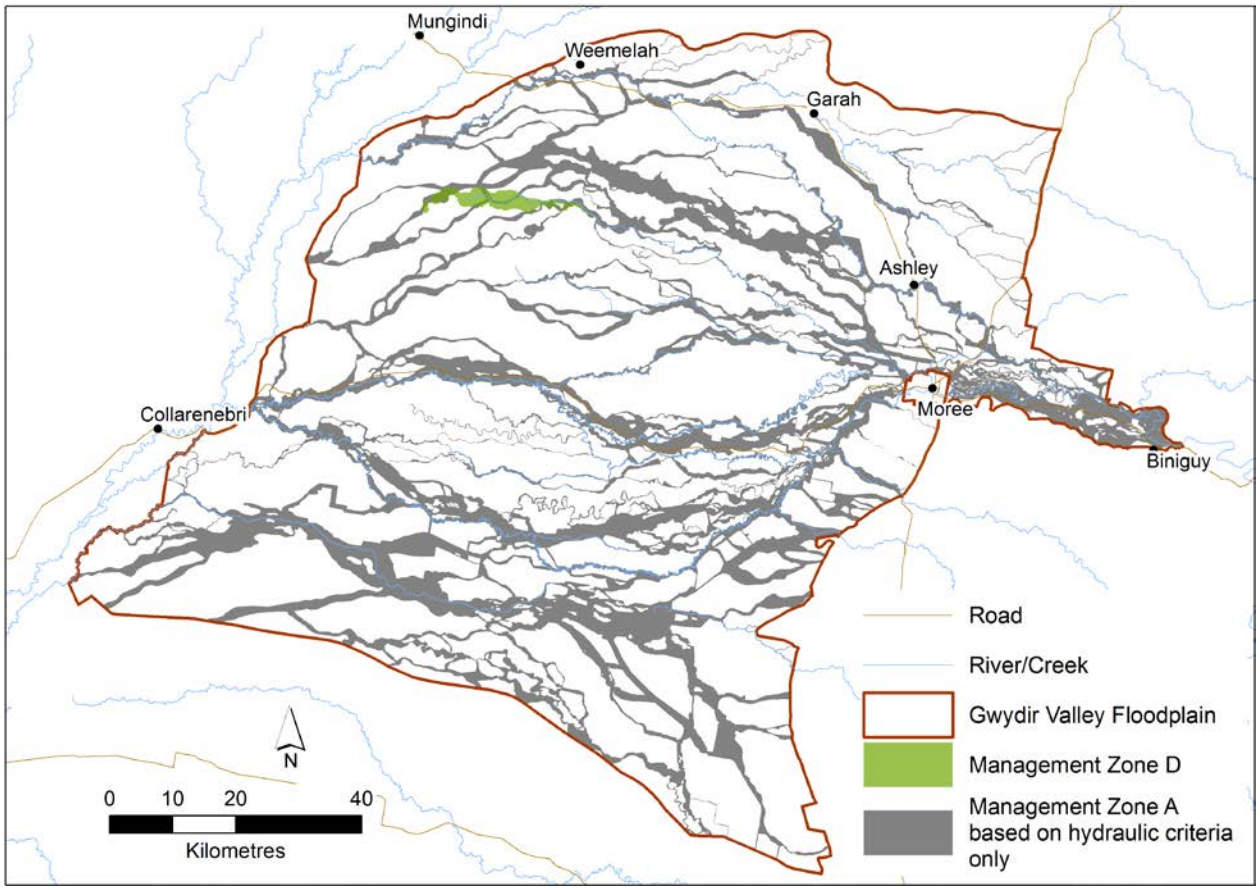

Figure 18: Management Zone D – special environmental protection zone

Step 8: Determine draft rules

The management zones and rules together provide the legal framework for DPI Water to assess flood-work applications. Step 8 was undertaken to develop specific rules to define the type, nature and construction of future flood works that can occur in each management zone. The rules vary between management zones to reflect differences in flooding behaviour and the floodplain environment. Step 8 was also undertaken to develop rules to license or modify existing licences for eligible existing flood works in Management Zones A and D.

The rules can be split into three general types, including:

- rules that specify the physical nature of authorised flood works
- assessment criteria that specify the acceptable impacts of flood works
- advertising requirements.

The Gwydir FMP is supported by assessment guidelines to assist DPI Water licensing officers when assessing flood-work applications against the rules.

Types of flood works

Existing flood works were categorised so that the rules could be tailored to ensure works likely to be approved would be fit-for-purpose. Six types of flood works were identified for the Gwydir Valley Floodplain:

- private access roads – to ensure landholders have basic provisions to access property
- below-ground supply channels – to ensure supply channels reach water sources so landholders can access water rights
- infrastructure protection works – to minimise risk to life and property

- stock refuges – to account for animal welfare and to minimise landholders' potential to lose stock to floodwaters
- other flood protection works that are less than or equal to 40 cm in height – generally used for crop and land protection against smaller floods
- other flood works that are greater than 40 cm in height – generally used for crop and land protection against larger floods.

Rules – authorised flood works

The types of flood works that can be applied for in each management zone (authorised flood works) are determined by considering the optimal balance between hydraulic, ecological, cultural, social and economic considerations on the floodplain. Rules relating to the physical nature of flood works are used to specify the types of authorised flood works and are easy to interpret and do not require technical assessment.

In Management Zones A and D there is a high risk that flood works may impact on flooding behaviour. To minimise this risk, restrictions were placed on the types of flood works that could be applied for in these zones. The restrictions on authorised flood works were made to be sympathetic to landholder needs and decisions were checked against:

- works likely to be approved under existing floodplain management planning arrangements (see Step 9 and Step 10: Phase 1)
- targeted consultation with the community and interagency officers.

The rules specify that the types of authorised flood works in Management Zone A are (restrictions apply, see FMP):

- access roads
- below-ground supply channels
- infrastructure protection works
- stock refuges.

The rules specify that the types of authorised flood works in Management Zone D are (restrictions apply, see FMP):

- infrastructure protection works
- stock refuges.

In Management Zones B and C all types of flood works are authorised.

Statewide exemptions for flood works include specified works vested in local and state government agencies. Outside Management Zones A and D, statewide exemptions also apply to some privately-owned flood works that are within specified size limits (see *Exemptions* under *Other considerations*).

Rules – specifications for authorised flood works

The rules specify the physical nature of all authorised flood works for each management zone.

Access roads

In Management Zone A:

- access roads must be less than or equal to 15 cm in height above the natural surface level at any location

  Note: Access roads greater than 15 cm in height will not be permitted.
- access roads must have causeways constructed at no higher than the natural surface level and there must be at least one causeway for every 200 m of road length

- the length of the causeways in the access roads must together be at least 10% of the total length of the access road in Management Zone A

  Note: This applies even to access roads that span multiple properties.
- borrow pits associated with the construction and maintenance of access roads must be located on the downstream side of the road and must not exceed 15 cm below the natural surface level.

Justification for specifications

The height limit of 15 cm for access roads has been successfully used as a threshold outside the core wetland area in the Lower Gingham Watercourse FMP. Furthermore, hydraulic modelling indicates that roads less than 15 cm high will be overtopped by most floods and will have minimal impact on flood flows.

The causeway requirement is to allow unimpeded flood flow during small flood events. The causeways also allow for connectivity that is important for fish passage. The requirements for causeway spacings were taken from the Lower Gingham Watercourse FMP.

Rules relating to borrow pits are new but represent current best practice principles. The positioning of the borrow pit on the downstream side and limiting the depth to 15 cm was selected to facilitate the passage of floodwater, prevent diversion of floodwater, minimise soil erosion and reduce disruption to access by maintaining the stability of the roadway.

Infrastructure protections works (IPW)

In Management Zones A and D, on landholdings:

- less than 20 ha in size, IPW must be less than or equal to 10% of the landholding
- greater than 20 ha in size, IPW can be up to 2 ha in size or up to 1% of the size of the landholding, whichever is the greater.

In Management Zones A and D, IPW must not block more than 5% of the width of the respective management zone at the location of the works.

Justification for specifications

To avoid flood flow redistribution impacts, IPWs are to be regulated and subjected to an assessment process. Size thresholds are based on those in the Lower Gingham Watercourse FMP. The rules recognise the different asset protection requirements of small and large properties.

Supply channels

In Management Zone A:

- supply channels must be constructed below the natural ground surface
- supply channels must be constructed in such a way as to allow for the adequate passage of floodwater and to adequately prevent the diversion of floodwater
- spoil from the construction and maintenance of supply channels must be windrowed parallel to the direction of flow such that it does not block more than 5% of the width of Management Zone A, or levelled to a maximum 10 cm above the natural surface at any location.

Justification for specifications

Low flows can be captured and/or diverted by below ground channels. Construction of siphons or equivalent structures will enable floods to pass through or under these works.

The rule specifying how spoil is managed will minimise impacts by limiting obstruction of active discharge areas.

This rule is new in relation to flood-work approvals but below ground supply channels may require approval under other parts of the WMA. The regulation of this type of work ensures flood connectivity during small flood events.

Stock refuges

In Management Zones A and D, stock refuges must be:

- less than or equal to 5% of the landholding
- less than 10 ha in size in any single location.

A stock refuge must be less than 5% of the width of Management Zone A at any location.

Justification for specifications

To avoid flood flow redistribution impacts, stock refuges are regulated and subjected to an assessment process. Thresholds for maximum area are taken from DPI Water interim working policies.

Rules – existing flood works

Step 8 was also undertaken to develop rules to license or modify existing licences for eligible existing flood works in Management Zones A and D.

