RURAL FLOODPLAIN MANAGEMENT PLANS

Background document to the Macquarie Valley Floodplain Management Plan 2021 – Appendices

Water Management Act 2000

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Contents

Abbreviations

Abbreviation	Description
ABS	Australian Bureau of Statistics
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AEP	annual exceedance probability
AHIMS	Aboriginal Heritage Information Management System
ASDST	Aboriginal Sites Decision Support Tool
DEM	Digital Elevation Model
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FMP	floodplain management plan
GVAP	gross value of agricultural production
IRP	Interagency Regional Panel
IRSAD	Index of Relative Socio-economic Advantage and Disadvantage
LGA	local government area
LiDAR	light detection and ranging
Macquarie Valley FMP	*Floodplain Management Plan for the Macquarie Valley Floodplain 2021*
MODIS	Moderate Resolution Imaging Spectrometer
NDVI	Normalised Difference Vegetation Index
NSW	New South Wales
NSW DPI	NSW Department of Primary Industries
OEH	former NSW Office of Environment and Heritage (now part of Environment, Energy and Science within the NSW Department of Planning, Industry and Environment)
PCT	plant community type
RORB	general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs
SA1	Statistical Area level 1
SA2	Statistical Area level 2

Abbreviation	Description
SDM	species distribution model
SEIFA	Socio-economic Indexes for Areas
TAG	Technical Advisory Group
TSC Act	*Threatened Species Act 1995*
TSR	Travelling Stock Reserve
Water Act	*Water Act 1912*
WM Act	*Water Management Act 2000*

Appendix 1: Rural floodplain management planning approach under the *Water Management Act 2000*

Table 1.1. Approach to rural floodplain management planning under the WM Act

Step	Key inputs/processes	Key outputs/outcomes
1 – define the floodplain boundary	• Information on the nature and extent of flooding over time • Floodplains designated under Part 8 of the *Water Act 1912* (Water Act) • Other statutory boundaries and infrastructure features (e.g. water sharing plans, roads and floodplain harvesting register of interest areas)	Map of floodplain boundary to be designated under the *Water Management Act 2000* (WM Act)
2 – identify existing flood works	• Flood-work licences • Area of land protected by flood works identified from spatial data such as flood imagery, LiDAR and aerial photography • Local knowledge of Department of Planning, Industry and Environment licensing officers	• Map of area of land protected by flood works • Number of existing approved flood work licences
3 – review existing rural floodplain management arrangements	• First-generation floodplain development guidelines and studies (non-statutory) • Second-generation rural floodplain management plans (FMPs) (Water Act)	Information on and analysis of key aspects of existing rural floodplain management arrangements
4 – determine the floodway network	• Design floods • Flood frequency analysis • Hydrological/hydraulic model input • Flood imagery • Existing floodway networks (Step 3) • Local knowledge	• Map of floodway network, including floodways, inundation extent and areas outside the floodway network • Better understanding of existing flooding regime
5 – identify and prioritise floodplain assets	• Identified from peer-reviewed literature, relevant legislation, policies, databases and registers • Various spatial data (e.g. plant community type (PCT) mapping) • Optimum watering requirements • Conservation significance of assets determined from the Technical Advisory Group (TAG) and Marxan • Cultural assets identified by the Aboriginal Technical Working Group and through community consultation	• Definition and maps of ecological and cultural assets • Grouping of ecological assets based on optimum watering requirements • Understanding of the flood dependency of cultural assets • Map of high-priority floodplain assets
6 – prepare a socio-economic profile	• Secondary data sources, including the Australian Bureau of Statistics (ABS), the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and NSW Government departments • Local knowledge	Understanding of the baseline profile of the floodplain, including stakeholder identification

Step	Key inputs/processes	Key outputs/outcomes
7 – delineate management zones	• Hydraulic criteria based on information from Steps 1, 2 & 4 • Criteria to ensure appropriate consistency between current and management options based on information from Step 3 • Ecological and cultural criteria based on information from Step 5 • Analysis to ensure equity based on information from Step 6 • Feedback from consultation	Definition and map of management zones, which will generally result in 4 zones: • major flood discharge • flood storage and secondary flood discharge • flood fringe and existing development • special ecological and cultural protection
8 – determine rules	• Understanding of management zones • Existing types of flood works • Existing and potential flooding problems • Rules from existing rural FMPs • Feedback from consultation	Rules and assessment criteria covering: • authorised flood works • acceptable impacts • advertising requirements • existing flood works and structures
9 – consider existing floodplain management arrangements	Information on existing floodplain management arrangements gathered in Step 3 is compared against the FMP to determine the extent of change	The extent of change between existing rural floodplain management arrangements and the FMP is determined
10 – assess socio-economic impacts	• Economic data • Area under irrigated crop • Gross margins • Prices • Hydrology data	Social and economic impacts assessed against the base case
Consultation and review	• The FMP, reviewed by the Interagency Regional Panel (IRP) at key stages before targeted consultation, public exhibition and plan commencement • Consultation with key stakeholders at targeted consultation and the wider community during public exhibition	• IRP provides whole-of-government endorsement of the FMP • Feedback from key stakeholders and the community is considered in FMP development • Information on community concerns and issues is gathered
Finalise and commence plan	• Revision of socio-economic assessment and impact mitigation strategies	The final FMP is implemented and plan outcomes are achieved

Appendix 2: History of floodplain management in the Macquarie Valley Floodplain

Floodplain management planning in the Macquarie Valley Floodplain has evolved in response to changing community needs, changes to land and water use, an increased awareness of the importance of floodplain ecology, and changes to the legislative and policy framework governing water management.

A detailed history of floodplain management in the Macquarie Valley Floodplain is outlined below.

Pre-1970s

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

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

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

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

1970 to early 1980s

During the early to mid-1970s, major flood events in inland NSW revealed that uncoordinated flood works were causing major changes in traditional flood patterns in many locations. These changes resulted in heavy crop losses and flood damage in areas that had previously been relatively flood-free.

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

- *Guidelines for Flood Plain Development, Macquarie River, Narromine to Warren* (New South Wales Water Resources Commission 1978)
- *Guidelines for Flood Plain Development, Macquarie River, Warren to Oxley Station* (New South Wales Water Resources Commission 1982).

While the guidelines were developed under this Act, they are non-statutory. The generalised network of floodways for the Macquarie Valley Floodplain region were delineated on plans that also identified property boundaries and named the respective landholders. Opportunity was provided for the community to comment on the guidelines.

The general principles that applied in the development of the guidelines, and generally in the development of leveeing a floodway scheme, are as follows:

i. Any system of floodways should conform as closely as is reasonably possible to the natural drainage pattern.
ii. Land that can be protected can be maximised providing that no other properties are adversely affected as a result.
iii. Floodways should discharge from a holding as closely as practicable to the location of natural floodways.
iv. The exit of floodwater from floodways should be at rates and depths similar to those that would have been experienced under natural conditions.
v. Care must be taken to ensure that sufficient pondage is retained on the floodplain so that the flood wave is not unduly accelerated to downstream areas and its height increased.
vi. Provision should be made for local drainage from protected areas, but the design of such drainage is the responsibility of individual landholders.

Other issues to consider included:

- The possibility of scour within floodways: Where land is cleared and ploughed for cultivation, its susceptibility to scour and erosion is increased. Floodways should be kept wide so that flows are not concentrated, which could lead to scour. Safeguards against scour could also be considered.
- Land use type: Certain land use types may impede flows. For example, dense, tall crops such as sorghum may impede flood flows, leading to increased flood levels. A lower crop such as wheat may be more desirable for a floodway, or a grazing land use.
- Potential adverse impacts of flood works on neighbouring properties.

1984–1985

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

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

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

The Lower Macquarie floodplain was designated under section 166 of Part 8 of the Water Act in 1985 to capture existing and potential floodplain developments within the floodplain. The Narromine to Oxley Station floodplain, which is the area to which the Macquarie River (Narromine to Oxley Station) floodplain management plan applies, was similarly designated in 2008.

1986

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

1990–1999

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

In 1999, Part 8 of the Water Act was amended to allow for more strategic coordination of controlled works through the preparation of statutory rural floodplain management plans for valleys faced with pressure from development, such as the Gwydir, Namoi and Macquarie valleys (section 166a). The amendments made rural floodplain management plans the statutory basis for determining flood control works to overcome difficulties with the assessment of works on an ad hoc basis. The amendments also allowed for areas not designated as part of a floodplain to be covered by Part 8 of the Water Act. This meant that works in these areas had to be assessed if they could potentially affect flood flow into and out of a stream and affect flooding. Section 166C of the Water Act provides guidelines for the assessment of such works. Rural plans also had to be developed in accordance with the provisions and policies of the *NSW Floodplain Development Manual* and *NSW Flood Prone Land Policy*.

Up until this point, the floodplain development guidelines produced were non-statutory. The new strategy was developed in response to strong community support for a change in the then-current practice. A key objective was to develop the floodplain management plans using community-based floodplain management committees. The process for developing the plans included undertaking:

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

To facilitate the revised strategy, a $5-million program was jointly funded by the Natural Heritage Trust and the NSW Government to develop plans in 18 inland rural areas across 3 million hectares. The amendment was to outline a new process for delivering strategic outcomes to manage flood control works on inland floodplains where these works did not require council consent under rural zonings. Where rural floodplain management plans and development guidelines existed, rural plans replaced the outdated development guidelines.

In the Macquarie, the former Department of Natural Resources began preparation of the *Macquarie River (Narromine to Oxley Station) Floodplain Management Plan*, in consultation with the Macquarie River Floodplain Management Committee, which comprised representatives from the community, government agencies and stakeholder groups. The floodplain management plan was created to replace the outdated 1978 and 1982 guidelines (see 1970 to early 1980s) by addressing current levels of development, using more recent flood information and considering the floodplain environment.

2000

In 2000, the WM Act was enacted to replace the Water Act and a range of other Acts dealing with water management. This was to achieve sustainable and integrated management for all water-based activities, including water use, drainage, floodplains and groundwater. The repeal of the Water Act has been an ongoing process.

The WM Act is the culmination of the NSW water reform process, driven by the Council of Australian Governments. The WM Act contains floodplain management provisions that relate closely to existing provisions under the amended Part 8. Sections 29 and 30 detail the core and additional provisions to be considered when developing floodplain management plans. The core provisions require plans to deal with:

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

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

2001

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

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

2005–2009

In 2005, the *Floodplain Development Manual* was again updated and gazetted, as the manual relating to the development of flood-liable land for the purposes of section 733 of the *Local Government Act 1993*. The updates reflect the significant change in the roles of state agencies and clarified some planning issues that had led to inconsistent interpretations. The manual supports the

NSW Government's *Flood Prone Land Policy* in providing for managing human occupation and use of the floodplain, considering risk management principles.

In 2008, the *Macquarie River (Narromine to Oxley Station) Floodplain Management Plan* (Macquarie River FMP 2008) was adopted, following public exhibition. The plan forms the basis for determining whether controlled works on the floodplain are granted approval under Part 8 of the Water Act.

2010–present

In 2010, work began on the NSW Healthy Floodplains project. This is a NSW Government initiative to reform the management of water on floodplains through the development of floodplain management plans, as well as licensing of floodplain harvesting water extractions. In June 2012, Stage 1 of the Healthy Floodplains project was awarded $36 million by the Australian Government, with additional contributions by the NSW Government.

Part 8 of the Water Act was repealed in 2016 and replaced by the floodplain management provisions of the WM Act, which enabled the development of the *Floodplain Management Plan for the Macquarie Valley Floodplain 2021* (Macquarie Valley FMP). The Macquarie Valley FMP will consolidate floodplain management measures and supersede all existing floodplain management arrangements in the Macquarie Valley Floodplain. The designation of the Macquarie Valley Floodplain will enable the administration and coordination of flood works in the floodplain.

Appendix 3: Design floods

A design flood is a flood of known magnitude or annual exceedance probability (AEP) that can be modelled. A design flood forms the basis of the floodway network, and this information is used as the hydraulic basis when developing the management zones.

As outlined in Step 4 of the main document, 3 design floods were selected for the Macquarie Valley FMP:

- 1990 large design flood – August 1990 (3% AEP at the Macquarie River at Narromine gauging station (GS 421006))
- 2000 large design flood – November 2000 (8% AEP at the Macquarie River at Narromine gauging station)
- small design flood – March 2012 (33% AEP at the Macquarie River at Narromine gauging station).

Flood frequency analysis

A flood frequency analysis for gauging stations throughout the Macquarie Valley Floodplain was undertaken to assist with the selection of the design floods for the Macquarie Valley FMP. The technique involved using observed peak flow (megalitre per day) data to calculate statistical information such as mean values, standard deviations, skewness and recurrence intervals. This statistical data was then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various flows as a function of recurrence interval or exceedance probability.

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

Flood frequency estimates for the Macquarie River at Narromine from the Macquarie Valley FMP scoping study (NSW Office of Environment and Heritage (OEH) 2013) were consistent with Lyall and Associates (2012) estimates for the major floods of 1990 and 2010; however, there was a significant variation between estimates from both studies for larger floods including the 1 in 100 AEP flood. This discrepancy resulted mainly from the method used to censor flows in the OEH study. The use of different techniques for fitting probability curves in both studies is also likely to have contributed to some variation in estimates.

The flood frequency analysis was amended using revised methods and is now consistent with estimates from the Lyall and Associates study.

Table 3.1. Annual flood series used in flood frequency analysis for Narromine

shows the pre– and post–Burrendong Dam annual series of flow used in the analysis. Pre-dam data was available for the Narromine gauging station from 1901 to 1964. Post-dam data was available for the Narromine gauging station from 1966 to 1977 and for the Baroona gauging station (GS 421127) from 1987 to 2016. A correlation of peak annual flows between the Dubbo gauging station (GS 421001) and Baroona gauging station from 1986 to 2010 was used to estimate the flows for the intervening years from 1978 to 1986. The Baroona gauging station is located about 12 kilometres upstream of Narromine and is below the confluence with Coolbaggie Creek. There are no significant tributary inflows between the gauge and town.