In Management Zones A and D, a flood work approval may be granted for existing unlicensed flood works that do not comply with the assessment criteria for future flood works, provided the flood work was constructed prior to the commencement of the Gwydir Valley FMP and is:

- an access road (in Management Zone D the access road must have been constructed prior to the commencement of the Lower Gingham Watercourse FMP 2006)
- a below-ground supply channel (in Management Zone A only)
- a stock refuge
- an infrastructure protection work.

The existing unlicensed flood work must also, as at the date of application, not be the subject of:

- an undetermined controlled work application under Part 8 of the WA 1912
- a previously refused Part 8 application under the WA 1912
- an undetermined flood work application under the WMA 2000
- a previously refused flood work application under the WMA 2000.

In Management Zones A and D, where an existing licensed flood work does not meet the requirements for future flood works, an application to modify the flood work will be accepted if:

- the flood work was constructed prior to the commencement of the Gwydir Valley FMP
- the proposed modification to the flood work will, in the Minister's opinion, reduce the impact of the works on flow patterns (distribution of flows, drainage, depth or velocity) in Gwydir Management Zones A or D.

All applications to license or modify the licence of an existing flood work will be assessed against the assessment criteria for assessing future flood works in the relevant management zone.

Rules – assessment criteria

Assessment criteria relating to the acceptable impacts of flood works have been designed to consider the potential for a flood work to have:

- ecological and cultural impacts
- drainage impacts
- hydraulic local impacts
- hydraulic cumulative impacts.

The above categories of impacts are considered in the assessment criteria in different ways depending on the management zone that a flood-work application is made for (see Table 14).

Table 14: The categories of impacts that flood-work applications in each of the management zones must be assessed against to be approved

Assessment criteria	MZ A	MZ B	MZ C	MZ D
Ecological and cultural impacts	☑	☑	☑	☑
Drainage impacts	☑	☑	☑	☑
Hydraulic local impacts	☒	☑	☒[a]	☒
Hydraulic cumulative impacts	☑	☑	☒[a]	☑

[a] Unless requested by the Minister to be assessed against these rules

Assessment criteria relating to the acceptable impacts of flood works follow a merit-based assessment approach and require technical assessment to interpret and apply. Flood-work applications may require supporting information to assist with interpretation during the determination.

Flood events are considered when applying the assessment criteria. The types of flood events depend on the management zone and the type of assessment criteria as outlined in the Gwydir FMP.

More information on each of the four assessment criteria categories is found below.

Ecological and cultural impacts

Description of the criteria

The ecological and cultural impacts assessment criteria are designed to ensure that flood connectivity to ecological and cultural assets is considered when determining a flood-work approval. Criteria were also developed to ensure that areas of cultural heritage significance are not disturbed during construction of flood works.

Flood-work applications must be assessed to ensure that flood connectivity to ecological and/or cultural assets and flood connectivity that facilitates fish passage are maintained.

Why are ecological and cultural impacts considered?

Ecological and cultural impacts assessment criteria were developed to ensure that floodplain assets were specifically considered during the assessment of flood-work applications. The management zones were designed on a strategic scale and may not always account for the complex network of flow paths and pathways that are important for maintaining the ecological character of floodplain assets.

Flood connectivity that facilitates fish passage will be specifically dealt with in the assessment criteria because consultation with the TAG and agency experts determined that fish habitat on the floodplain is a significant asset that requires additional protection measures. Regulatory structures and flow alteration have contributed to a significant decline in the abundance and distribution of native fish in the Murray-Darling Basin (Cadwallader 1978; Horwitz 1999; Thorncraft & Harris 2000; Humphries et al. 2002).

Consultation with the ATWG and agency experts identified that some heritage sites are at risk from being impacted during the construction of a flood work or as a result of erosion from changes to flood behaviour caused by a flood work. Sites that may be potentially impacted by flood-work development will be identified in the FMP and the information made available to DPI Water licensing officers. If a flood work is proposed in the vicinity of such a site, the *National Parks and Wildlife Act 1974* will be triggered and a due diligence assessment will be required to be undertaken to ensure the sites are not impacted by the proposal.

How were the criteria determined?

The criteria were determined by considering current floodplain management arrangements and after discussions with the Fisheries NSW representative of the TAG and the ATWG.

How will the criteria be applied?

Ecological and cultural impacts assessment criteria will be assessed by DPI Water licensing staff. Licensing staff will have access to maps of the floodplain assets and will draw on available mapped information as well as observations made on the ground. Licensing staff will also be required to check state and Commonwealth heritage registers to identify any heritage sites within the local area of a flood-work application. Licensing officers will consider flow paths that may be active across a range of floods, including the 2004 and 2012 design floods. Landholders will not have to provide information on ecological and cultural impacts in their flood-work applications.

Drainage impacts

Description of the criterion

The drainage impacts assessment criterion was designed to ensure that local drainage on neighbouring properties is maintained.

Why are drainage impacts considered?

The drainage impacts assessment criterion was developed to ensure that flood-work applications do not impact on drainage on neighbouring properties. The management zones were designed on a strategic scale and may not always account for the possibility that a type of flood work might impact on local drainage that may cause a significant disruption to the daily life of surrounding landholders. For instance, changes to local drainage may cause considerable local issues, nuisance or conflict, or property access may be disrupted.

How was the criterion determined?

The criterion was determined by considering current floodplain management arrangements.

How will the criterion be applied?

The drainage impacts assessment criterion will be assessed by DPI Water licensing staff. Licensing staff will have access to topographical maps and flood photography as well as observations made on the ground. Licensing officers will consider local topography to minimise the likelihood of new flood works changing local drainage lines in a disruptive manner. Licensing officers may consider local flooding patterns across a range of floods, including the 2004 and 2012 design floods. Landholders will not be required to provide information on drainage impacts in their flood-work applications.

Hydraulic local impacts

Description of the criteria

The hydraulic local impacts assessment criteria were designed to ensure that within the local area, a flood-work application has a minimal impact (thresholds apply) on:

- the redistribution of peak flood flow
- flood levels
- flow velocity.

Why are hydraulic local impacts considered?

Hydraulic local impacts assessment criteria were developed to ensure that flood-work applications do not significantly change key hydraulic parameters in the local area. The management zones were designed on a strategic scale and may not always account for the possibility that a type of flood work might impact on local hydrology. To best assess these impacts, each relevant flood-work application must be assessed on a case-by-case basis. This assessment will reduce the likelihood that flood works will impact on flood behaviour, including the potential to redistribute peak flood flows, increase the flood risk and inundation extents by raising flood levels, and increase the potential for erosion and siltation by increasing flood flow velocities.

How were the criteria determined?

The criteria were determined by considering current floodplain management arrangements. Specifically, the selected thresholds were referenced from current floodplain management plans in the following areas:

- Moomin Creek
- Namoi River (Carroll to Boggabri)
- Lower Gingham Watercourse
- Macquarie River (Narromine to Oxley Station)
- Lower Coxs Creek.

The thresholds were selected to limit the impact of future development on flooding behaviour.

How will the criteria be assessed?

Hydraulic local impacts assessment criteria will be assessed by DPI Water licensing staff using information provided by the landholder as part of the flood-work application. To assist with preparation of the required technical detail, the DPI Water will maintain and provide records of the current level of development as well as the 2014 level of development. The hydraulic local impacts will be assessed by comparing:

- natural flow conditions (refers to the floodplain without flood-work development)
- existing conditions (refers to the floodplain and level of flood-work development at the time that the Gwydir FMP was made)
- proposed conditions (the proposed work and existing conditions combined).

Specifically:

- flood flow redistribution is to be assessed by comparing proposed conditions with existing conditions and must not redistribute the peak flood flow by more than 5% on adjacent and other landholdings
- flood level increases are to be assessed by comparing natural flow conditions with existing and then proposed conditions and summing the impacts to ensure flood levels are not increased by greater than or equal to 10 cm on adjacent and other landholdings

- flow velocity increases are to be assessed by comparing natural flow conditions with existing and proposed conditions to ensure that flow velocity:
    - is not increased by more than 50% on the landholding under application, adjacent landholdings and other landholdings
    - is not increased above a threshold, determined by the Minister, that is likely to have more than a minimal impact on soil erodibility on adjacent and other landholdings, taking into account the ground cover on those landholdings.

In Management Zone B, the large design flood (2012) must be considered as a minimum. The Minister may also require additional flood scenarios to be used to assess hydraulic local impacts.

In Management Zone C, the Minister may require hydraulic local impacts to be assessed and will specify the flood scenarios to be used in this assessment.

Hydraulic cumulative impacts

Description of the criteria

Hydraulic cumulative impacts assessment criteria are split into two parts.

The first part is concerned with limiting the redistribution of flood flow. The 2012 large design flood is to be used for the assessment, and redistribution is to be limited to less than or equal to five per cent of the peak flow in this event at specific locations across the floodplain. All flood-work applications received for Management Zone B must be assessed against this part of the criterion. If a request is made by the Minister, a flood-work application in Management Zone C must also be assessed against this part of the criterion but for floods larger than the design flood, typically the 1 in 100 AEP flood.

The second part is concerned with ensuring that the potential cumulative impacts of works in Management Zones A and D are assessed in conjunction with existing works on the property where the work is to be located. All flood works in Management Zones A and D must be assessed against this part of the criterion.

Why are hydraulic cumulative impacts considered?