Table 3.1. Annual flood series used in flood frequency analysis for Narromine

Year	Flow (ML/d)	Year	Flow (ML/d)	Year	Flow (ML/d)	Year	Flow (ML/d)
1901	34,474	1931	149,990	1961	43,114	1991	13,219
1902	10,022	1932	17,798	1962	41,558	1992	43,200
1903	41,386	1933	16,416	1963	33,264	1993	32,227
1904	27,562	1934	97,114	1964	56,074	1994	6,307
1905	25,834	1935	24,538	1965	-	1995	24,710
1906	78,278	1936	78,278	1966	14,256	1996	39,139
1907	15,638	1937	12,528	1967	12,355	1997	5,357
1908	13,478	1938	6,221	1968	14,256	1998	85,363
1909	19,613	1939	22,982	1969	86,400	1999	17,798
1910	78,278	1940	5,011	1970	39,658	2000	94,435
1911	72,662	1941	111,974	1971	135,907	2001	9,072
1912	42,163	1942	130,032	1972	27,043	2002	7,344
1913	11,491	1943	57,542	1973	67,997	2003	14,774
1914	15,638	1944	1,987	1974	54,432	2004	3,197
1915	30,586	1945	85,882	1975	11,491	2005	22,550
1916	77,242	1946	5,357	1976	67,565	2006	3,283
1917	50,112	1947	32,486	1977	9,850	2007	16,589
1918	27,562	1948	44,064	1978	60,048	2008	3,024
1919	7,776	1949	46,742	1979	10,195	2009	22,032
1920	191,030	1950	199,930	1980	9,418	2010	185,587
1921	85,622	1951	93,658	1981	40,349	2011	29,462
1922	97,891	1952	142,042	1982	9,590	2012	36,720
1923	48,643	1953	24,019	1983	21,514	2013	10,898
1924	52,618	1954	67,738	1984	36,029	2014	3,737
1925	21,773	1955	501,120	1985	14,947	2015	3,588
1926	191,030	1956	301,018	1986	17,539	2016	74,365
1927	26,698	1957	3,197	1987	10,541	n/a	n/a
1928	91,411	1958	44,237	1988	17,021	n/a	n/a
1929	14,170	1959	139,018	1989	24,278	n/a	n/a
1930	55,296	1960	97,891	1990	179,453	n/a	n/a

A Log-Pearson Type III distribution was fitted to the pre- and post-dam annual series of flood peaks for the Macquarie River at Narromine.

Since the recorded flood peaks are only a small sample of the peaks that actually occurred over a longer period, an expected probability adjustment was made using the procedure set out in Kuczera and Franks (2006). This procedure recommends implementing the expected probability adjustment to remove bias from the estimate. The resulting frequency curves, along with the 90% confidence limits for pre- and post-dam periods, are shown in Figure 3.1 and Figure 3.2 respectively.

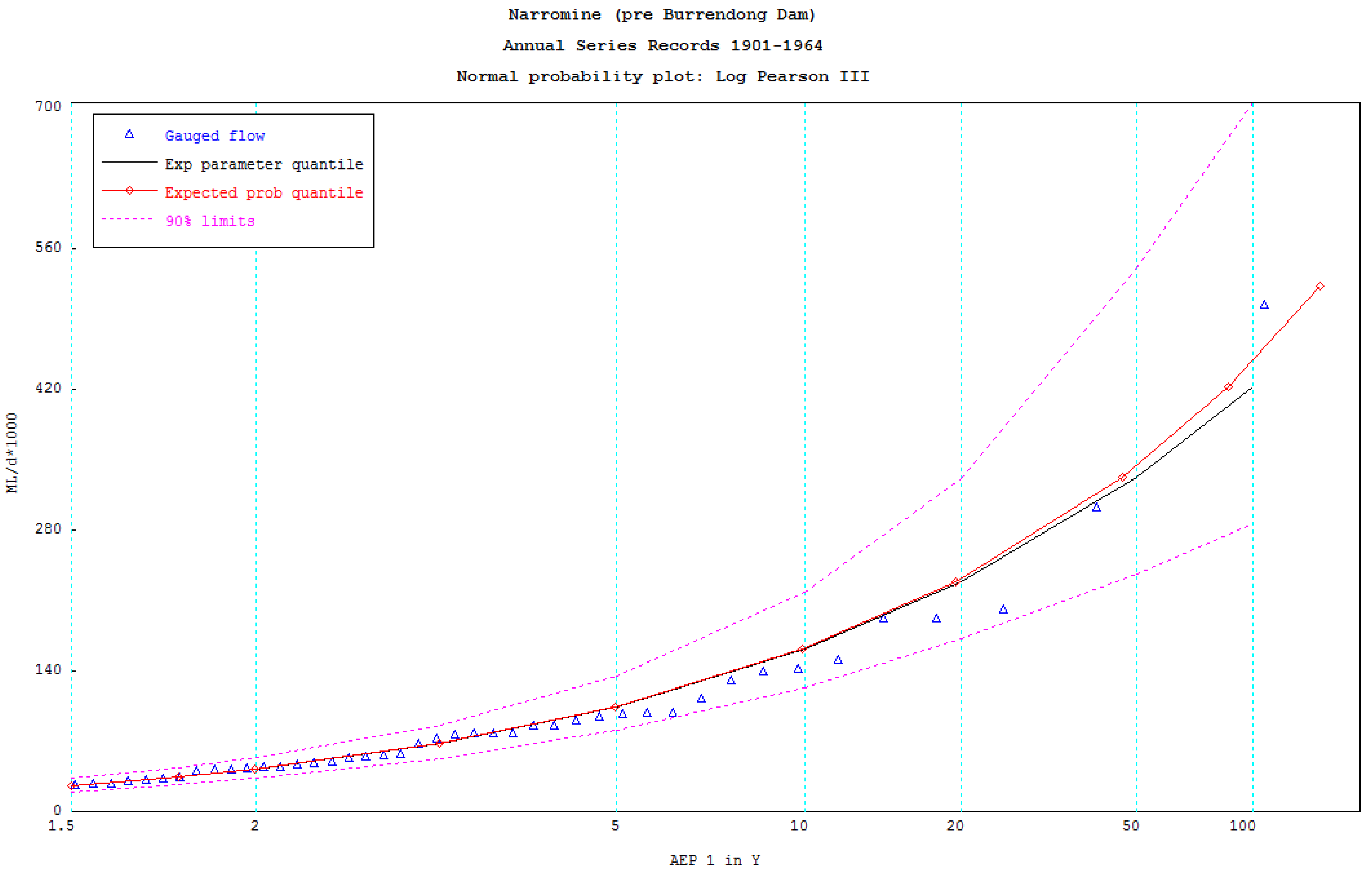

Figure 3.1: Macquarie River at Narromine flood frequency curve from 1901 to 1964

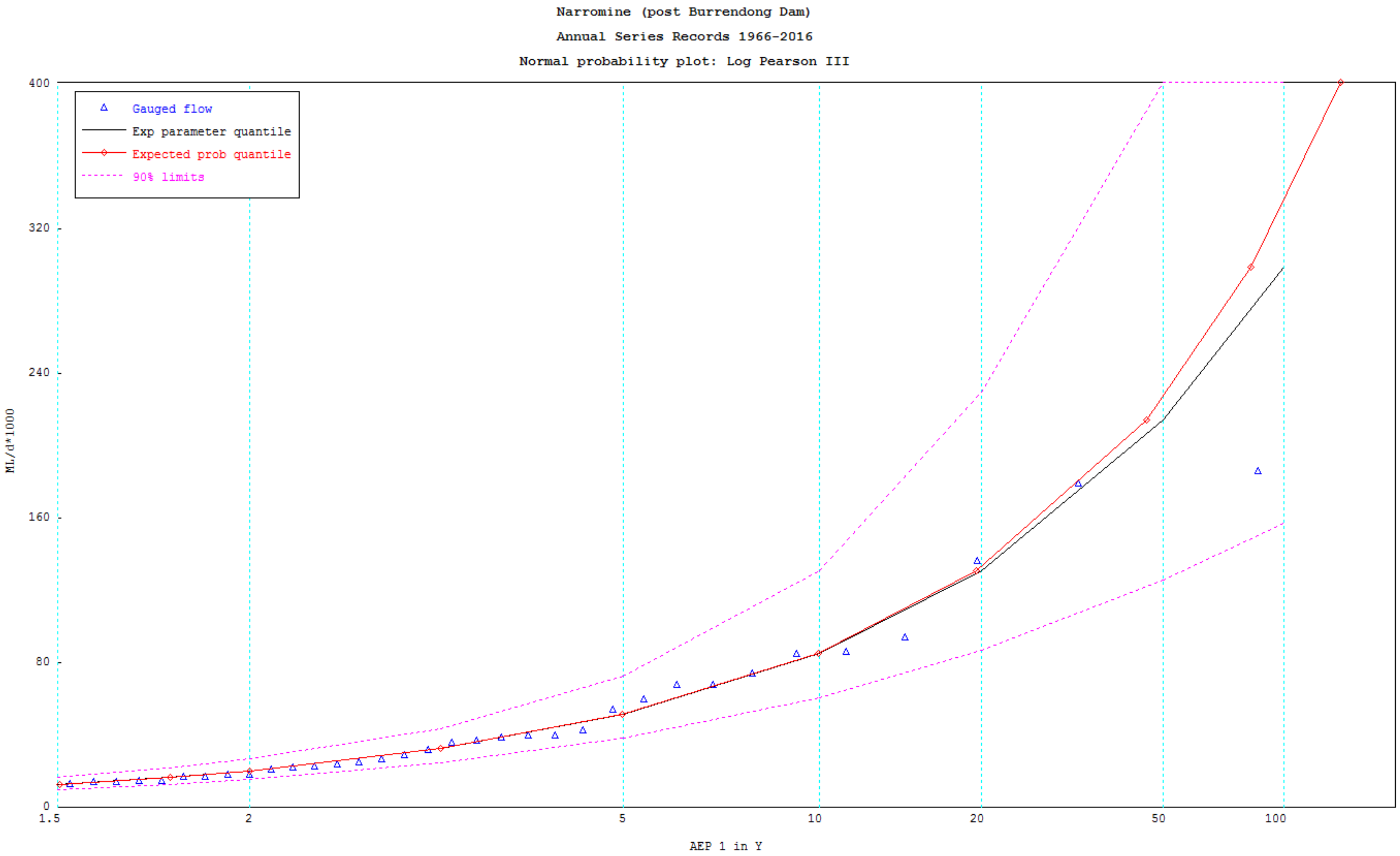

Figure 3.2: Macquarie River at Narromine flood frequency curve from 1966 to 2016

Gauge sites selected for flood frequency analysis – Macquarie Valley Floodplain

Gauging records in addition to those at Narromine have been investigated to determine suitable stations for preparing flood frequency estimates across the Macquarie Valley Floodplain. Factors affecting the suitability of gauging stations for the analysis included:

- length of records
- continuity of records
- impacts of regulated flows
- representation of key streams.

A total of 6 suitable gauging stations were selected to provide flood frequency estimates for historical flooding across the floodplain. These are shown in Figure 3.3. A Log-Pearson Type III distribution was fitted to the annual series of flood peaks for the selected gauging stations.

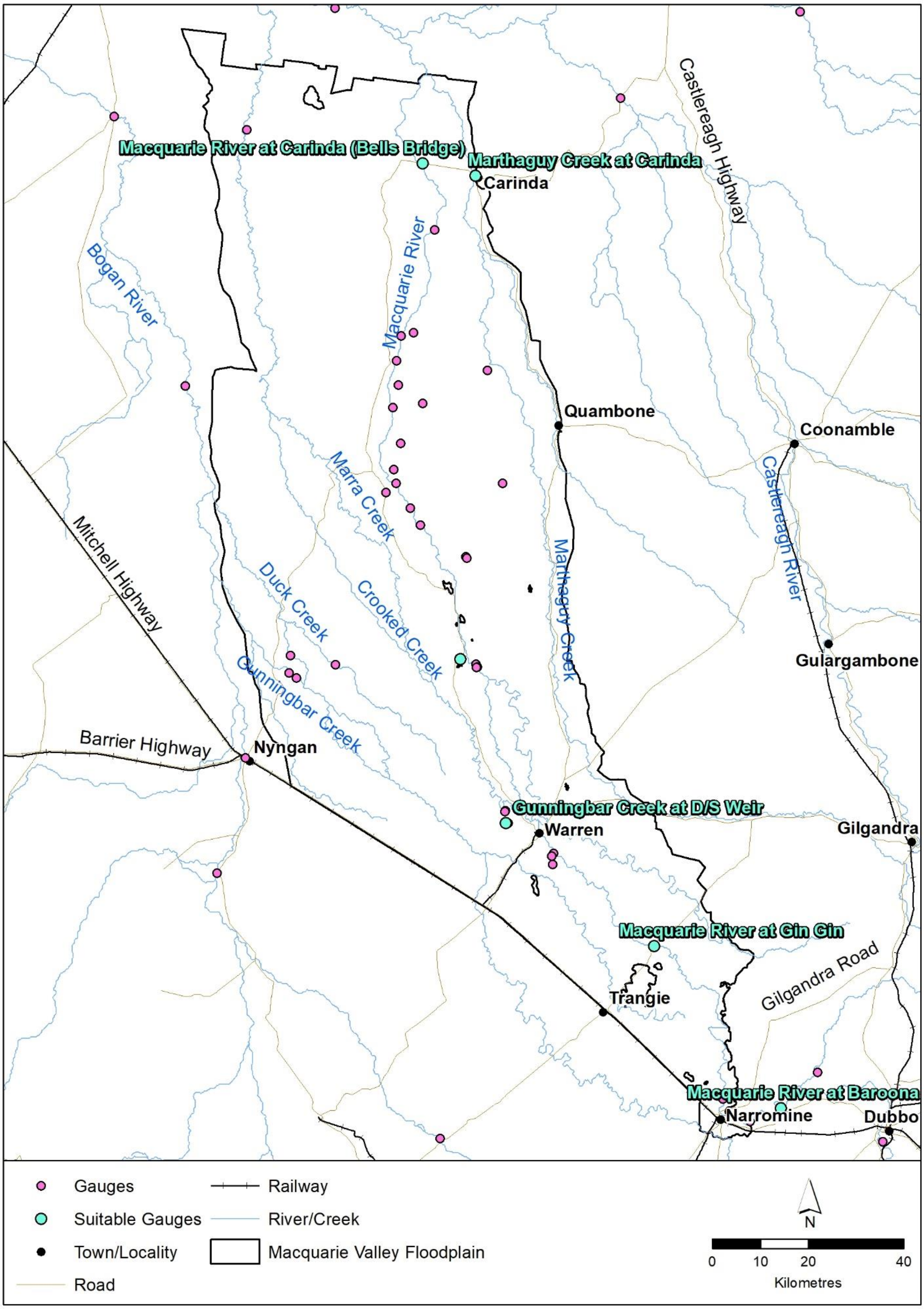

Figure 3.3: Gauging stations selected for flood frequency analysis

Appendix 4: Further detail on hydrologic and hydraulic modelling

Hydrologic modelling

There are several tributary inflows into the Macquarie Valley Floodplain that have the potential to influence the flood behaviour:

- Ewenmar Creek
- Boothaguy Creek
- Marthaguy Creek
- Merrigal Creek
- Weemabung Creek
- Bullagreen Creek
- Merri Merri Creek
- Back Creek.