Current estimates are that the area protected by flood works (hereafter *developed areas*) makes up approximately 20 per cent of the Gwydir floodplain (see Step 2). Typically the developed areas are protected by levees, which will only overtop in extreme floods and so are likely to impact on flooding behaviour in small and large floods.

The hydraulic models developed as part of Step 4 were used to estimate the redistribution of floodwater that may have occurred due to the current level of development. Existing flood-work development has been found to have altered the flow distribution between major branches of the Gwydir Valley Floodplain.

Further redistribution may have consequences from socio-economic, hydraulic, ecological and cultural perspectives. Therefore the cumulative impact of current and future works must be assessed to ensure that the current flood flow distribution is maintained.

How were the thresholds for the criteria determined?

The thresholds for the hydraulic cumulative impacts have been determined by comparing the modelling results from the current floodplain conditions with a natural flow regime modelling scenario, where all flood works had been removed from the model bathymetry.

The two scenarios were compared at cross-sections at key locations within the floodplain. The basis for the assessment was the peak flood flow for the 2012 design flood event.

It was found that some redistribution has likely occurred due to existing flood works, and that this redistribution is variable across the floodplain; however, limitations with representing the pre-

development floodplain in the model preclude a quantitative analysis of the redistribution within the sub-floodplain areas. Therefore a uniform threshold has been set across the entire floodplain.

How will the criteria be assessed?

For Management Zones A, B, C and D, the hydraulic cumulative impacts will be assessed by comparing the peak flow distribution (for the 2012 event) of the 2014 level of development (see Schedule 6 of the FMP) to the current level of development in addition to the proposed works. For Management Zone C, the hydraulic cumulative impacts may need to be assessed against the 1 in 100 AEP flood as well. Information from the 1 in 100 AEP flood will need to be obtained from DPI Water.

DPI Water will maintain records of the current level of development as well as the 2014 level of development and will provide these in order to assist with the assessment.

Rules – advertising requirements

Advertising requirements were determined by considering the level of impact flood works would likely have on flood behaviour, floodplain connectivity and on neighbouring properties. Therefore, the Gwydir FMP does not require advertising for works deemed to be minor in nature, which varied for each management zone due to differences in flooding behaviour.

The types of flood works that can be applied for in Management Zones A and D are minor in nature and therefore flood-work applications in these zones do not need to be advertised.

There are no restrictions on the types of flood works that can be applied for in Management Zone B; however, because this zone is a major flood storage area, there is a reasonable risk that some flood works will impact on flood behaviour and floodplain connectivity. To address this issue, the rules for this zone divide flood-work applications into two groups:

- flood-work applications that do not require advertising, including:
    - infrastructure protection works that are less than or equal to 1% of the total area of the landholding
    - stock refuges that are less than or equal to 5% of the total area of the landholding and less than 10 ha in size in any single location
    - minor flood protection works that are less than or equal to 40 cm above the natural surface level at any location.
- flood-work applications that do require advertising, which are all other flood-work applications not already listed as requiring advertising.

There are no restrictions on the types of flood works that can be applied for in Management Zone C; however, because Management Zone C includes flood fringe and existing developed areas, there is a low risk that flood works will impact third parties except for during very large floods, such as the 1 in 100 AEP flood. Therefore, flood-work applications do not need to be advertised unless requested by the Minister.

Step 9: Consider existing floodplain management arrangements

Step 9 provides a summary of the key aspects of current floodplain management arrangements that were considered and incorporated into the Gwydir FMP, as well as justification for changes from current floodplain management arrangements. For further details on current floodplain management arrangements, refer to Step 3.

The level of change from current floodplain management arrangements is indicated at the beginning of each key aspect. The level of change can be minor, moderate or major.

Floodplain management principles

The level of change is minor.

The WMA 2000 contains floodplain management provisions that relate closely to existing provisions under the amended Part 8 of the WA 1912.

Ecological and cultural considerations

The level of change is minor.

Ecological assets from existing floodplain management plans were considered and included as ecological assets in the Gwydir FMP. Management Zone D corresponds to the core wetland area from the *Lower Gingham Watercourse Floodplain Management Plan* (2006). There was no change in location or extent.

Floodway networks

The level of change is moderate.

The Gwydir FMP floodway network was compared against, and where appropriate aligned with floodway networks in existing floodplain management plans and development guidelines. In most instances, the new floodway network had greater accuracy than the existing floodway networks.

Floodways in the Gwydir FMP were delineated using more sophisticated data and modelling, which provided greater accuracy and greater capability to set quantitative criteria. In some areas outside the 2D hydraulic model areas, the current floodway networks were referenced.

Hydraulic models

The level of change is moderate.

New models were created using the latest available data and modelling software for the majority of the floodplain. Where modelling has been done previously, such as Moomin Creek and the Lower Gingham, existing models were updated to the latest software version and used to assist with calibration as well as to support the new model data.

Design flood event

The level of change is major.

New design floods were selected to represent more recent historic floods. See Step 4 for more detail.

Rules – authorised flood works

The level of change is minor.

The types of flood works that will be considered for approval will differ from current management practices because of changes to statewide exemptions and the implementation of the new rural floodplain management planning process.

Management Zone A

The level of change is moderate.

Under current management practices, a landholder can apply for any type of flood work to be built in areas that correspond to Management Zone A areas.

The Gwydir FMP will only allow flood-work applications in Management Zone A for (restrictions apply):

- access roads
- below-ground supply channels
- infrastructure protection works
- stock refuges.

The change is minimal because under current assessment practices, works other than those listed above would be unlikely to be approved. Areas corresponding to Management Zone A in current plans (floodway network areas) are non-complying areas where works need to satisfy stringent assessment criteria before being approved. By limiting applications to certain types of flood works in the Gwydir FMP, landholders save time and money by applying only for those works likely to be approved. This rule also reduces the chances of inconsistency in DPI Water discretionary approvals.

One or more of the types of flood works that will be considered for approval in Management Zone A of the Gwydir FMP, were exempt from needing approval under the suite of current management arrangements (see Table 15). In these areas, the new rule is more restrictive due to changes in the DPI Water exemptions policy.

Table 15: Flood works considered for approval in Management Zone A of the Gwydir FMP that are exempt under current management arrangements (tick) and those requiring approval (cross)

Current management (% area that MZA makes up in current management area)	Access roads	Below-ground supply channels	Infrastructure protection works	Stock refuges	Other types of flood works
Lower Gingham Watercourse FMP (32%)	☑[a]	☒	☑[a]	☑[a]	☒
Moomin Creek FMP (27%)	☒	☒	☑	☑	☒
Guideline areas (50%)	☑	☑	☑	☑	☒
Remaining Part 8 areas (11%)	☑	☑	☑	☑	☒

[a] Not exempt in core wetland area, which is Management Zone D in the Gwydir FMP

Management Zone B

The level of change is minor.

Under current management practices, a landholder can apply for any type of flood work to be built in areas that are equivalent to Management Zone B areas.

Similarly, the Gwydir FMP does not restrict the types of flood works that will be considered for approval in Management Zone B.

Management Zone C

The level of change is minor.

Under current management practices, a landholder can apply for any type of flood work to be built in areas that correspond to Management Zone C areas.

Similarly, the Gwydir FMP does not restrict the types of flood works that will be considered for approval in Management Zone C.

Management Zone D

The level of change is minor.

Under current management practices, a landholder can apply for any type of flood work to be built in areas that correspond to Management Zone D areas.

The Gwydir FMP will only allow flood-work applications in Management Zone D for (restrictions apply):

- infrastructure protection works
- stock refuges.

The change is minor because under current assessment practices, works other than those listed above would be unlikely to be approved.

The core wetland area of the Lower Gingham Watercourse FMP corresponds to the area of Management Zone D. The core wetland area is a non-complying area where raised roads are prohibited and other works need to satisfy stringent assessment criteria before being approved. By limiting applications to certain types of flood works in the Gwydir FMP, landholders save time and money by applying only for those works likely to be approved. This rule also reduces the chances of inconsistency in DPI Water discretionary approvals.

There were no exempt works in the core wetland area of the Lower Gingham Watercourse FMP.

Rules – assessment criteria

The level of change is minor.

A summary of the types of assessment criteria considered in current floodplain management plans is provided in Table 16. These assessment criteria have been incorporated into the Gwydir FMP. Assessment criteria that have been explicitly addressed in the rules are highlighted in green. To varying degrees, all existing assessment criteria have been considered in the development of the management zones and rules of the Gwydir FMP.

Table 16: Summary of assessment criteria in current floodplain management plans in the Gwydir Valley Floodplain

Assessment criteria highlighted in green have been explicitly incorporated into the Gwydir FMP as rules. All the assessment criteria were considered during the development of the management zones.

Historical	Socio-economic	Ecological	Flooding
Old guidelines	Disruption to daily life (relates to local drainage)	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	

Rules – advertising requirements

The level of change is major.

Advertising requirements have been updated in the Gwydir FMP to reflect changes made to the types of flood works that will be considered for approval. Some of the proposed rules will have advertising requirements depending on the management zone in which the flood work is proposed to be developed as well as the purpose, nature and construction of the work. These factors relate directly to the potential of the work to cause or exacerbate flooding problems. Therefore, advertising requirements reflect the level of impact that flood works are likely to have on flood behaviour, floodplain connectivity and neighbouring properties.

Management Zone A

The level of change is major.

Under existing floodplain management plans, flood-work applications in areas that correspond to Management Zone A areas (in the floodway network) require advertising (assessed as 'non-complying').

In other areas covered by Part 8 of the WA 1912 (including guideline areas), all flood works require advertising.

The Gwydir FMP will not require flood-work applications in Management Zone A to be advertised. This is because the types of flood works that can be applied for are minor in nature and unlikely to impact flooding patterns.

Management Zone B

The level of change is moderate.

Under existing floodplain management plans, flood-work applications in areas that correspond to Management Zone B areas (areas outside the floodway network) do not require advertising (assessed as 'complying').

In other areas covered by Part 8 of the WA 1912 (including guideline areas), all flood works require advertising.

The Gwydir FMP outlines two categories of flood-works applications in Management Zone B, those that:

- do not require advertising because the work is minor in nature relative to the flooding behaviour typical of the zone
- do require advertising because of the potential for the work to impact on flood behaviour, floodplain connectivity and neighbouring properties.

Management Zone C

The level of change is minor.

Under existing floodplain management plans, flood-work applications in areas that correspond to Management Zone C (areas outside the floodway network) do not require advertising (assessed as 'complying').

In other areas covered by Part 8 of the WA 1912 (including guideline areas), all flood works require advertising.

The Gwydir FMP does not require flood-work applications to be advertised as it is unlikely that a work in this area would impact on flood behaviour, floodplain connectivity or neighbouring properties.

Management Zone D

The level of change is major.

Under the Lower Gingham Watercourse FMP, a flood-work application in the core wetland area which corresponds to Management Zone D requires advertising (assessed as 'non-complying').

The Gwydir FMP will not require flood-work applications in Management Zone D to be advertised.

Management zones

The level of change is moderate.

The management zones for the Gwydir FMP have changed from current management practices in terms of the number of zones, as well as the spatial distribution of these zones.

Current management arrangements in the Gwydir Valley Floodplain do not contain management zones, per se. The Lower Gingham Watercourse FMP includes a mapped core wetland area which is similar to a management zone, as it contains rules that are specific to flood-work approvals in the area. Existing floodplain management plans and guidelines contain mapped floodway networks. The floodplain management plans use the floodway networks as a basis for assessing if a flood-work application is required to be advertised or not (see advertising requirements). The guidelines assisted landholders by informing them of the areas where applications are more likely to be approved. The floodway networks in the guidelines and current floodplain management plans were prepared using hydraulic parameters that are consistent with the hydraulic requirements for approval under Part 8 provisions.

Assessment of flood-work applications using management zones has been updated in the Gwydir FMP to reflect that:

- the floodplain boundary was extended to capture areas of major flooding
- there is better ecological, hydraulic and cultural data across a greater area
- flood connectivity throughout the entire floodplain was considered in a strategic way
- there is significantly more accurate hydraulic modelling data (supported by LiDAR across most of the floodplain) available which offers the opportunity to delineate three management zones based on hydraulic criteria.

Designated floodplain

The level of change is major.

For practical management, the Gwydir FMP contains a hierarchy of management units. The largest unit in the plan is the designated floodplain, called the Gwydir Valley Floodplain. The Gwydir Valley Floodplain will contain all of the existing Gwydir floodplain and the northern portion of the Lower Namoi designated floodplain. The proposed and existing floodplains are similar in that their delineation considered the hydrological effects of development and cadastral relevance. Key differences are that the boundary of the new designated floodplain was considered relative to the boundaries covering unregulated and regulated water sharing plans for ease of administration and clarity for water users. The proposed floodplain also includes floodplain harvesting works identified through the Floodplain Harvesting Project's register of interest process, to ensure consistency with the NSW Floodplain Harvesting Policy (DPI 2013).

Management Zone A

The level of change is moderate.

The floodway networks of the guidelines and existing floodplain management plans are equivalent in principle to the hydraulic criteria used to develop Management Zone A; however, the data used to develop Management Zone A is more sophisticated and better represents flooding behaviour in the area. As a result, Management Zone A was based on quantitative criteria including depth velocity product thresholds where 2D hydraulic models were available.

Other key differences are that:

- hydraulic modelling for the Gwydir FMP considered smaller environmental floods to ensure continuity of the floodways to floodplain assets (see Step 4)
- ecological and cultural assets were identified and prioritised and considered in the design of Management Zone A (see Step 7).

Management Zone B

The level of change is moderate.

The areas outside the floodway networks of the guidelines and existing floodplain management plans are equivalent in principle to the hydraulic criteria used to develop Management Zone B. Similarly, Management Zone B does not contain floodways.

Key differences are that:

- the non-floodway network areas under the guidelines and current floodplain management plans also contain flood fringe and developed areas that form Management Zone C in the Gwydir FMP
- ecological and cultural assets were identified and prioritised and considered in the design of Management Zone B (see Step 7).

Management Zone C

The level of change is major.

Flood fringe and developed areas that form part of the new Management Zone C were not specifically identified in current floodplain management arrangements but were considered as part of the non-complying areas.

Management Zone D

The level of change is minor.

Management Zone D corresponds to the core wetland area from the *Lower Gingham Watercourse Floodplain Management Plan* (2006). There was no change in location or extent.

Step 10: Assess socio-economic impacts

Step 10 was undertaken in two phases to ensure community stakeholders would have the opportunity to provide feedback on potential socio-economic impacts of the Gwydir FMP. Phase one was undertaken prior to community consultation, whereas phase two was conducted post consultation with the community. The extent of the change between the Base Case and the Gwydir FMP was assessed to determine the negative socio-economic impact of the plan.

Methodology

The assessment approach is based on the *Socio-economic Assessment Guidelines for River, Groundwater and Water Management Committees* prepared by the Independent Advisory Committee for Socio-economic Analysis (IACSEA 1998). This approach has been and is being applied to the development and remake of water sharing plans in NSW.

This assessment only considers the negative impacts of the proposed FMP and is therefore an impact assessment. Because benefits of the proposed FMP are not enumerated it is not a cost–benefit analysis. There are significant benefits from the plan that are expected to outweigh the negative impacts. The negative effects of the implementation of the proposed FMP are quantified in 2011 dollars.

The method applied identifies and assesses the socio-economic effects in a two phase process. The first phase is the Preliminary Assessment. Phase 2, Detailed Assessment, will be conducted if the Preliminary Assessment indicates that the impact is greater than the threshold or there are major concerns raised during the public exhibition. Each problem or issue being analysed will:

- clearly state the key assumptions underlying the proposed analysis
- consider the key quality assurance principles in defining the analysis
- identify an appropriate method of analysis and the tools and techniques to be utilised, and
- identify appropriate sources of data to collect.

The detail of the methodology used in this analysis is included in the Technical Manual.

The Base Case

In the Gwydir FMP Base Case it is assumed that flood work approvals would continue under the provisions of Part 8 of the WA 1912 or similar provisions under the WMA 2000. It is also

assumed that more floodplain area will be covered with FMPs in due course and previous floodplain guidelines[8] may be revised as better data and modelling become available. It is expected that over the next 10 years more emphasis will be put on environmental issues associated with flood work approvals consistent with the expected increase in general awareness of environmental issues in the community of NSW. Flood works are expected to continue to be approved in areas outside the floodway networks identified by the FMPs and guidelines, while the approval rate of flood works within the floodway network is expected to decline as cumulative impacts approach acceptable limits.

In addition to the Part 8 legislative provisions, there are two FMPs and several floodplain guidelines for floodplain development that have been prepared for almost half of the Gwydir FMP area. While the floodplain guidelines have no legal status they are public documents that assist landowners to identify areas included as part of floodway networks and where applications for flood works are more likely to be approved. These guidelines were prepared using hydraulic parameters that are consistent with the hydraulic requirements for approval under Part 8 provisions. Applications for flood work approvals or amendments in the Gwydir Base Case, will be assessed under the provisions of Part 8 of the WA 1912 and should be consistent with any guidelines that may exist (although this is not a legislative requirement).

Floodplain management plan construct

In the course of preparing the Gwydir FMP, hydraulic models were developed and existing models updated by Office of Environment and Heritage (OEH) floodplain engineers. These models produced a map that reflects exclusively hydraulic parameters (depth velocity product). This map is included in the Gwydir FMP as the hydraulic floodway network. The hydraulic floodways contained in this updated floodway network are consistent with the floodway network definitions used for the first generation guidelines and second generation floodplain management plans. The floodway network prepared for the Gwydir FMP contains floodways that reflect the location of floodway networks where flood work applications under Part 8 would be unlikely to be approved.

The Gwydir FMP identifies four management zones, A, B, C and D, which incorporate the whole floodplain. Each of these zones have a different suite of rules for granting or amending flood work approvals. Statewide exemptions will apply in the Gwydir FMP area. These statewide exemptions may go some way to mitigating the potential negative impacts of defined rules.

The rules are presented in Step 8. Zone restrictions on flood work approvals may lead to a reduction in land-use options available to the landholder, or change the risk of inundation and/or secured access to floodwater afforded to flood-dependant vegetation communities.

Rule changes

Hydraulic flood modelling has been completed for the majority of the Gwydir floodplain and the basic flood modelling data will be available to the consulting floodplain engineers when preparing reports for applicants on the impact of proposed flood works. This will provide consistent input data and reduce the requirement for pre-development modelling by consultants and detailed engineering recalculation by OEH prior to approval. This will provide benefits to landholders, floodplain engineers and the approving department.

The expansion of flood modelling and identification of the floodways across the whole floodplain (hydraulic Zone A), has increased the residual area (hydraulic Zone B) where applications for flood works can be considered for approval with the need to advertise. This is somewhat tempered in hydraulic Zone B by specifying that limited height flood works, stock refuges subject

[8] These guidelines are indicative and while being informative, do not carry any legal status. They form a starting point that discourages frivolous applications but allows some room for the landholder and the department to negotiate a compromise position in the face of uncertain modelling.

to size conditions and infrastructure protection works subject to size conditions can be approved without advertising. This is expected to provide additional benefits to landholders and streamline the assessment process for the approving department. A summary of the specific rule changes is presented in (Table 17).