All of these tributaries flow into the Macquarie Valley Floodplain from the east.

None of the major tributaries have been reliably gauged in the past, therefore it was difficult to determine the inflows of the chosen design floods. The approach used was to develop hydrological models for the tributaries using the RORB software package. A model was also prepared for the nearby Coolbaggie Creek, which has been gauged. The Coolbaggie Creek model was calibrated to historical flood events so that the calibration parameters could be applied to the ungauged tributaries.

The individual creeks were combined into 4 modelling areas:

- Coolbaggie Creek
- Ewenmar Creek
- Marthaguy Creek
- Merri Merri Creek.

As Merri Merri Creek flows into Marthaguy Creek (approximately 100 kilometres downstream of the main catchment area), these 2 creeks were combined into one model area.

RORB model building and calibration

Coolbaggie Creek catchment is a gauged catchment that was selected to calibrate a RORB model so that the parameters could be transferred to the nearby ungauged catchments, Ewenmar, Marthaguy, and Merri Merri creeks. Coolbaggie Creek catchment was selected because it is:

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

Figure 4.1 shows a detailed location map of the Coolbaggie Creek catchment including rainfall and river gauge stations. Figure 4.2 shows a comparison of Coolbaggie Creek to the ungauged tributary creek catchments.

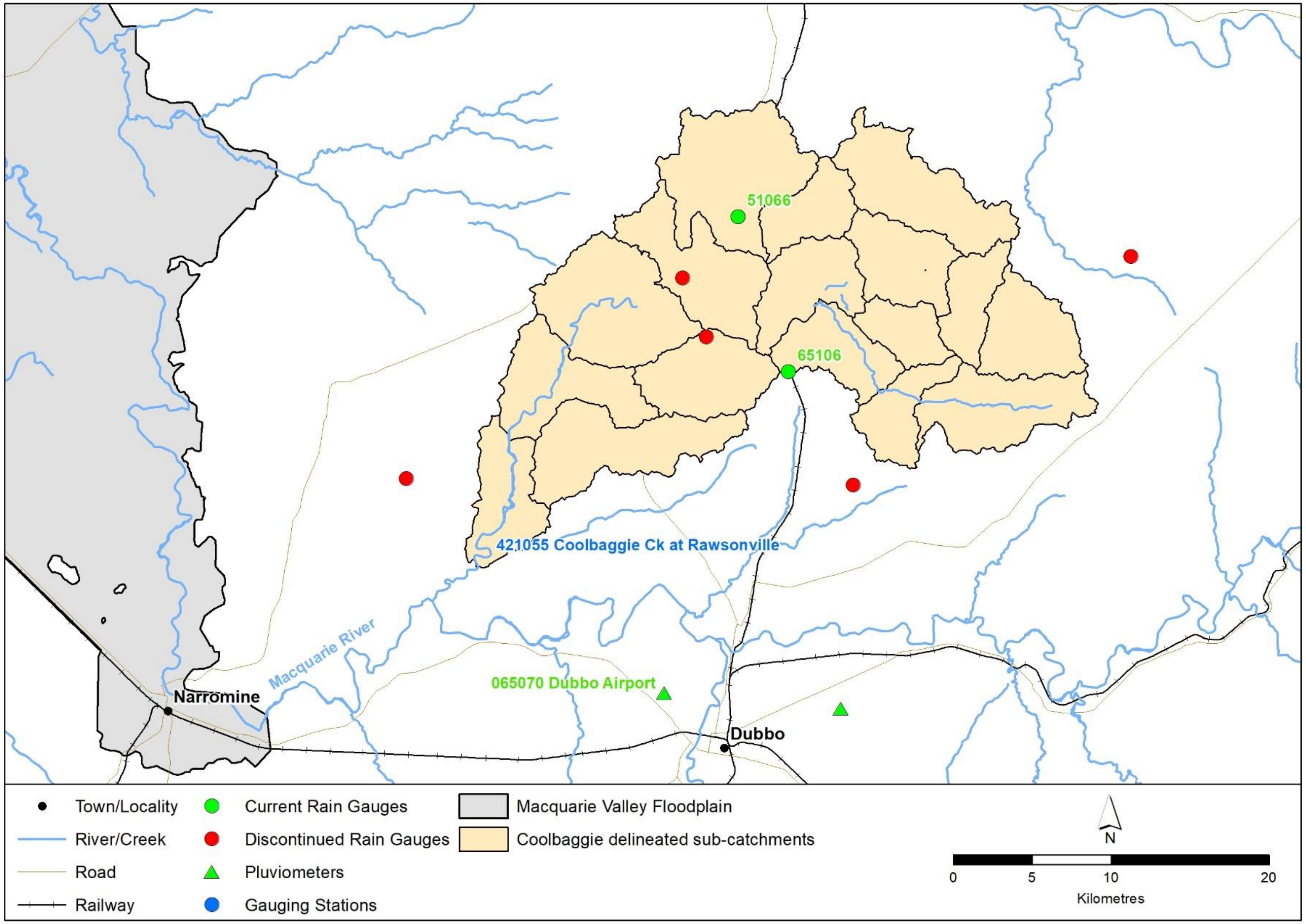

Figure 4.1: Location map of Coolbaggie Creek and sub-catchments

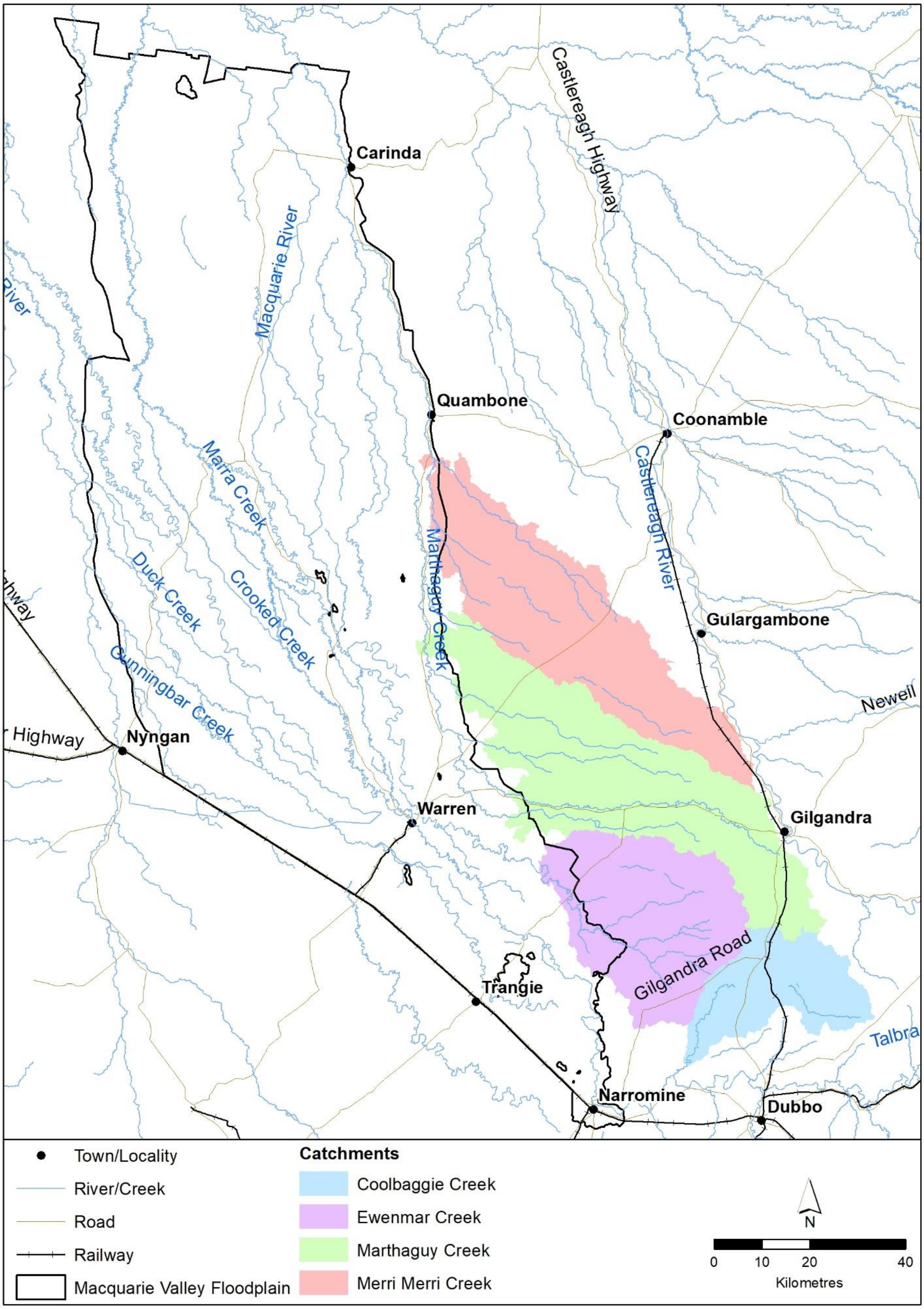

Figure 4.2: Sub-catchments to the southeast of the Macquarie Valley Floodplain

Catchment delineation

Coolbaggie Creek was delineated into 17 sub-catchments using the Shuttle Radar Topography Mission (SRTM) 30-metre Digital Elevation Model (DEM). The process was in accordance with the guidelines from the RORB user manual (Laurenson et al. 2010) regarding the size of catchment areas, branching and the location of the gauging station. The catchment outlet was defined at the Coolbaggie Creek at Rawsonville gauging station (GS 421055).

The catchment area of Coolbaggie Creek was estimated to be 60,700 hectares, which corresponds relatively well to the catchment area estimated by the NSW Office of Water (62,600 hectares). Stream lengths and the location of sub-catchment centroids were estimated using ArcGIS.

The average sub-catchment size was 3,570 hectares, with a standard deviation of 1,200 hectares.

Daily rainfall data

Rainfall data around the catchment area is relatively scarce, with 7 rain gauges identified within 5 kilometres of the catchment area. Two of these gauges have a period of record that corresponds to the same period of record as the Coolbaggie Creek at Rawsonville gauging station (1980–current). See Table 4.1 for the rain gauge details.

Table 4.1: Details of rainfall stations in the Coolbaggie Creek catchment

Station no.	Name	Period of record
65106	Dubbo (Mogriguy (Kyarra))	2003–current
51066	Eumungerie Post Office	1944–current

Examination of the 2 active stations (65106 and 51066) showed relatively similar rainfall totals; therefore, the average rainfall for both of these gauges was applied across the whole catchment and no Thiessen weighting was undertaken.

Hourly rainfall data

No hourly rainfall (or intensity) stations were located within the catchment. The closest pluviometer (rain gauge) station was located at Dubbo Airport (065070), which is approximately 25 kilometres from the centroid of the Coolbaggie Creek catchment.

Dubbo Airport is an automatic weather station and is owned by the Bureau of Meteorology. The station measures rainfall every half-hour.

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

Flow data

Coolbaggie Creek at Rawsonville (GS 421055) is a gauging station located about 40 kilometres downstream from the centroid of the catchment. This gauge is owned and operated by the NSW Office of Water and has a period of record from 1980 to the present day. The rating of the gauge has been relatively extensive, with gaugings taken up to approximately 0.45 metres below the maximum recorded stage and with 77% of flows now gauged. A large number of floods have been recorded at the gauging station. The hydrographs of these floods and their peak discharges are shown in Figure 4.3 and

Table 4.2.

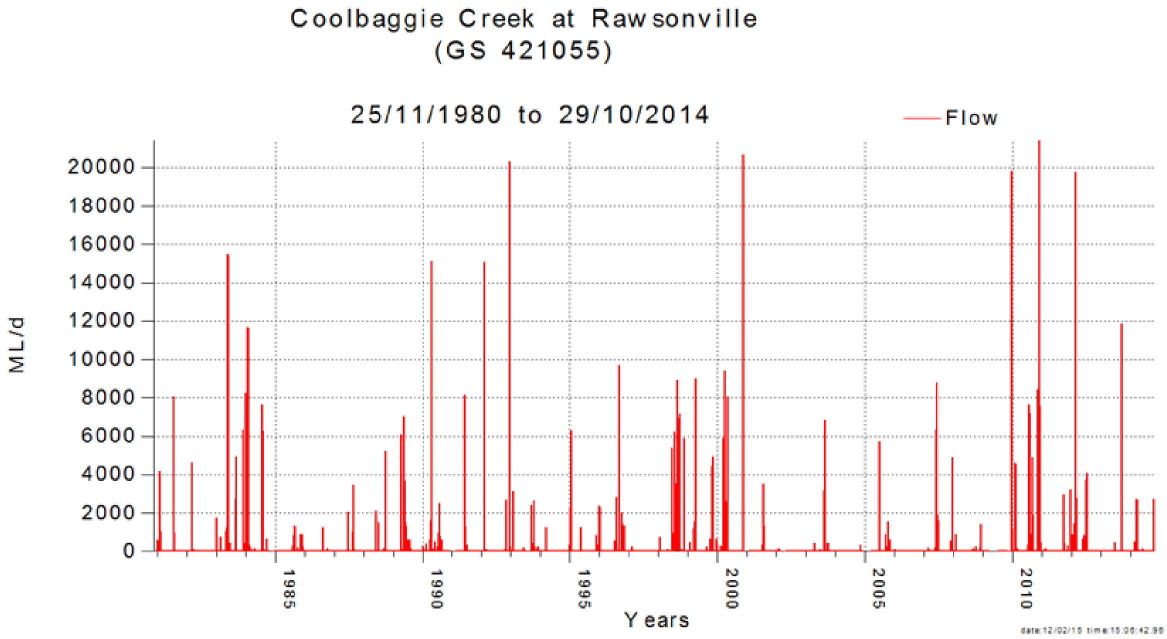

Figure 4.3: Observed floods at Coolbaggie Creek at Rawsonville

Table 4.2: Details of observed floods at Coolbaggie Creek at Rawsonville

Flood rank	Date	Peak discharge (m^3/s)
1	Feb 2010	247
2	Nov 2000	239
3	Dec 1992	234
4	Dec 2009	229
5	Mar 2012	229
6	May 1983	178
7	July 1990	175
8	July 1998	163
9	Jan 1993	155
10	Jan 1995	147

RORB input files

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

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

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

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

Calibration results

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

Model calibration was based on 3 floods over the period of record, which were chosen to represent both large floods as well as a range of hydrograph types, with compound peaks occurring in the 1998 and 2010floods.

The modelled events and model calibrations are discussed below, and model parameters are presented in Table 4.3.

Table 4.3: Calibrated model parameters

Parameter	1998	2010	2012	Adopted for ungauged
K_c	26.5	26.5	26.5	26.5
m	0.8	0.8	0.8	0.8
Initial loss	0	20	48	30

July 1998 (91-millimetre total rainfall depth, with peak flow of 163 cubic metres per second)

The July 1998 flood in Coolbaggie Creek occurred across 4 days with 2 distinct peaks. Rainfall fell across 3 days, with 47 millimetres in the first 2 days, followed by a dry day and then another storm burst with 43 millimetres. This rainfall pattern is noticeable in the runoff response, with 2 distinct peaks occurring.

The catchment conditions before the event were relatively wet, with 145 millimetres of rainfall occurring in the month before the event. The event also occurred in winter, when it is expected that there would be low evapotranspiration leading up to the event and that the catchment storage would be full.

The model performed relatively well, matching the peak to within 6 cubic metres per second or 3.6% of total peak flow. The timing and shape was also relatively good, considering the double-peaked nature of the event; however, the model appeared to underestimate the volume, particularly in the first peak (Figure 4.4).

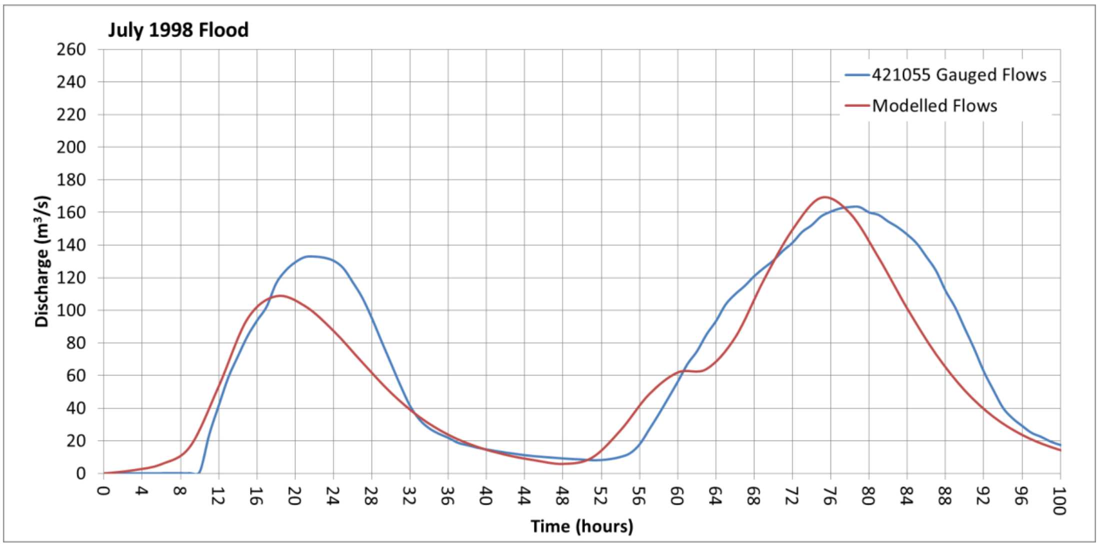

Figure 4.4: Hydrograph for the July 1998 flood comparing gauged and modelled flows at the Coolbaggie Creek at Rawsonville gauge

November 2010 (222-millimetre total rainfall depth, with peak flow of 247 cubic metres per second)

The November 2010 flood is the largest flood on record within the Coolbaggie Creek catchment. It has several peaks and troughs due to the rainfall occurring over approximately 2 weeks, and 4 separate days of rainfall over 40 millimetres and a lower amount of rainfall occurring across most of the other days.

Similarly to the July 1998 flood, the catchment had relatively wet antecedent conditions, with 120 millimetres of rainfall occurring in the month before the flood. However, the evapotranspiration during November would have been greater than before the July flood in 1998.

Also like the 1998 flood, the model matched the peak flow very well; however, there were some issues with timing, with the model predicting the peak approximately 12 hours before the gauge (Figure 4.5). This issue may be to do with the 3-hour time step; however, it is more likely due to possible differences in the temporal rainfall pattern between Dubbo Airport and the catchment during the November 2010 storm. For overall volume, the model was relatively accurate, despite the timing issue.

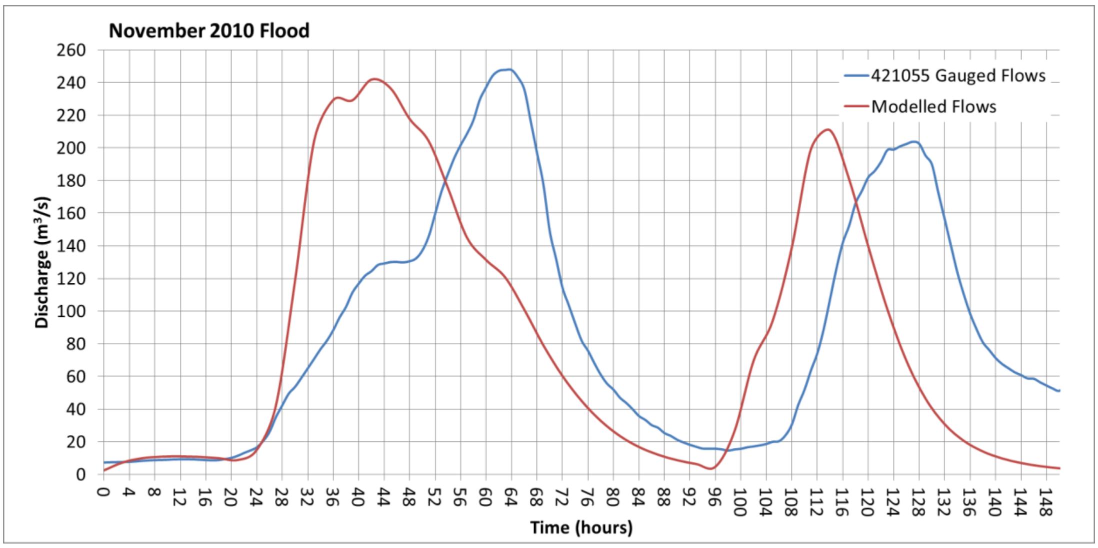

Figure 4.5: Hydrograph for the November 2010 flood comparing gauged and modelled flows at the Coolbaggie Creek at Rawsonville gauge

March 2012 (91-millimetre total rainfall depth, with peak flow of 229 cubic metres per second)

The March 2012 storm event produced a relatively simple runoff response, with one major peak and a slight peak approximately one and a half days later.

The month before the event had approximately 75 millimetres of rainfall, which had fallen in a much warmer and higher evapotranspiration period than the other events.

As with the other events, the model produced an accurate peak flow rate. The timing of the peak was also relatively good (Figure 4.6). However, both limbs of the hydrograph were sharper than the gauged hydrograph. While the final part of the recession and the second, much smaller peak match extremely well, the model under-predicted the volume within the hydrograph.

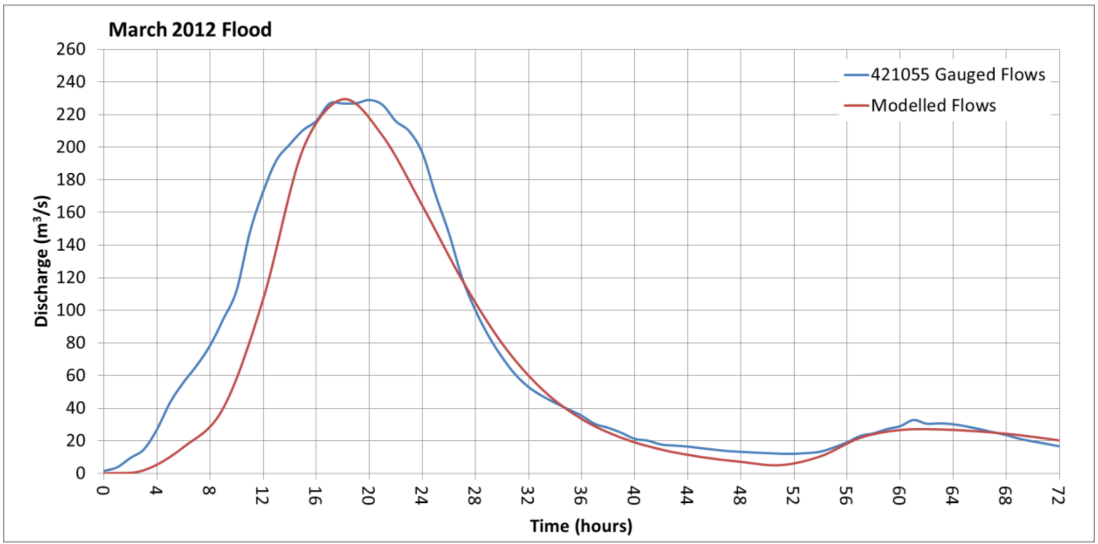

Figure 4.6: Hydrograph for the March 2012 flood comparing gauged and modelled flows at the Coolbaggie Creek at Rawsonville gauge

Conclusions

The model performed very accurately for the March 2012 event, reasonable accurately for the July 1998 event and acceptably for the November 2010 event. There are several factors that are likely to be influencing the model's performance for the different events:

- antecedent catchment and channel conditions
- the difference in rainfall distribution and timing between the catchment and the rain gauge at Dubbo Airport
- the variation in peak rainfall across the catchment.

These factors are generally a product of the lack of data within the catchment, making model development and calibration difficult. However, the model predicts the peak flow magnitude very well, despite some potential issues with timing and volume. The initial loss and continuing loss conform largely with the expected antecedent conditions.

Similar to the approach taken in modelling for the Gwydir Valley FMP 2016, it is that the parameters and method used to build this model are adopted for the adjacent ungauged tributaries, where it is impossible to calibrate a similar model. Given the relatively good performance in the calibration events, it is deemed that this approach and model is acceptable for use in this manner. The ungauged catchments will use parameters adopted in Table 4.3.

Details of ungauged modelled inflows

The ungauged tributaries can be divided into 3 systems: the Ewenmar, Marthaguy and Merri Merri creeks. See Table 4.4 for their sizes and main components and Figure 4.7 for their location in relation to the Macquarie Valley Floodplain. The majority of Ewenmar flood flows join the Macquarie around Warren, and these flows can have a significant impact on the flow distribution as well as some impact on levels in this area. The Marthaguy and Merri Merri flood flows merge and then join the Macquarie downstream of the floodplain near Carinda. However, flows from the Marthaguy can interact with the Macquarie flood flows, and water goes both into the Marthaguy and also from the Marthaguy back into the Macquarie. The Marthaguy Creek and Merri Merri Creek floodplains are also within the boundary of the FMP area and therefore need to be considered in the modelling.

Table 4.4: Ungauged tributary details

Catchment	Area (ha)	Key channels
Ewenmar	112,400	Ewenmar, Emogandry, Kickabil, Milpulling and Long Plain creeks
Marthaguy	189,000	Marthaguy, Boothaguy, Merrigal, Wemabung and Bullagreen creeks
Merri Merri	133,800	Merri Merri and Back Quandong creeks

Inflows for the ungauged models were developed using RORB, and sub-catchment delineation was similar to the Coolbaggie Creek model (Figure 4.7). The parameters for this model were then transferred to the ungauged catchment models and run using available rainfall data.

Despite no suitable gauge being located in each of these catchments, some limited calibration was made.

The Marthaguy and Merri Merri creek systems meet and are gauged at a significant distance downstream at Carinda (Marthaguy at Carinda, GS 421011); however, at this point some floodwaters within Marthaguy Creek would have crossed into the Macquarie system and vice versa through Terrigal Creek. These inflows were accounted for using gauging networks and hydraulic models, so a simple mass balance at the gauge could be created to determine the flow contributions from the combined Marthaguy and Merri Merri creek systems.