Comparing Base Case and FMP rules

The assessment initially identified the effect of the change between the Base Case and the Gwydir FMP on different sectors of the community. Once the effects were identified a socio-economic impact table was developed that assessed the extent, likelihood, intensity and timing of the effect. Where significant impacts are indicated by the initial assessment a detailed analysis was developed.

The impact of the FMP was assessed in net terms across the whole floodplain. Depending on the location of affected land, and as the Gwydir FMP is 1.14 million hectares, there may be particular areas that are likely to be relatively heavily impacted by the proposals.

Table 17: Rule changes

Base Case	Gwydir FMP
Flood works across the whole floodplain require an application for a Part 8 approval or WMA 2000 flood work approval under similar criteria.	Flood works in the designated flood plain management area are subject to the FMP and require application for a flood work approval under the WMA 2000.
Floodway network in FMP and guideline areas where Part 8 approvals are unlikely to be approved. If an application is for a flood work in an identified floodway in an FMP area or in a suspected unidentified floodway in a guideline or non-guideline area, the applicant is required to provide a consultant floodplain engineer's report identifying that the Part 8 parameters are not exceeded. All applications are deemed to be non-complying and **require** advertising, and objections are to be considered before possible approval.	**Zone A** provides for flood work approvals by application that are one of the following: • an access road less than 15 cm in height, or • a supply channel below the natural surface level, or • a stock refuge, or • an infrastructure protection work.
	Zone D provides for flood work approvals by application that meet the following conditions: • a stock refuge, or • an infrastructure protection work.
If the application is outside the identified floodway in a FMP area the applicant is required to provide a consultant floodplain engineer's report identifying that the Part 8 parameters are not exceeded. A complying application **does not** require advertising. A non-complying application **does** require advertising and objections are to be considered before possible approval. If the application is outside an FMP area the applicant is required to provide a floodplain engineer's report identifying that the Part 8 parameters are not exceeded. All applications are deemed to be non-complying and **require** advertising, and objections are to be considered before possible approval.	**Zone B** provides that flood work approvals or modifications by application do not require advertising if they are one of the following: • less than 0.4 m in height, or • a stock refuge less than 5 per cent of the property area and less than 10 ha in a single location, or • infrastructure protection less than 1 per cent of the property area. The application **does** require advertising if it is does not meet the above conditions. The application **must not** be approved if it exceeds the assessment criteria defined in the FMP. Statewide exemptions apply in this zone. See the DPI Water website for the list of exemptions.
	Zone C provides for flood work approvals by application if they meet the assessment criteria. The application does not require advertising. Statewide exemptions apply in this zone. See the DPI Water website for the list of exemptions.

Impact of rule changes in existing FMP areas

There are currently two second generation FMPs enacted within the Gwydir FMP area: Lower Gingham Watercourse FMP and Moomin Creek FMP.

Zone D

Zone D is an environmental protection zone taken from the Lower Gingham FMP. This zone includes a core wetland area that is highly significant. The inclusion of this zone in the Gwydir FMP is to ensure consistency with the existing FMP arrangements and flood connectivity to this asset is maintained and protected. Only minor flood works – a stock refuge or an infrastructure protection work – are permitted in this zone with approval. These flood work provisions have been carried across from the Lower Gingham Watercourse FMP. Flood work approvals in this area are not likely to be substantially negatively affected by the Gwydir FMP.

Zone A

Generally land in the second generation FMP areas that were within the floodway networks will become the hydraulic Zone A in the Gwydir FMP. In the second generation FMP floodway network areas it is highly unlikely that any works other than those permissible in Zone A would have been approved in the Base Case. Flood work approvals in this area are not likely to be substantially negatively affected by the Gwydir FMP.

Zone A in the Gwydir FMP includes areas in addition to the hydraulic floodways that are important for flood connectivity to significant flood-dependent vegetation or are areas of flood-dependant vegetation. These are known as ecological refinements to Zone A. Land included as the ecological refinements to Zone A will be subject to significant change in management of flood works. If the Gwydir FMP had not been developed, it is likely that flood work proposals in these areas would have been assessed in general accordance with the rules in Zone B; however, with the addition of the ecological refinements to Zone A, these areas can now only have: approved access roads equal to or less than 15 cm in height; supply channels below the natural surface level; stock refuges; or infrastructure protection works (see Table 17 for rule changes). This will incur costs to landholders in the form of lost option value on this land compared with the Base Case. Flood work approvals in these areas may be significantly negatively affected by the Gwydir FMP.

Zone B

Floodplain land that is outside Zone D and Zone A but is within the large design flood area will become Zone B. Flood works in excess of the size limits in Zone B will now require advertising and thus will be restricted compared to the Base Case (see Table 17 for rule changes). This rule will incur some minor costs to landholders and the approving department in the form of advertising and considering objections, compared with the Base Case. The area and number of applications within Zone B that will be impacted by this rule is unknown as it depends upon the intentions of the current and future landholders. It is not possible to forecast number and complexity of applications or the time needed to advertise, assess objections, negotiate modifications and consider approval or rejection. Considering the maturity of the irrigation water market in the area, and that future expansion of the irrigation industry will depend on water use efficiency gains, the number of applications is expected to decrease but the complexity of applications increase. This cost will not be estimated. Former non-complying flood work applications in Zone B, which were unlikely to be approved in the Base Case, are unlikely to be approved under the Gwydir FMP. Flood work approvals in this category may be marginally negatively affected by the Gwydir FMP.

Zone C

Areas above the design flood or afforded protection by approved works will be in Zone C. Flood work applications in Zone C will be required to meet assessment criteria but will not require advertising. Flood work approvals in this area will not be substantially negatively affected by the Gwydir FMP.

Impact of rule changes in guideline and other floodplain areas

Zone A

Land that would probably have been recognised as floodway network in the Base Case, that is, would have been in a guideline floodway area or in a creek or flood runner, will become Zone A under the Gwydir FMP. In these areas it is highly unlikely that any works other than those permissible in Zone A would have been approved in the Base Case. Flood work approvals in this area will not be substantially negatively affected by the Gwydir FMP.

Ecological refinements to Zone A would probably not have been recognised as floodway network in the Base Case and will be subject to significant change. In this area approval can only be given to: access roads less than or equal to 15 cm; supply channels below the natural surface level; stock refuges; or infrastructure protection works (see Table 17 for rule changes). This will incur costs to landholders in the form of lost option value on this land compared with the Base Case. Flood work approvals in this area may be substantially negatively affected by the Gwydir FMP.

Zone B

Land that is not in Zone A but is within the design flood area will become Zone B. Flood works below the size limits in Zone B will not require advertising (see Table 17 for rule changes). This will provide additional benefits to landholders and the approving department as all applications required advertising in the Base Case. Flood works in excess of the size limits in Zone B will require advertising which is the same requirement as the Base Case. Former non-complying flood work applications in Zone B, which were unlikely to be approved in the Base Case, are unlikely to be approved under the Gwydir FMP. Flood work approvals in this category may be marginally positively affected by the Gwydir FMP.

Zone C

Areas above the design flood or afforded protection by approved works will be in Zone C. Flood work applications in Zone C will be required to meet assessment criteria but will not require advertising. This will provide additional benefits to landholders and the approving department as all applications required advertising in the Base Case. Flood work approvals in this category may be marginally positively affected by the Gwydir FMP.

Summary of negative impacts

Considering the changes from the Base Case to the Gwydir FMP the following negative impacts have been identified and are presented in Table 18:

1. lost access by landholders to all but limited applications in the area of ecological refinement to Zone A for both the current FMP areas and the floodplain guideline and other floodplain areas, and
2. the requirement to advertise applications for flood works that are greater than limited height flood works, stock refuges subject to size conditions and infrastructure protection works subject to size conditions in Zone B of land in the Lower Gingham Watercourse and Moomin FMP areas.

Table 18: Impact table of Gwydir FMP

Category	Total area (ha)	Impact	Who is impacted	Data sources	Scale: extent & intensity[a]	Likelihood & duration[a]
Land flood-dependant vegetation area included in Zone A	23,690 **Possible land use:** Wheat	Lost access to complying works other than access roads, infrastructure protection & below ground supply channels	Landholder **Quantifiable ($) (Yes/No):** Yes	GIS – area ABS – $ Wheat GVAP	Plan: Negative Low Regional: Negative Low Local: Negative Low Owner: Negative Medium	Low, Permanent Low, Permanent Low, Permanent Medium, Permanent
Land in Zone B of the two FMPs	Unknown area **Possible land use:** Cropping and grazing	Lost access to non-advertising of former complying applications for works greater than 0.4 m in height in Zone B of the Moomin and Lower Gingham Watercourse FMPs	Landholder **Quantifiable ($) (Yes/No):** No	Unknown area and number of applications: not estimated	Plan: Positive Low Regional: Positive Low Local: Positive Low Owner: Negative Medium	Low, Permanent Low, Permanent Low, Permanent Low, Permanent

[a] Impact: Assess each factor with the other three factors held constant. Magnitude: Low, Medium, High.