Ewenmar Creek has been gauged during a number of floods at the Oxley Highway near Warren (GS 421063) and at the Trangie-Collie Road during the 2000 flood. However, these flows are affected by overflows from the Macquarie River that join the Ewenmar upstream from the gauging sites. As above, using the hydraulic models, a mass balance calculation was undertaken to determine the inflows from the catchment and further calibrate the Ewenmar rainfall runoff model.

Similar to Coolbaggie Creek, there was limited rainfall data available within the catchments, so pluviometer data was used from outside of the catchment to determine rainfall distributions.

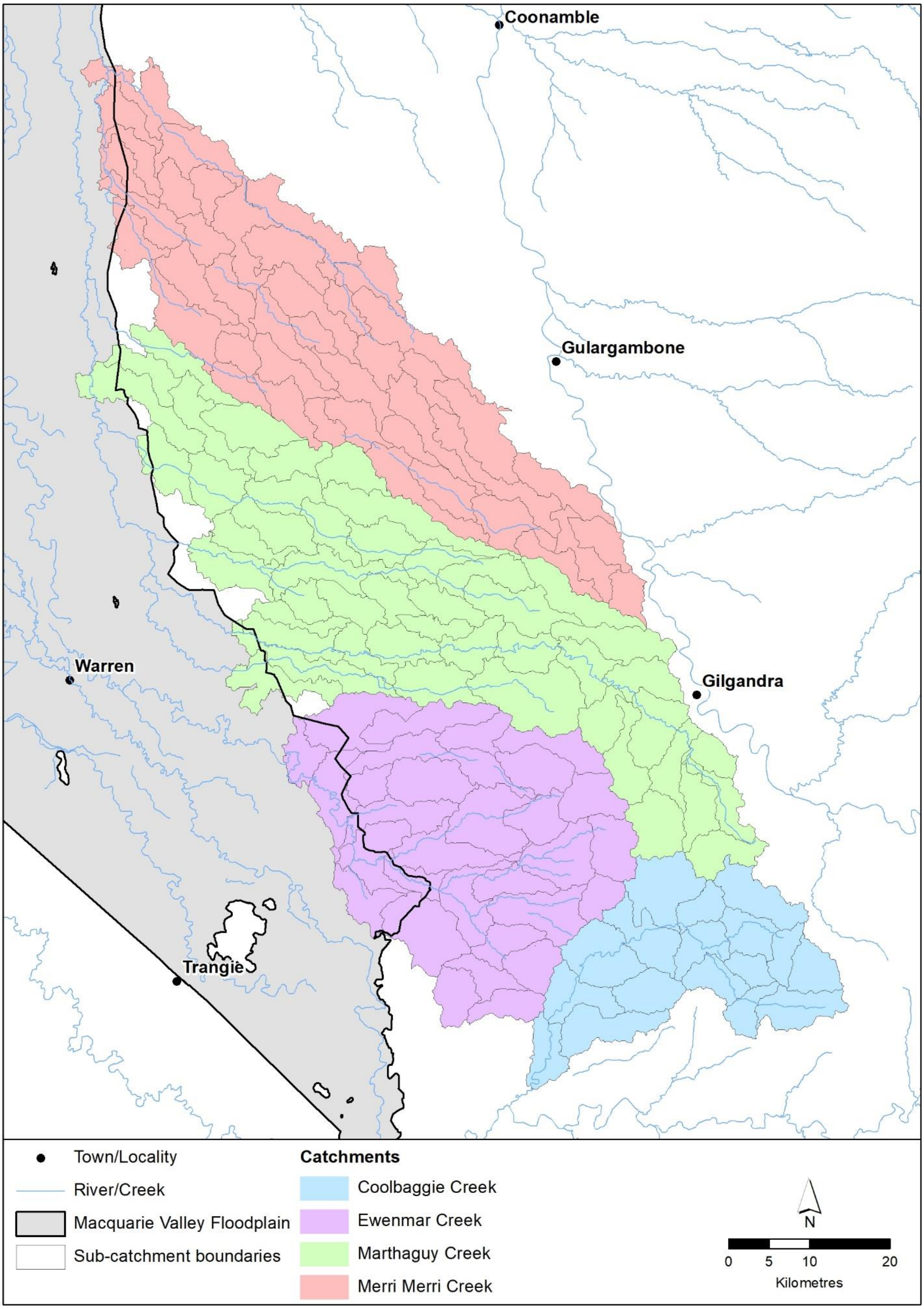

Figure 4.7: Ungauged tributary catchments in relation to the Macquarie Valley Floodplain

Hydraulic modelling

The MIKE FLOOD coupled one- and two-dimensional software modelling package was used to model flow throughout the floodplain. MIKE FLOOD uses a one-dimensional channel network (MIKE11) that represents the channel cross-section in high detail, which is dynamically coupled with a two-dimensional (MIKE21) model representing the floodplain.

Extents and layout

Consideration was given to the following elements in constructing the model:

- topographical data coverage and resolution
- location of recorded data (for example, levels/flows for calibration)
- location of controlling features (for example, dams, levees and bridges)
- desired accuracy to meet the study's objectives
- computational limitations.

MIKE FLOOD models were constructed to cover most of the floodplain, extending from the flow gauge at Baroona (upstream of Narromine) to the flow gauges on the Macquarie River and Marthaguy Creek at Carinda. In the effluent creek system, the models extend out to the boundary of the Macquarie floodplain with the Bogan River floodplain. The floodplain computational grid was too large to be run efficiently in one model. Therefore, the model was split into 4 reaches where the flows were passed along each model in series. That is, upstream model outflows were applied as downstream model inflows.

The main upstream model covers the floodplain down to Oxley Station, encompassing the vast majority of the flood works; the downstream Marshes model then covers the area from Marebone to Carinda; and the downstream effluents model covers the complex area around the Overflow down to the Bogan River floodplain. The north-west area, primarily fed by Marra Creek, is modelled using only a one-dimensional channel network as the flow is generally confined to channel corridors. Significant areas of overlap exist between the model reaches; this is to prevent boundary effects from influencing the development of the floodway network.

Base topography

The ability of the model to provide an accurate representation of the overland flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. LiDAR coverage of most of the floodplain was acquired from the Rivers Environment Restoration Program (DHI 2008) and the Healthy Floodplains project. It was captured in 2014 covering the area outside of the Macquarie Marshes and also in 2015 covering the Marshes area. Some channel survey also exists, and this was collated as part of the 2009 DHI MIKE FLOOD model of the Macquarie Marshes and the SKM MIKE11 modelling for the Macquarie River FMP 2008.

Topographic controls

The Macquarie Valley Floodplain is characterised by flat topography with a large number of linear features elevated above the floodplain. These features include road alignments, levee banks and channels associated with irrigation supply, drainage infrastructure and farming practices. The largest of these features present barriers to flood flows and often have associated cross-drainage infrastructure to transfer flows through them. The smaller features act as hydraulic controls, resulting in flood water ponding behind them before spilling over the crest.

To ensure that the extensive network of topographic features is correctly represented within the model, breaklines were created representing elevations along the crests of the embankments from the LiDAR survey. The breaklines were imported into the model to ensure that a continuous crest elevation is represented within the model topography. Water levels in the upstream model cells must exceed the crest of the embankment before spilling into the downstream cells. This approach ensures that the influence of the topographic controls across the floodplain is correctly represented.

Hydraulic roughness

The development of the MIKE FLOOD models required the assignment of 'hydraulic roughness' to different areas within the floodplain. These areas were delineated from aerial photography and land use data and assigned into roughness categories. Categories for the Macquarie modelling included roads and impervious surfaces, floodplain forest or grasslands, cropped lands, watercourses and wetlands. The roughness values were varied as part of the calibration process and were initially based on previous model roughness and values of similar areas presented in literature.

Structures

There are a number of bridge and culvert crossings over the main channel alignments and tributaries within the model extents. These structures vary in terms of construction type and configuration, with varying degrees of influence on local hydraulic behaviour. Incorporation of these major hydraulic structures in the models provides for simulation of the hydraulic losses associated with these structures and their influence on peak water levels within the study area.

The in-channel structures were modelled as per their geometry by using the MIKE11 structures module, which allows for detailed representation of the structure geometry. Floodplain structures, such as road culverts, were represented by locally increasing the Manning's 'n' roughness coefficient. Testing found that this approach produced similar results to the MIKE11 structure.

Boundary conditions

The model boundary conditions were derived as follows:

- Inflows: The models used a steady-state inflow to reduce the model run time. The primary model inflows were derived from the gauged flows at the Baroona gauge. Additional inflows were provided using the hydrological models for the ungauged tributaries (Ewenmar, Marthaguy and Merri Merri creeks and their tributaries).
- Outflows: These were applied using a rating curve that is derived using the downstream cross-section and Manning's equation, or using gauge rating curves where appropriate.

Model calibration

The selection of suitable historical events for calibration of computer models is largely dependent on available historical flood information. Ideally, the calibration and validation process should cover a range of flood magnitudes to demonstrate the suitability of a model for the range of design event magnitudes to be considered.

The 1990, 2010, 2000 and 2012 floods formed the principal calibration events. The 1990 and 2012 events form the large and small design floods, respectively, and it is therefore important to calibrate to these events. However, there was significantly more (and higher quality) data available for the 2010 event. For this reason, the 2010 event was calibrated in addition to the design events.

All 3 events have a reasonable coverage of gauge peak water levels and flood aerial photography and satellite imagery.

Appendix 5: Overview of flood imagery

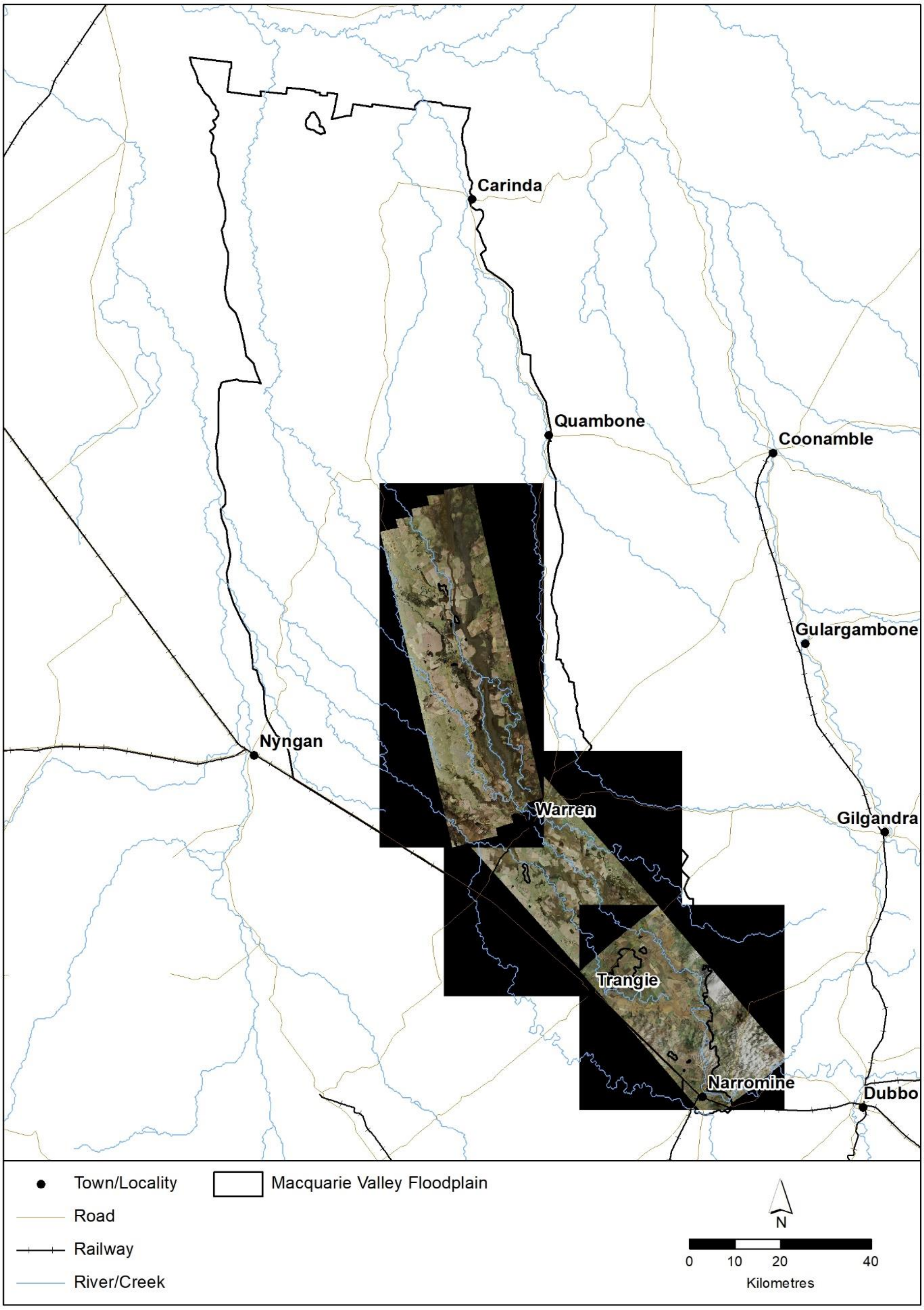

Figure 5.1: ADS40 imagery captured at the peak of the December 2010 flooding in the Macquarie Valley Floodplain

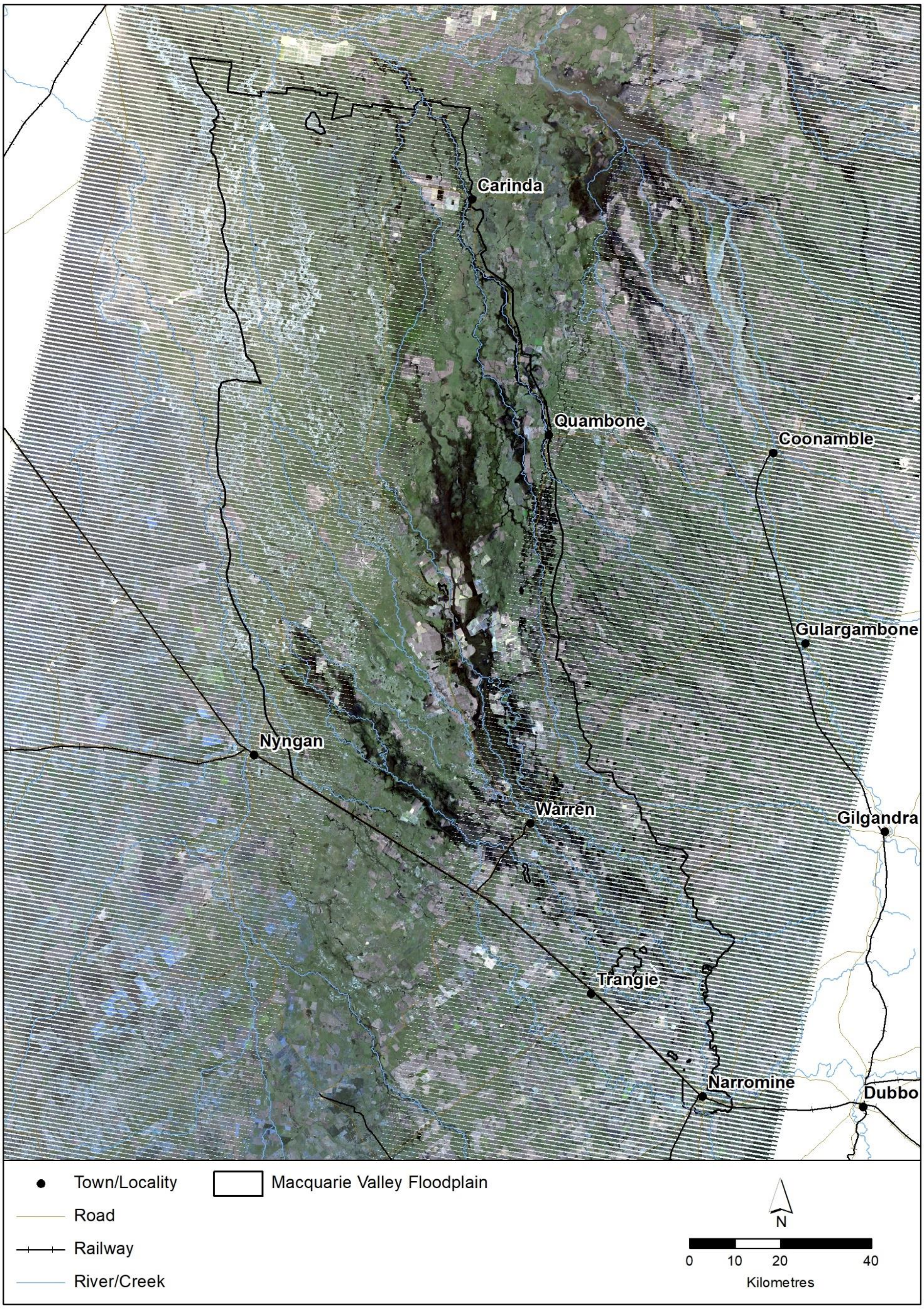

Figure 5.2: Landsat 7 satellite imagery showing flooding in the Macquarie Valley Floodplain, December 2010 (RGB – 1,2,3)

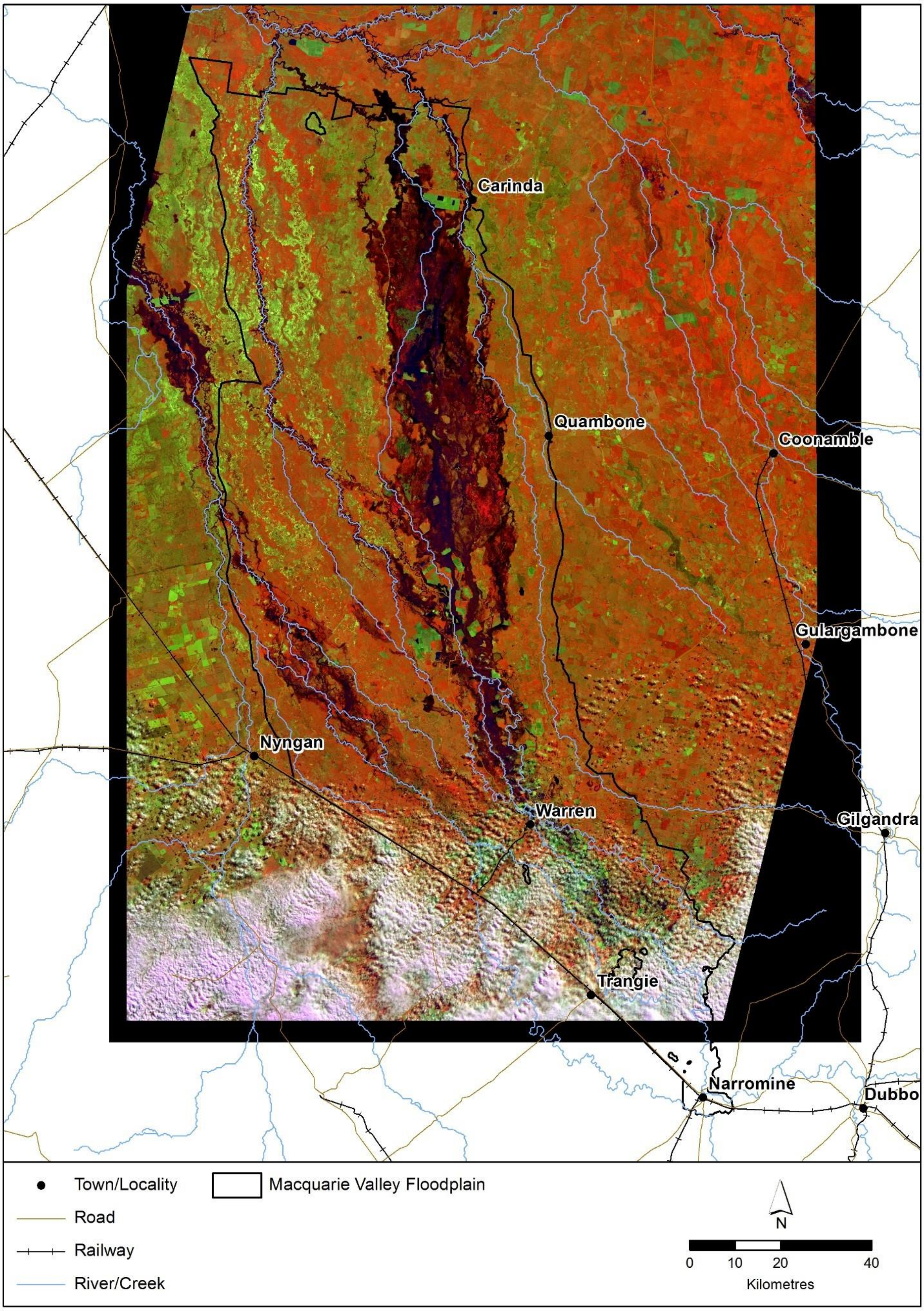

Figure 5.3: Landsat satellite imagery of flooding on 23 August 1990 in the Macquarie Valley Floodplain (RGB – 4,6,1)

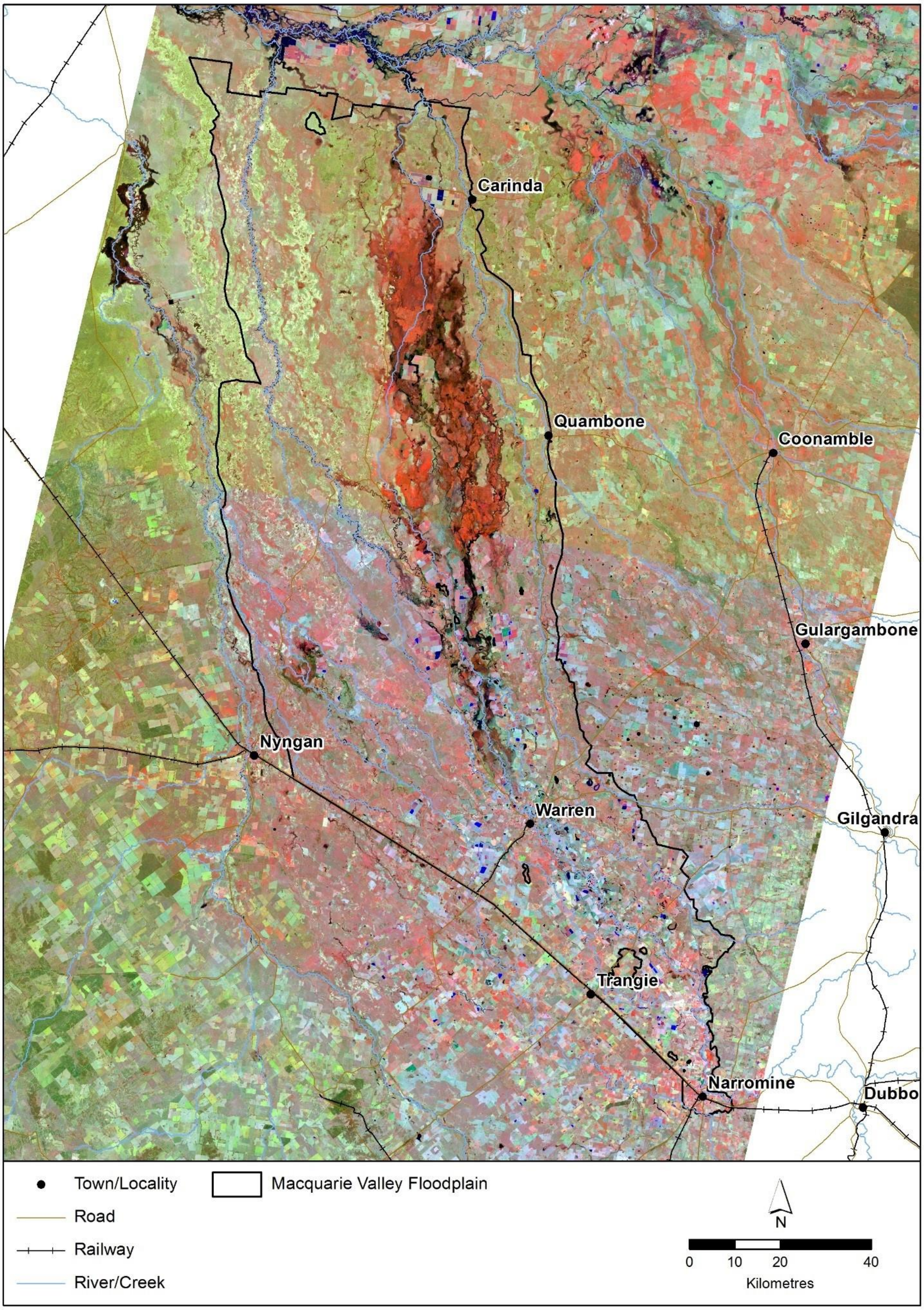

Figure 5.4: Landsat 7 satellite imagery of flooding on 16 December 2000 in the Macquarie Valley Floodplain (RGB – 4,6,1)

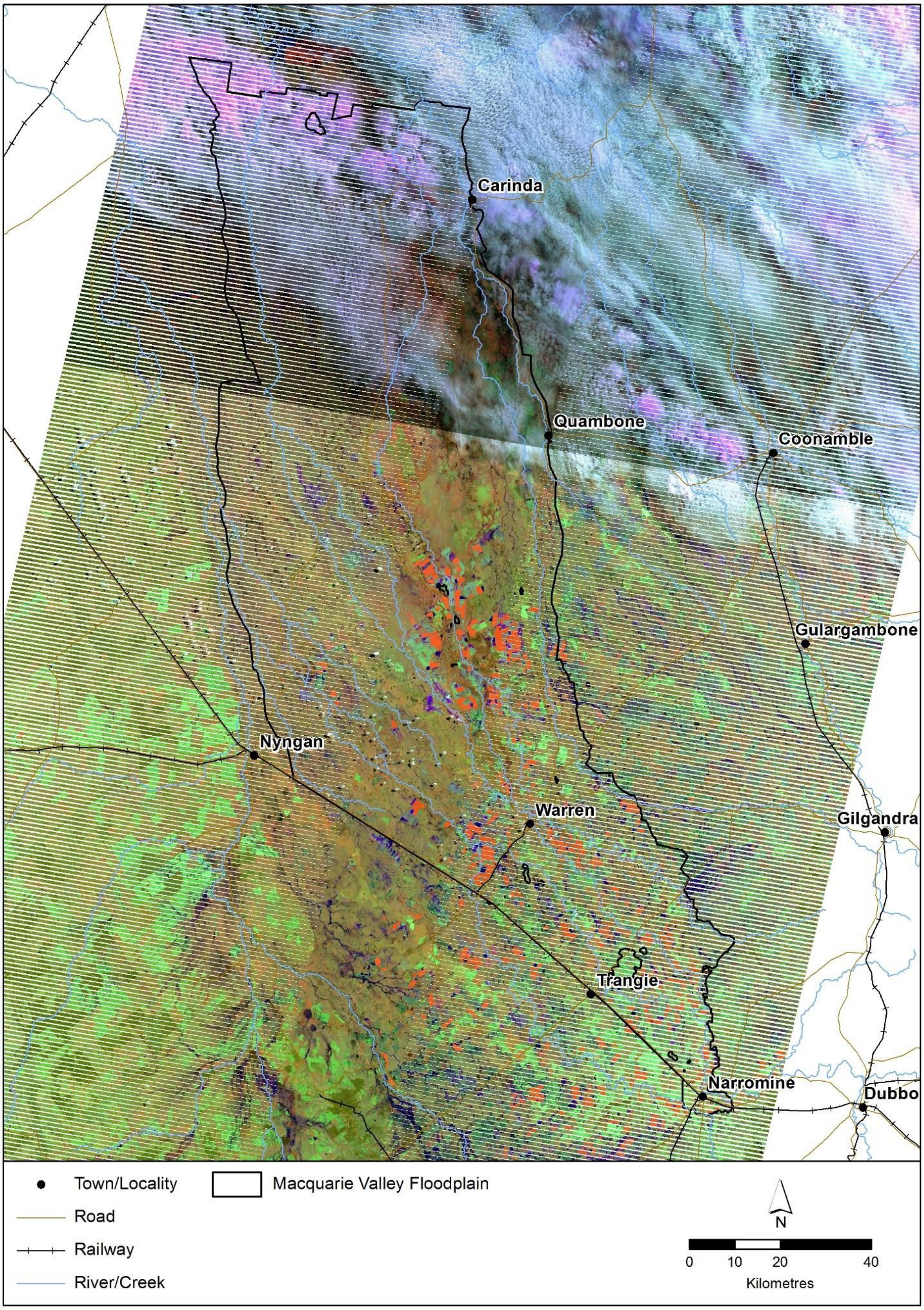

Figure 5.5: Landsat 7 satellite imagery of flooding captured on 4 March 2012 in the Macquarie Valley floodplain (RGB – 4,6,1)