Impacted areas

The total area of ecological refinements to Zone A (flood-dependant vegetation and ecological flow corridors) from outside the modelled hydraulic floodway networks is estimated to be 24,160 hectares. This land was included to provide appropriate flood connection to high priority flood-dependant assets. There are 470 hectares of crown land and 23,690 hectares that is held privately. The land capability[9] of the 23,690 hectares of private land area is identified in Table 19 and the distribution is presented in Figure 19. It should be noted that land capability mapping was developed for broad scale application and may not be applicable to small scale portions of the landscape. The area most likely to be economically worth protecting with flood works is land that is classified 'Suitable for regular cultivation'.

Table 19: Land capability of private land area of ecological refinement to Zone A

Land capability	Area (ha)	
Other – unsuitable for agriculture and pastoral production	22	
Suitable for grazing with no cultivation	10,658	
Suitable for grazing with occasional cultivation[a]	6,449	
Suitable for regular cultivation	6,560	
Flood-dependent vegetation		3,760
Flood connectivity		2,800
Flood irrigation	1	
Urban area	1	
Total area of ecological refinement to Zone A	**23,690**[b]	
Total area of the Gwydir FMP (Zones A, B, C and D)	**1,141,700**	

Notes:
[a] It is assumed that these areas are likely to benefit from flooding and the landholder would not therefore want to protect themselves from flooding under the FMP.
[b] Numbers do not sum due to rounding.

[9] Land-use classification developed by the Soil Conservation Service that identifies the suitability of land for cultivation or grazing.

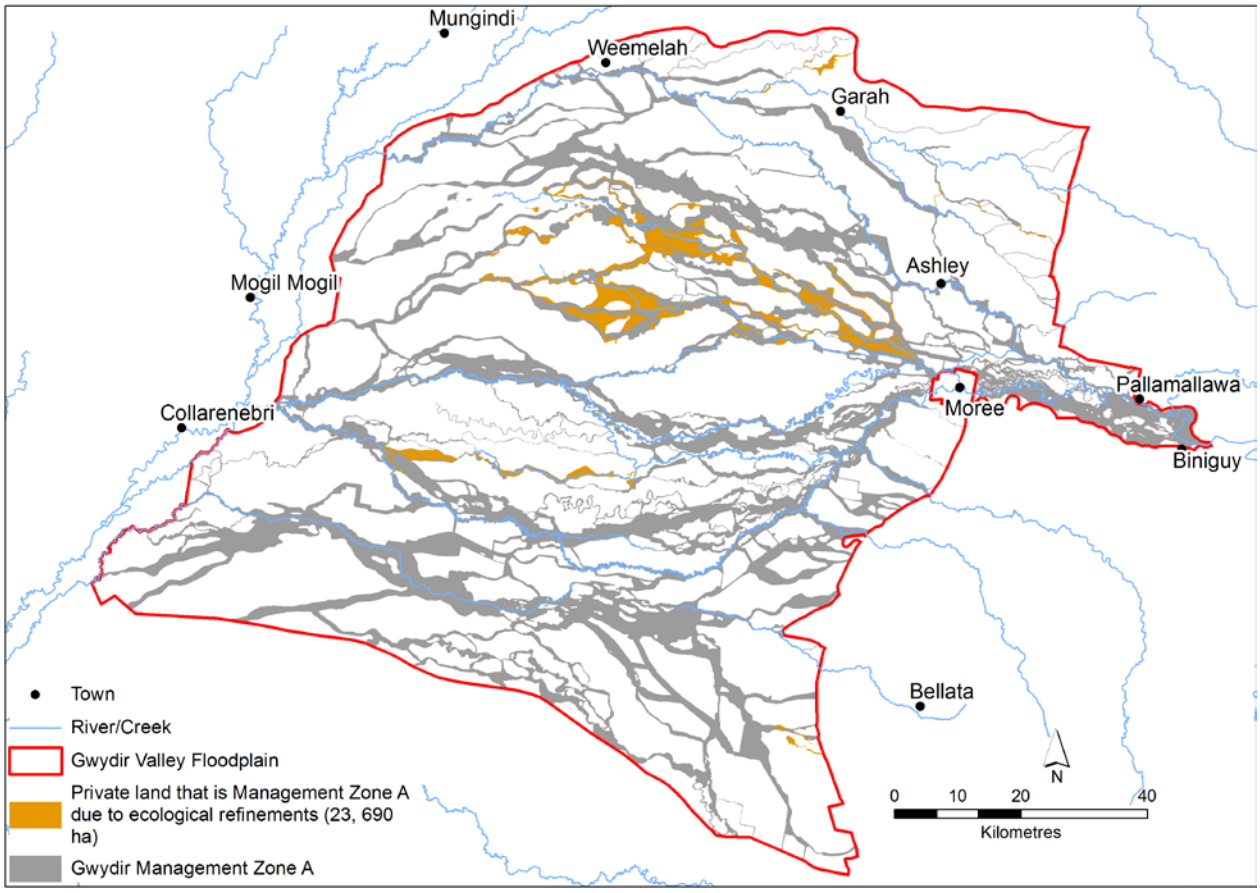

Figure 19: Ecological refinement to Zone A on private land

There are 6560 hectares within the 23,690 hectares of ecological refinements to Zone A that have a land capability classification of 'Suitable for regular cultivation'. This area is adjacent or in close proximity to the hydraulic floodway network. This amounts to less than 0.6 per cent of the floodplain area. It is acknowledged that, depending on the property size, these areas may have a large impact on option value for individual landowners. The distribution of ecological refinements to Zone A that are 'Suitable for regular cultivation' is presented in Figure 20.

The Gwydir FMP rules regulate only the construction of flood works and do not regulate land use such as cultivation or grazing of the land. Actual development of these areas may be limited by other legislation including the *Native Vegetation Act 2003* (NV Act).

Flood-dependent vegetation

Within the 6560 hectares that are 'Suitable for regular cultivation' that has been included in the ecological refinements to Zone A, there is currently existing flood-dependent vegetation on 3760 hectares. For one reason or another, including frequency and duration of flooding, this area remains as flood-dependent vegetation. The restrictions on flood work approvals to be implemented under this FMP only regulate the construction of flood works and do not prevent cultivation or grazing of the land. The actual development of these areas for cultivation may be limited by other legislation including the NV Act.

Notwithstanding the NV Act, it is expected that it would not be practical for a large proportion of this land to be developed for reliable cultivation. In the absence of information on the proportion of the area that could practically be developed for reliable cultivation, we have assumed that all of this area, (3760 hectares), could be developed for cultivation in order to estimate the annual gross value associated with the 'option value', knowing that it will result in an over-estimate of the value.

Flood connectivity

Within the 6560 hectares that are 'Suitable for regular cultivation', the remaining 2800 hectares have been included to provide flood connectivity to flood-dependant vegetation. Though much of the 2800 hectares is currently or has recently been cropped, it remains hydraulically connected to the floodway network. It is apparent that there are four possible positions that the current landholders are in with respect to flood works on this land. They may have:

1. decided that they are advantaged by any flooding that may occur and will not apply for flood works
2. recognised that flood works would not be approved and have not applied
3. applied for flood work approval and been rejected, or
4. planned to protect the area from floodwater but have not yet applied for approval.

There is no 'option value' loss for landholders who hold land for which flood work approval has been rejected, position 3. The proportion of the 2800 hectares that is subject to this situation, position 3, is unknown. In the course of the life of the FMP, as land is bought and sold, and both farm enterprises change relative profitability and farmers' enterprise preferences change, the area subject to positions 1, 2 and 4 may change. Those current or future landholders who in the Base Case may plan to move from position 1 and 2 to position 3, 'planned to protect the area from floodwater but have not yet applied for approval' may have lost 'option value' under the Gwydir FMP compared with the Base Case, in that under the FMP it will be certain that they will not be able to protect the cultivation land from floodwater with flood works.

In the absence of meaningful information on the area subject to position 3, the total area of 2800 hectares has been included in the estimate of the annual gross value associated with the 'option value', knowing that it will result in an over-estimate of the value.