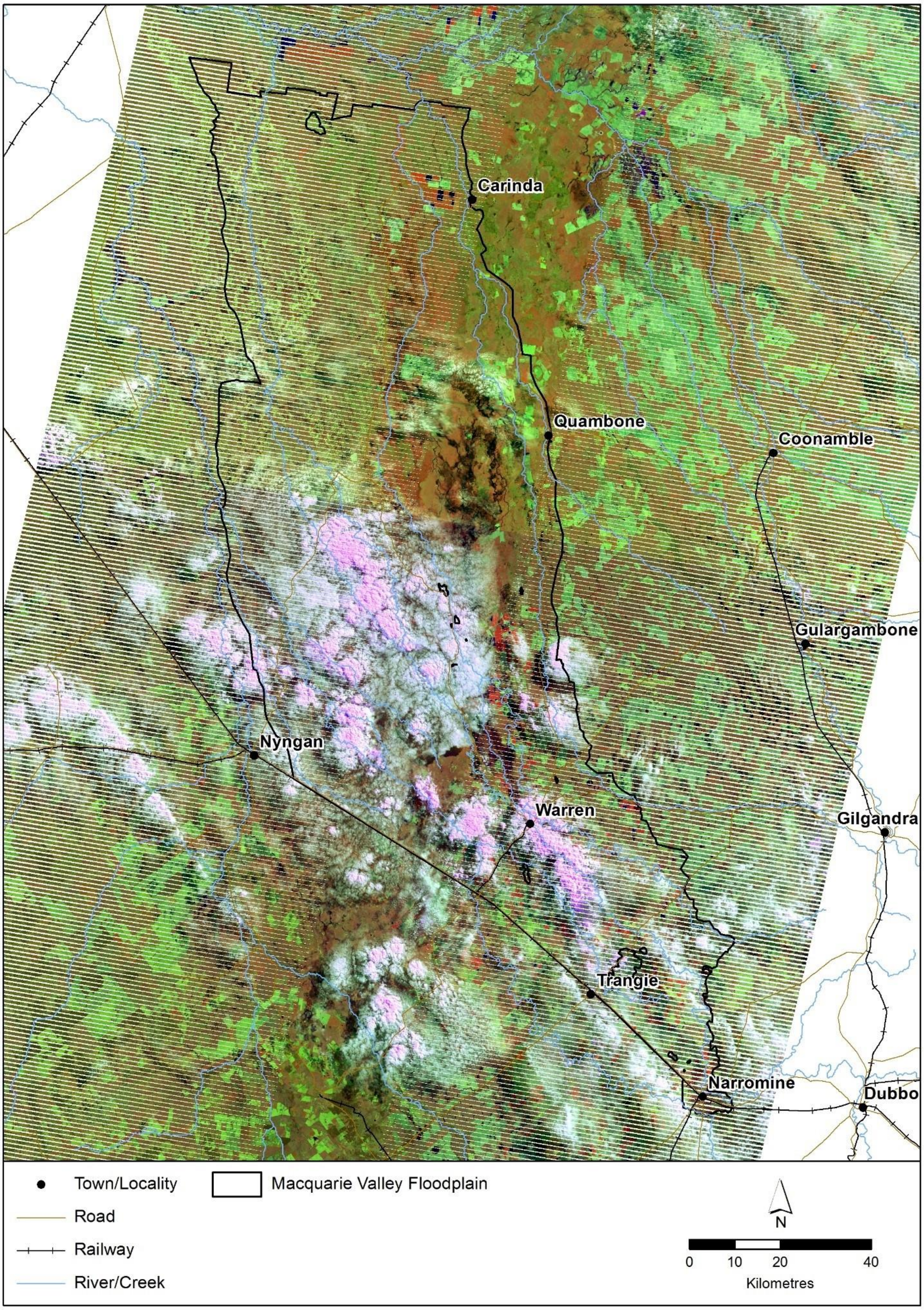

Figure 5.6: Landsat 7 satellite imagery of flooding captured on 20 March 2012 in the Macquarie Valley Floodplain (RGB – 4,6,1)

Appendix 6: Marxan prioritisation (planning units)

Planning units are area-based polygons that cover the entire study area. Marxan analysis is an iterative process involving several steps.

The first step involves dividing the landscape into 'planning units', which form the basis of the Marxan analysis. Planning units are small parcels of land of a pre-determined shape and size that could potentially be included in (or excluded from) the final Marxan solution.

The Macquarie Valley Floodplain was divided into 20-hectare hexagonal planning units (n = 63,139) using the Qmarxan plugin (Apropos Information Systems 2014) executed within the Quantum GIS Version 1.8.0 software (QGIS Development Team 2013) (Figure 6.1). These hexagonal-shaped planning units were selected to be the most appropriate shape and size for fine-scale floodplain management planning and they have been demonstrated to produce more efficient and less fragmented planning portfolios (Nhancale and Smith 2011). An additional advantage of the hexagonal-shaped planning units is that their consistent size may reduce area-related bias (Loos 2011).

Marxan planning units partition the floodplain landscape and are the basis upon which data on the abundance of conservation features is compiled within the entire planning region. The amount of each biodiversity feature in each planning unit was calculated using the Qmarxan plugin within Quantum GIS Version 1.8.0 software. The extent of all biodiversity features within each planning unit is assessed to determine the relative importance of individual planning units, and this forms the basic Marxan data matrix.

Marxan can be parameterised to 'lock in' (that is, a planning unit may be forced into the final solution before the algorithm is run) or 'lock out' (that is, a planning unit may not be considered in the final solution) through the use of status codes. For example, planning units that intersected the length of the Macquarie River were allocated a status value of 2 to force them into the final solution, as the upstream/downstream reaches of the Macquarie River are major discharge areas essential for maintaining floodplain connectivity. These planning units were forced into the final solution, as the Macquarie River supports a range of ecological processes and movement requirements of aquatic biodiversity, including a diverse collection of aquatic species such as native freshwater fish.

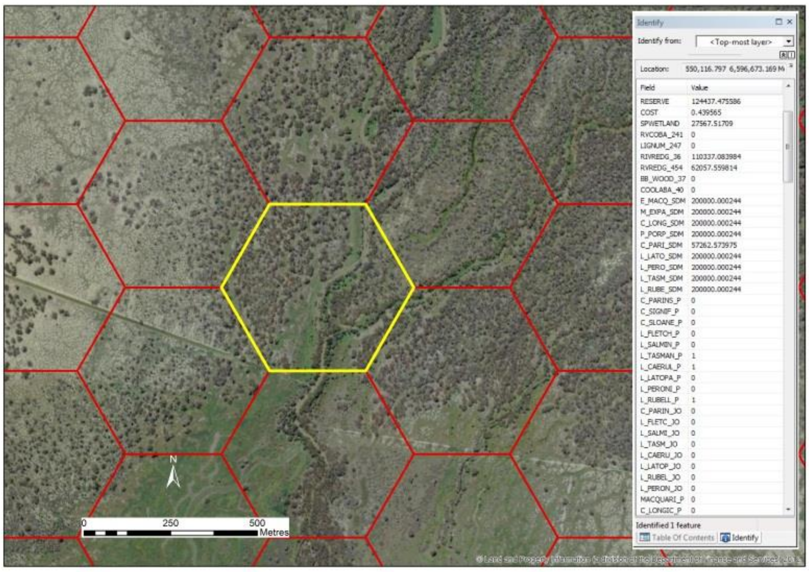

Figure 6.1: The Macquarie Valley Floodplain was partitioned into 20-hectare hexagonal planning units. The amount of each flood-dependent surrogate was calculated in each planning unit, which formed the Marxan data matrix

Appendix 7: Marxan prioritisation (targets for ecological surrogates)

To represent biodiversity patterns of the Macquarie Valley Floodplain, several key flood-dependent ecological surrogates were chosen for input into the Marxan process to identify priority ecological assets. Surrogates are needed because it is impossible to measure all aspects of biodiversity, so surrogate features are chosen as proxies for biodiversity patterns (Margules et al. 2002).

Surrogates were divided into 2 dataset types: area- and point-based data. These included subsets of taxa, assemblages and/or environments and environmental variables (Margules and Pressey 2000; Margules et al. 2002). For each ecological surrogate, targets or conservation objectives were established to specify the amount of an ecological surrogate that would be needed to be conserved to ensure the persistence of that surrogate (Margules and Pressey 2000). Targets provide a clear purpose for conservation decisions, giving them accountability and defensibility (Pressey et al. 2003). Formulation of explicit targets may be constrained by limited or undocumented information on biodiversity and habitat requirements (Pressey et al. 2003; Possingham et al. 2007). Targets were selected for each of the ecological surrogates during TAG meetings in September and November 2014 with local experts.

Area-based datasets (mapped vegetation)

Area-based data for vegetation was the primary ecological surrogate for the Marxan prioritisation. Mapped vegetation was chosen as a surrogate if it was dependent on flooding and/or provided habitat to flood-dependent fauna. The area-based data derived from mapped vegetation community types were grouped into the following flood-dependent 'hydro-ecological functional group' surrogate categories:

- semi-permanent wetlands
- floodplain wetlands (flood-dependent shrubland wetland)
- flood-dependent forest/woodland (wetland)
- flood-dependent woodland.

Mapped vegetation was also used as area-based surrogates for floodplain fauna, which included consideration of:

- the spatial extent of flood-dependent vegetation communities that provide breeding and feeding habitat for waterbirds
- the spatial extent of small lagoons, billabongs and anabranches that provide breeding and feeding habitat for waterbirds and a range of aquatic species, including freshwater native fish, frogs and turtles
- modelled species distributions.

Targets

Formulation of vegetation targets focused on the medium- to long-term goal of using 1991 as a contemporary baseline for the spatial distribution of flood-dependent vegetation communities defined by the Wilson (1992) communities of the core wetland system. A spatial analysis was undertaken to determine the change in the spatial extent of vegetation communities since 1991 within the inner wetland system defined by the boundaries of the 2013 Bowen and Fontaine mapping. Comparisons were made between the spatial extent of vegetation communities from previous vegetation mapping in 1991, 2008 and 2013.

These comparisons revealed that the 2013 mapped spatial extent of semi-permanent wetland – water couch marsh grassland wetland of frequently flooded inland watercourses (PCT 204) – and flood-dependent shrubland wetland – lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South bioregion and Darling Riverine Plains bioregion (PCT 247) – were less than 80% of their 1991 spatial extents (40% and 32% respectively). Remaining flood-dependent PCTs exceeded 80% of their 1991 spatial extents.

Targets were also developed using previously available information, including estimates of changes in the extent and distribution of vegetation communities over time provided by previous studies. There was limited accurate temporal spatial data for variability of vegetation communities within the greater floodplain beyond the spatial extent of the most recent mapping by Bowen and Fontaine in 2013. It was therefore not possible to determine changes in spatial extent over time for a large part of the Macquarie Valley Floodplain.

In the Macquarie Valley Floodplain, the TAG endorsed conservation targets of 100% for most asset types to ensure their future persistence. The exceptions were:

- water couch marsh grassland wetland of frequently flooded inland watercourses (PCT 204)
- lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South bioregion and Darling Riverine Plains bioregion (PCT 247)

for which the TAG endorsed targets to restore the asset extent to more than 80% of the distribution defined in the 1991 baseline. As a result, the Marxan analysis determined that all ecological assets were a high priority.

A description of each of these area-based surrogates is outlined in Table 6.1: Area-based vegetation surrogates and their conservation targets for the Macquarie Marxan analysis showing hydro-ecological functional groups.

Table 6.1: Area-based vegetation surrogates and their conservation targets for the Macquarie Marxan analysis showing hydro-ecological functional groups

Category	Surrogate	Total area (ha)	Target (% of Bowen and Fontaine 2013 mapped spatial extent)	Justification
Mapped waterbird colonies	**Colonial waterbird breeding sites**	5,920	100%	One of the most important colonial nesting waterbird breeding sites in Australia (Kingsford et al. 2013), supporting 16 colonial nesting waterbird species (OEH 2012a; Kingsford and Thomas 1995; Kingsford and Auld 2005). Protection of breeding sites is essential for the long-term persistence of waterbirds. Protection of flow paths for habitat maintenance flows to waterbird colony sites is essential for the successful completion of colonial nesting events.
Natural waterbodies, watercourses and named swamps	**Natural waterbodies, watercourses and named swamps**	2,514	100%	Maintenance, including exposed muddy margins, is essential to provide feeding areas for many waterbird species (including migratory waders visiting during summer), and habitats and refuges for fauna and flora.