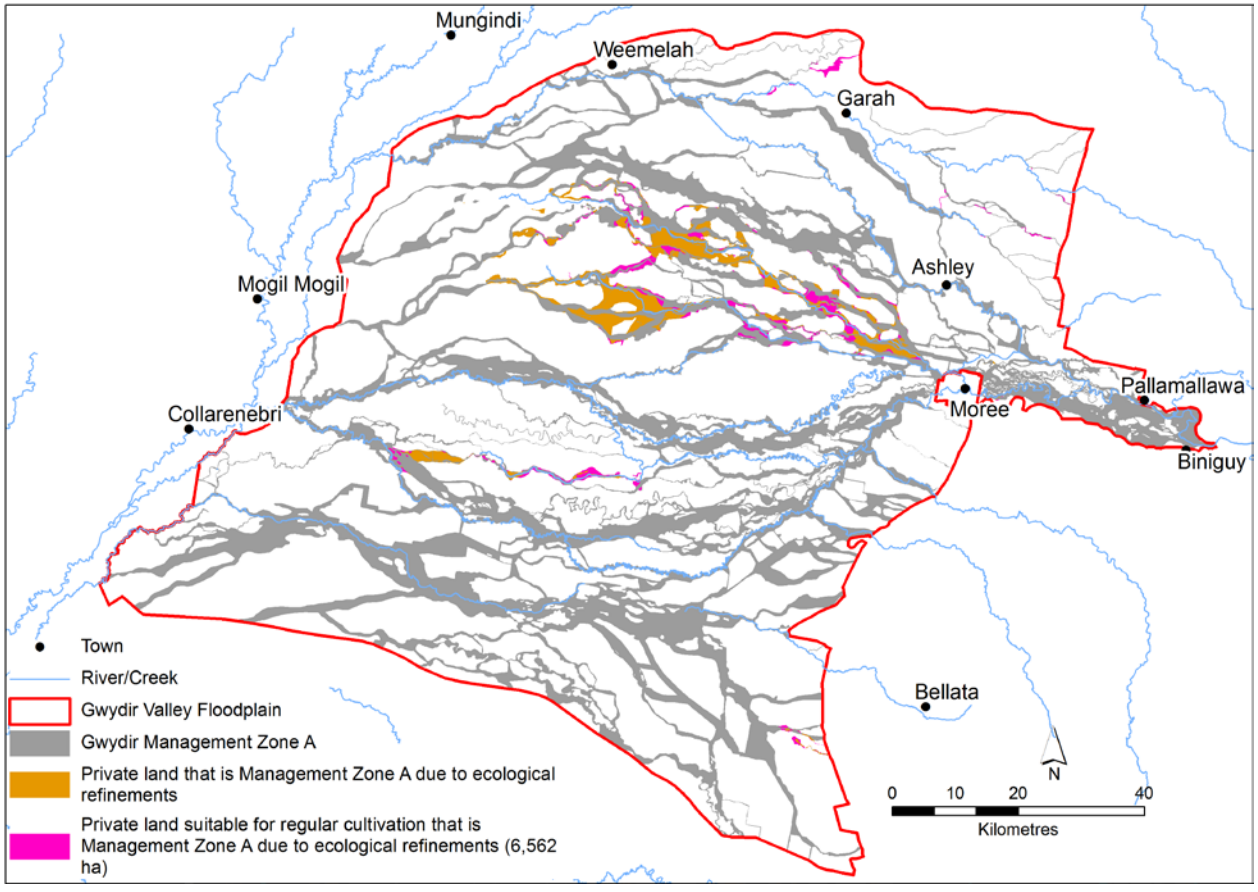

Figure 20: Private land suitable for regular cultivation included as the ecological refinement to Zone A

Estimated values of economic impacts

The financial impact of the restrictions imposed on the area of flood-dependant vegetation included in Zone A can be estimated using data on the area of land 'Suitable for regular cropping' and the 'Gross value of agricultural production 2011'. The potential use of the area suitable for regular cropping (6560 hectares) is assumed to be continuous wheat production. Wheat returns from this land are estimated to produce $627 gross value of production per hectare. This is based on the estimated gross value and area of 'Wheat for grain' produced in the Gwydir FMP area. These estimates were prepared as part of the socio-economic profile of the Gwydir FMP area and are based on ABS data for 2011. The gross value of production loss due to the prevention of the capacity to construct flood protection banks in this area under the FMP will be compared to the total gross value of production for the Gwydir FMP to identify the level of significance.

The area of flood-dependant vegetation included in Zone A is largely adjacent to watercourses and is therefore likely to be exposed to frequent flooding. Some of these flood events are beneficial to the crop or pasture and some are devastating depending on the timing (relative to crop and pasture growth cycle), depth, duration and speed of the floodwater. As flood works to protect crops cannot be constructed in Zone A, it is assumed that the outcome of these events is an additional one crop failure in four years.

Likewise, the impact on the grazing part of the area of flood-dependant vegetation included in Zone A will depend upon the timing and duration of flood events; however, in this case it is assumed that the inundation will not be of sufficient duration or frequency to cause a total loss of pasture production but will increase pasture production as a result of increased soil moisture after the flood event. As the gross value of grazing production on 17,110 hectares of grazing land would be reduced if flood protection banks were erected under the FMP compared with the Base Case, this is unlikely to occur. The implementation of the Gwydir FMP will therefore have no negative impact on the gross value of production from grazing.

On average, the gross value of wheat production from the 6560 hectares of cropping land could potentially produce $4.11 million per year in the Base Case with bank protection. Without bank protection under the FMP this area would potentially produce $3.08 million per year from cropping – a reduction of $1.03 million. The upper limit of the net impact of the implementation of the FMP on the area of private cropping ecological refinement to Zone A land is estimated to be a reduction of $1.03 million. This is very small, 0.19 per cent, when compared to the gross value of agricultural production for the Gwydir Valley Floodplain area of $543.9 million.

Many landholders will not be impacted; however, there may be some individual farm level impacts that could be more significant depending on the proportion of their land that is affected. A counter balancing item is that the area of ecological refinement to Zone A would probably have a discounted land value due to flooding frequency.

This potential estimated impact is expected to be an over-estimate due to much of the 6560 hectares, identified in the analysis as holding potential for continuous wheat production, is currently used for grazing because it floods too often to be cropped reliably. In such cases the farmer's assessment would be that the higher cost of cropping and the risk of loss is greater than the more reliable pasture grazing option of lower cost and smaller gain.

Requirement for detailed analysis (Phase 2)

The methodology used in this analysis requires that a detailed analysis (Phase 2) be conducted, if the preliminary analysis, Phase 1, indicates that there may be significant socio-economic impact. Considering that the estimated impact of the Gwydir FMP rules (estimated to be a reduction of 0.19 per cent of the gross value of agricultural production for the Gwydir floodplain area) is of low significance for the regional economy, no further investigation is currently proposed. In addition, there was no other major issue raised during the public exhibition period that warrants further detailed assessment.

Detailed summary

In considering change from the Base Case to the Gwydir FMP, the following key negative impacts were identified:

- lost opportunities to get approval for new works in the area of ecological refinement to Zone A, other than access roads, below ground supply channels, stock refuges and infrastructure protection works, and
- works greater than 0.4 metres in height, stock refuges that exceed size conditions and infrastructure protection works that exceed size conditions in Zone B that would previously have been considered 'complying' and not requiring advertising under the two existing FMPs, now require advertising.

The impact of the Gwydir FMP is estimated to be a reduction of 0.19 per cent of the gross value of agricultural production for the Gwydir floodplain area and therefore no further investigation is currently proposed. This is the estimated upper limit considering that it is unlikely that all the area of ecological refinement to Zone A that is 'Suitable for regular cultivation' could be cropped. The cost of advertising applications in Zone B of the two existing FMPs has not been estimated due to the unknown size, number and complexity of possible applications that may have occurred in the Base Case compared to the Gwydir FMP.

Community consultation occurred as part of targeted consultation and public exhibition of the draft Gwydir FMP. The community has had the opportunity to provide feedback on potential socio-economic impacts of the draft management zones and rules for the draft Gwydir FMP. Potential socio-economic impacts and/or options identified by the community have been included in the socio-economic impact analysis where appropriate.

Many landholders will not be impacted by these estimated costs; however, there may be some individual farm level impacts that are more significant depending on where the land is situated in the landscape.

Role of socio-economics in FMP development

This impact assessment concludes that there is limited significant negative socio-economic impacts from the Gwydir FMP and therefore no further investigation is currently proposed.

Socio-economic advice has influenced the development of the Gwydir FMP zones, rules and assessment criteria. Key consideration was given to achieving a balance at each stage between the environment and economic outcomes.

Some examples include:

- categorising the types of flood works enabled consideration of important information on the socio-economic benefits of flood works along with the level of risk that a flood-work type would significantly impact on flooding behaviour (Step 3)
- ensuring socio-economic impacts were included in the criteria for 'reasonable consistency' with previous floodplain management arrangements (Step 9)
- incorporating, wherever possible, areas with approved existing flood work developments into Zone C (Steps 4 and 7)
- including community and stakeholder acceptance in determining the appropriate depth velocity product threshold for defining the modelled hydraulic floodway network. If the threshold is too low then the management zones may be too restrictive for future development and not accepted by the floodplain community. On the other hand, if the threshold is too high it may be difficult to determine continuity of flow paths in the downstream reaches of the floodplain. This would potentially increase flood risk to land occupiers by under-representing major discharge areas (Step 4)

- weighing up the socio-economic impacts of development controls against the potential for different types of flood works to impact on flooding behaviour. The restrictions on the types of flood works that could be applied for were made to minimise the risk that flood works would impact flooding behaviour, whilst being sympathetic to landholder needs. These decisions were checked against the works likely to be approved under existing floodplain management planning arrangements, and discussions held during targeted consultation with the community and interagency officers (Step 8)
- requiring proposed works to be advertised provides local landholders with an opportunity to comment on any impact that a proposed flood work could have in causing or exacerbating flooding depth, duration or flow rate problems on their land
- non-advertising of proposed minor flood works enables landholders to construct approved flood works of a more minor nature without advertising their proposed works, which will save both money and time (Step 8), and
- carrying across the extent and intent of the rules from the core wetland area in the *Lower Gingham Watercourse Floodplain Management Plan* (2006) into the Gwydir FMP to ensure consistency with current floodplain management arrangements (Step 7).

Consultation and review of the plan

Consultation to identify and prioritise floodplain assets

Technical Advisory Group

The Gwydir Technical Advisory Group (TAG) was involved in the identification and prioritisation of floodplain assets that require protection under the FMP. The TAG comprised of floodplain specialist staff from NSW Government agencies. Prior to development of the FMP a number of workshops were held with the Gwydir TAG to:

- identify assets that are dependent on flooding
- identify watering requirements of flood-dependent assets
- establish conservation targets for assets for inclusion in prioritisation software (Marxan)
- document the existing flooding regime in the floodplain
- identify and map existing flood works
- document the ecological and social benefits of flooding
- develop a socio-economic profile for land occupiers in the floodplain.

Information provided by the TAG was incorporated into the development of the draft FMP and is outlined in Steps 1 to 10 of this document.

Aboriginal Technical Working Group

The Gwydir Aboriginal Technical Working Group (ATWG) was formed to assist with the identification and prioritisation of cultural assets that require protection under the plan. The ATWG is comprised of state and regional cultural heritage experts. Prior to development of the plan a number of workshops were held with the Gwydir ATWG to:

- define and identify Aboriginal values that are dependent on flooding
- identify watering requirements of Aboriginal values and other floodplain assets that have Aboriginal value
- identify and document significance of Aboriginal values and other floodplain assets that have Aboriginal value
- develop a community consultation process for identification of Aboriginal values in data gap areas.

Information provided by the ATWG was incorporated into the development of the draft FMP and is outlined in Steps 4, 6 and 7.

Consultation with the local Aboriginal community

Consultation was undertaken with the local Aboriginal community in parts of the floodplain where there was a paucity of cultural heritage information. Consultation was undertaken through direct discussion with Aboriginal community members to:

- identify Aboriginal values important to the local Aboriginal community
- identify flood dependency associated with Aboriginal values
- understand the nature of the value, and how it connected with floodwater.

The consultation process identified nine areas that contained flood-dependent Aboriginal values of high significance, such as ceremonial grounds. These areas were identified as requiring protection from future flood works to ensure their ongoing preservation. Refer to Steps 4, 6 and 7 for further information on how Aboriginal values from consultation have been incorporated into developing the FMP.

Consultation to inform development of management zones and rules

Technical Advisory Group and Aboriginal Technical Working Group

The Gwydir TAG and ATWG were involved in the review of the draft management zone methodology and review of the draft zones and rules. Table 20 outlines the actions performed by the TAG and ATWG including changes required to the draft FMP as a result of the review process.

Table 20: Actions performed and resultant changes from TAG and ATWG review

Aspect of FMP	Action performed	Change required
Management zone methodology	Review of: • conservation targets for ecological assets • zone recommendations for ecological and cultural assets • depth velocity threshold for delineation of management zones	Inclusion of environmental water pathways into delineation of management zones Use of Marxan outputs, such as selection frequency, to validate allocation of ecological assets to management zones Adoption of depth velocity threshold (0.1 m^2/sec)
Management zones	Review of spatial extent of management zones including: • flow paths • connection to assets • existing developed areas	Addition of: • flow paths to high value frequently flooded ecological assets that are identified as Commonwealth and state priority assets • cultural assets identified from community consultation to Management Zone A
Rules	Review of: • types of flood works that will be accepted for approval • rule thresholds and construction requirements	Addition of: • low level flood works (<40 cm) to act as protection banks during small flood events in Zone B • causeway requirement for access roads in Zone A • flow regulation device to ensure passage of floodwater • borrow pit construction requirements associated with access roads in Zone A
Assessment criteria	Review of assessment criteria requirements and thresholds	Addition of: • cumulative impact thresholds in the assessment criteria for assessment at the regional scale • ecological and cultural assessment criteria pertaining to maintenance of flood connectivity to ecological and cultural assets

Targeted consultation

Targeted consultation on the draft management zones and rules for the draft FMP was undertaken in March and April 2014.The objectives of this consultation were to:

- provide background for key stakeholders as to why the plans were being developed, how they were developed, what management zones and rules were proposed in the Gwydir floodplain and how stakeholders could provide feedback, and
- 'road test' the proposed Gwydir plan boundary, management zones and rules.

Targeted consultation involved the following key stakeholder groups and individuals within the Gwydir floodplain:

- graziers, dryland and irrigation landholders and organisations
- local Aboriginal community members
- environmental groups
- local and state government representatives
- local agronomists and consultants.

An issue with Management Zone A pertaining to the types of works that can be applied for was identified during targeted consultation. Stock refuge was originally not permitted in Zone A. During consultation it was highlighted that stock refuge should be added as a type of work that can be applied for in Zone A. The addition of this type of work is imperative for landholders whose whole landholding resides within Management Zone A. This suggestion was adopted and incorporated as a recommendation for consideration by the Interagency Regional Panel (IRP).

Interagency Regional Panel

The IRP was established to review the management zones and rules contained in the FMP. The IRP consists of two representatives from the Department of Primary Industries: one from DPI Water and another DPI representative covering agricultural, fisheries and water management interests, and one representative from OEH to cover environmental interests.

Representatives from the Local Land Service, State Water, TAG and Department of Trade and Investment (Economics Branch) also attended meetings (as observers) to provide advice on the management zones and rules and other matters within their area of expertise.

The key responsibilities of the IRP were to:

- ensure that proposed management rules achieved the objectives of the WMA 2000
- provide information and analysis
- bring a balanced approach to the development of the plan: economic, social, environmental, and cultural considerations.

The IRP had steering responsibilities prior to public exhibition and post public exhibition. The IRP reviewed the proposed management zones and rules and feedback from targeted consultation in April 2014. No changes were made to the proposed management zones but the IRP recommended changes to some of the rules and assessment criteria based on feedback from targeted consultation and advice from the TAG.

The IRP also provided key considerations for the implementation of management zone rules. The following considerations will be incorporated into departmental guidelines and used by DPI Water when assessing flood-work applications.

Considerations for stock refuges

DPI Water must consider that:

- exemptions relating to stock refuges do not apply in Management Zones A and D
- multiple landholders may wish to share a single stock refuge
- areas where flood durations are long will need stock refuges to be an adequate size for feeding stock
- stock refuges will need to be high enough that they are not inundated
- if in the wrong position or location, a stock refuge could negatively impact on flooding behaviour.

Considerations for infrastructure protection works

DPI Water must consider that:

- exemptions relating to IPW do not apply in Management Zones A and D
- IPW will need to be high enough that they are not inundated.

The IRP's involvement post public exhibition included:

- consideration of community feedback
- recommending changes to management zones and rules based on feedback from public exhibition
- review and endorsement of final management zones and rules prior to plan commencement.

Public exhibition

The draft Gwydir FMP was on public exhibition from Monday 8 September 2014 to Friday 24 October 2014. The objectives of this consultation were to provide background to stakeholders on:

- why the plan was being developed
- how the plan had been developed to date
- what rules were proposed in the various areas, and
- how stakeholders could make a formal submission.

The draft plan was made available on the DPI Water website and was displayed at regional locations within the plan area. Submissions were accepted in writing, submitted electronically or by post.

The feedback received during public exhibition was considered by the IRP prior to finalising the FMP.

Plan finalisation and commencement

The IRP was reconvened after public exhibition to review outcomes and to recommend changes to management zones and rules based on community feedback. Changes supported by the IRP were made to the Gwydir FMP Order.

The FMP was then submitted for endorsement to the Minister for Primary Industries, Lands and Water who was required to seek concurrence with the Minister for the Environment prior to commencement of the plan.

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Glossary

Aboriginal values are sites, objects, landscapes, resources and beliefs that are important to Aboriginal people as part of their continuing culture.

annual exceedance probability is the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 ML/day has an AEP of 5%, it means there is a 5% chance (that is a one-in-20 chance) of a 500 ML/day or larger event occurring in any one year.

borrow is an area of land where material is excavated or removed to construct a flood work at another location. The removal of material from this area results in a depression or 'hole' in the ground.

connectivity refers to the unimpeded passage of floodwater through the floodplain. Connectivity is important for instream aquatic processes and biota and the conservation of natural riverine systems.

cultural asset is an object, place or value that is important for people to maintain their connections, beliefs, customs, behaviours and social interaction.

design flood is a flood of known magnitude or annual exceedance probability (AEP), that can be modelled. A design flood is selected to design floodway networks which are used to define management zones for the planning and assessment of the management of flood works on floodplains. The selection is based on an understanding of flood behaviour and associated flood risk. Multiple design floods may be selected to account for the social, economic and ecological consequences associated with floods of different magnitudes.

discharge (or flow) is the rate of flow measured in volume per unit of time (e.g. megalitres per day = ML/day).

ecological assets are a wetland or other floodplain ecosystem, including watercourses that depend on flooding to maintain their ecological character. Areas where groundwater reserves are recharged by floodwaters are also considered to be ecological assets. Ecological assets are spatially explicit and are set in the floodplain landscape.

ecological values are surrogates for biodiversity that are used to prioritise the ecological assets and included fauna and fauna habitat, vegetation communities and areas of conservation significance.

ecosystem is a biological system involving interactions between living organisms and their immediate physical, chemical and biological environment.

fish passage refers to connectivity that facilitates the movement of native fish species between upstream and downstream habitats (longitudinal connectivity) and adjacent riparian and floodplain areas (lateral connectivity). Areas that are important for fish passage include rivers, creeks and flood flow paths.

flood-dependent assets refers to assets that have been identified in the plan as having important ecological or cultural features which rely on inundation by floodwaters to sustain essential processes.

flooding regime refers to the frequency, duration, nature and extent of flooding.

floodways are areas where a significant discharge of floodwater occurs during small and large design floods.

groundwater recharge areas are areas where water from a flood event leaks through the soil profile into the underlying aquifers.

heritage sites are cultural heritage objects and places as listed on Commonwealth, state and local government heritage registers.

infrastructure protection works are flood works that are for the protection of houses, stock yards and other major infrastructure, such as machinery sheds.

management zones are areas in the floodplain that have specific rules to define the purpose, nature and construction of flood works that can occur in those areas.

natural surface level is the average undisturbed surface level in the immediate vicinity.

recharge means the addition of water, usually by infiltration, to an aquifer.

windrow refers to a row or line of material.