Category	Surrogate	Total area (ha)	Target (% of Bowen and Fontaine 2013 mapped spatial extent)	Justification
Mapped vegetation: Semi-permanent wetlands	**Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains (PCT 53)**	10,469	100%	Altered flooding regimes threaten the regularity and degree of flood inundation, and ploughing for cropping remains a major threat to shallow wetlands. Provides feeding areas for many waterbird species, and habitats and refuges for fauna and flora.
Mapped vegetation: Semi-permanent wetlands	**Common reed – bushy groundsel aquatic tall reedland grassland wetland of inland river systems (PCT 181)**	4,956	100%	Drainage of river systems and alterations in stream flows and flooding regimes due to dams, weirs and control of river flow may affect the extent of this community. Provides a waterbird breeding and feeding habitat.
Mapped vegetation: Semi-permanent wetlands	**Cumbungi rushland wetland of shallow semi-permanent water bodies and inland watercourses (PCT 182)**	1,609	100%	Drainage and river regulation may affect the extent of this community. Provides a waterbird breeding and feeding habitat.
Mapped vegetation: Semi-permanent wetlands	**Water couch marsh grassland wetland of frequently flooded inland watercourses (PCT 204)**	5,851	Restore to >80% of 1991 distribution [a]	Major reduction (>70%) in extent and/or range Provides a waterbird feeding habitat that directly supports waterbird colonies. Greatly reduced extent associated with reductions in frequency and flooding (OEH 2012a; OEH 2012b; Torrible & Wettin 2009).
Mapped vegetation: Semi-permanent wetlands	**Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains (PCT 53)**	10,469	100%	Altered flooding regimes threaten the regularity and degree of flood inundation, and ploughing for cropping remains a major threat to shallow wetlands. Provides feeding areas for many waterbird species, and habitats and refuges for fauna and flora.

Category	Surrogate	Total area (ha)	Target (% of Bowen and Fontaine 2013 mapped spatial extent)	Justification
Mapped vegetation: Flood-dependent shrubland wetlands	**Cane grass swamp tall grassland wetland of drainage depressions, lakes and pans of the inland plains (PCT 24)**	20	100%	Major alteration of species composition since European settlement. Some occurrences are threatened by changed flooding regimes on floodplains as they require periodic inundation to stimulate germination. Torrible and Wettin (2009) indicate a decline in distribution in Duck Creek. Provides a shallow-water habitat favoured by ground-nesting waterbirds such as stilts, avocets and brolgas. The wetland-dependent magpie goose is also associated with this vegetation community.
Mapped vegetation: Flood-dependent shrubland wetlands	**River cooba swamp wetland on the floodplains of the Darling Riverine Plains bioregion and Brigalow Belt South bioregion (PCT 241)**	20,403	100%	Provides a nesting habitat for birds, especially colonial nesting waterbirds including egrets, cormorants and darters. Medium-sized reduction (30%–70%) in extent and/or range. Major alteration of species composition since European settlement. May be negatively impacted by altered flooding regimes.
Mapped vegetation: Flood-dependent shrubland wetlands	**Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South bioregion and Darling Riverine Plains bioregion (PCT 247)**	6,652	Restore to >80% of 1991 distribution[a]	Provides a breeding habitat for waterbirds including colonial breeders such as the straw-necked ibis (*Threskiornis spinicollis*), royal spoonbill (*Platalea regia*) and glossy ibis (*Plegadis falcinellus*), and shelter and refuge for fish, birds, mammals and reptiles. Major reduction (>70%) in extent and/or range. Major alteration of species composition since European settlement. May be negatively impacted by altered flooding regimes.

Category	Surrogate	Total area (ha)	Target (% of Bowen and Fontaine 2013 mapped spatial extent)	Justification
Mapped vegetation: Flood-dependent forest/woodland (wetlands)	**River red gum tall to very tall open forest/woodland wetland (PCT 36)**	90,606*	100%	Changed flooding regimes due to irrigation draw-off are leading to a lack of regeneration and severe stress/death of river red gum in some locations (Bacon 2004; Torrible and Wettin 2009). Provides nesting and habitat for both waterbirds and populations of woodland birds. Essential for connectivity of riverine corridors and habitat diversity of the channels, banks and floodplain (Torrible and Wettin 2009). Root masses and limbs provide habitat for in-stream biota during low flows (Sheldon and Walker 1998).
Mapped vegetation: Flood-dependent forest/woodland (wetlands)	**River red gum grassy chenopod open tall woodland (wetland) on floodplain clay soil of the Darling Riverine Plains bioregion and western Brigalow Belt South bioregion (PCT 454)**	90,606*	100%	Provides nesting and habitat for both waterbirds and populations of woodland birds. Major reduction (>70%) in extent and/or range since European settlement. Many river red gum trees are dying due to water stress and lack of flooding on floodplains.
Mapped vegetation: Flood-dependent woodlands	**Black box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains bioregion and Brigalow Belt South bioregion (PCT 37)**	140,896*	100%	An Endangered Ecological Community under the *Biodiversity Conservation Act 2016* and endangered under the EPBC Act. Major reduction (>70%) in extent and/or range. Major alteration of species composition since European settlement. Less flooding has led to dieback in some areas and lack of recruitment of trees. Provides habitat features important to a range of fauna.
Mapped vegetation: Flood-dependent woodlands	**Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40)**	140,896*	100%	An Endangered Ecological Community under the *Biodiversity Conservation Act 2016* and endangered under the EPBC Act. Major alteration of species composition. Major reduction (>70%) in extent and/or range since European settlement. The rate of clearing and lack of flooding are key reasons for listing this community as endangered. Provides habitat features important to a range of fauna.

Data sourced from Bowen and Fontaine (2014), DIPNR (1998), DLWC (2002), Hunter (2012), Kerr et al. (2003), Peasley and Walsh (1999), Porteners (2010), Steenbeeke (1995), Andrews and Flemons (1998), Metcalfe et al. (2003) and Witts (1995). Selected natural waterbodies are represented by the Hydro Area feature class from the Digital Topographic Database (Land and Property Information 2012).

[a] **Area defined by Wilson (1992), *Vegetation map of the Macquarie Marshes*, Department of Environment and Climate Change NSW, Sydney. Target relates to the limits of acceptable change identified in OEH 2012a. Refer to the NSW Vegetation Information System for detailed information regarding characteristic trees (upper stratum species), shrubs/vines/epiphytes (mid stratum species) and groundcover (ground stratum species).**

* **Area estimates are considered to be approximations constrained by compilation of older mapping studies and classifications (which were regarded as less reliable) with more recent mapping data. These were grouped into flood-dependent woodland as state and federal legislation considers these communities together as coolibah-black box woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain and Mulga Lands bioregions, which is classified as an Endangered Ecological Community under the** *Biodiversity Conservation Act 2016* (NSW) and as endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act).

Area-based datasets (species distribution models)

Species distribution models (SDMs) are numerical tools that combine observations of species' occurrence or abundance with environmental estimates. They are used to gain an understanding of species' ecological requirements and to predict species' distributions across landscapes, sometimes requiring extrapolation in space and time. Correlative SDMs are often used as area-based surrogates to identify priority conservation areas in freshwater river ecosystems (Esselman and Allan 2011; Hermoso et al. 2013a). SDMs aim to estimate the environmental conditions that are suitable for a species by numerically relating known species occurrence records with suites of environmental variables of those locations. The environmental variables used to fit SDMs for the Macquarie Valley Floodplain included topographic and bio-climatic variables, and satellite-derived vegetation indices (that is, MODIS NDVI) using species occurrence records, but excluded occurrence records associated with human infrastructure (Table 6.2).

SDMs provide a powerful way of overcoming sparseness of point-based fauna distribution data by relating them to geographic or environmental predictors (Elith and Leathwick 2009). These predictive SDMs were used as area-based surrogates for Macquarie Valley Floodplain fauna. Maxent v. 3.3.3k (Phillips et al. 2010) was used to predict the distribution of 7 frog species, 3 freshwater turtle species and one snake species in the NSW Murray–Darling Basin (Table 6.3: Targets for area-based ecological surrogates (fauna species distribution models)). A common way to set species targets in conservation planning is to use a proportion of species distributions (for example, Carvalho et al. 2010; Hermoso et al. 2013a; Hermoso et al. 2013b). Marxan software was used to find an optimal set of planning units that represented at least 50% of each modelled species distribution (Table 6.3: Targets for area-based ecological surrogates (fauna species distribution models)).

Species distribution models may overestimate the likelihood of a species occurring. It can be difficult to evaluate overestimation in species distribution models that use presence data only (Hernandez et al. 2006). The species distribution models for this project were evaluated using the Receiver Operating Characteristic (ROC). This assesses plot sensitivity (or true positives) against specificity (or false positives) for a range of threshold values, and the area under the curve provides a measure of the ability of the model to discriminate between presences and absences (Wen et al. 2015).

Table 6.2: Environmental variables used to fit SDMs in the NSW Murray–Darling Basin for the Macquarie Valley Floodplain

Type	Resolution	Source	Description
Climate	1 km	Bioclim[1]	• Annual mean temperature • Mean diurnal range (mean of monthly temperature or maximum temperature to minimum temperature • Temperature seasonality (standard deviation multiplied by 100) • Mean temperature of the wettest quarter • Mean temperature of the driest quarter • Precipitation in the driest month • Precipitation of seasonality (coefficient of variation) • Precipitation in the wettest quarter • Precipitation in the warmest quarter • Precipitation in the coldest quarter
Topography	250 m	Geoscience Australia[2]	• Altitude • Built from 9-second DEM-derived streams database • Amount of upstream area (in number of cells) draining into each cell calculated from the 90-metre SRTM elevation data
Vegetation[3]	250 m	CSIRO	• Annual mean Normalised Difference Vegetation Index (NDVI) calculated from the monthly Moderate Resolution Imaging Spectroradiometer (MODIS) NDVI (2000–2012) • Annual maximum NDVI calculated from the monthly MODIS NDVI (2000–2012) • Standard deviation of the annual mean NDVI • Annual mean of the standard deviation of the monthly NDVI (January 2000–December 2012)

[1] Busby 1991

[2] Geoscience Australia 2011

[3] MODIS Normalized Difference Vegetation Index (NDVI). As the MODIS NDVI was available from February 2000, the mean January NDVI (2001–2012) was used for January 2000.

Table 6.3: Targets for area-based ecological surrogates (fauna species distribution models)

Asset type	Surrogate	Total area (ha)	Target (% of area)	Justification
Frogs	Barking marsh frog (*Limnodynastes fletcheri*)	790,409	50	The realised niche is likely to be a subset of the modelled areas. Frogs are an important component of the floodplain which provides important breeding and foraging grounds (Ocock 2013).
Frogs	Common green tree frog (*Litoria caerulea*)	826,076	50	The realised niche is likely to be a subset of the modelled areas. Frogs are an important component of the floodplain which provides important breeding and foraging grounds (Ocock 2013).
Frogs	Peron's tree frog (*Litoria peronii*)	357,034	50	The realised niche is likely to be a subset of the modelled areas. Frogs are an important component of the floodplain which provides important breeding and foraging grounds (Ocock 2013).
Frogs	Broad-palmed frog (*Litoria latopalmata*)	373,356	50	The realised niche is likely to be a subset of the modelled areas. Frogs are an important component of the floodplain which provides important breeding and foraging grounds (Ocock 2013).
Frogs	Desert tree frog (*Litoria rubella*)	845,162	50	The realised niche is likely to be a subset of the modelled areas. Frogs are an important component of the floodplain which provides important breeding and foraging grounds (Ocock 2013).
Frogs	Salmon striped frog (*Limnodynastes salmini*)	936,899	50	The realised niche is likely to be a subset of the modelled areas. Frogs are an important component of the floodplain which provides important breeding and foraging grounds (Ocock 2013).

Asset type	Surrogate	Total area (ha)	Target (% of area)	Justification
Frogs	Spotted grass frog (*Limnodynastes tasmaniensis*)	545,647	50	The realised niche is likely to be a subset of the modelled areas. Frogs are an important component of the floodplain which provides important breeding and foraging grounds (Ocock 2013).
Frogs	Eastern sign-bearing froglet (*Crinia parinsignifera*)	197,882	50	The realised niche is likely to be a subset of the modelled areas. Frogs are an important component of the floodplain which provides important breeding and foraging grounds (Ocock 2013).
Turtles	Eastern snake-necked turtle (*Chelodina longicollis*)	107,832	50	The realised niche is likely to be a subset of the modelled areas. Water-dependent species may be negatively affected by aquatic barriers, riverine habitat modification, changes in river flows and flood frequency (Bower et al. 2012; Kennett et al. 2009).
Turtles	Murray turtle (*Emydura macquarii*)	179,501	50	The realised niche is likely to be a subset of the modelled areas. Water-dependent species may be negatively affected by aquatic barriers, riverine habitat modification, changes in river flows and flood frequency (Bower et al. 2012; Kennett et al. 2009).
Turtles	Broad-shelled turtle (*Chelodina expansa*)	223,861	50	The realised niche is likely to be a subset of the modelled areas. Water-dependent species may be negatively affected by aquatic barriers, riverine habitat modification, changes in river flows and flood frequency (Bower et al. 2012; Kennett et al. 2009).
Snake	Red-bellied black snake (*Pseudechis porphyriacus*)	329,693	50	This species is of special significance Macquarie Marshes Adaptive Environmental Management Plan (DECCW 2010). Maintenance of viable populations is essential as they are likely to be an important indicator of overall wetland system health.

Point-based occurrence data (fauna)

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

- 12 species of fish
- 10 species of frogs
- 6 species of reptiles
- 4 species of aquatic snails
- one species of mammal.

These fauna species and assemblages were selected because they have a high dependence on floodwater. A score for the presence or absence of the species was assigned to all planning units. If the point record was within a planning unit, the species was considered present. Point-based records of fauna observations were sourced from:

- government agencies (NSW Department of Primary Industries (NSW DPI) 2014a)
- the Australian Museum Research Institute (30 July 2014)
- scientific literature (Davies et al. 2008, 2012; Growns and West 2008)
- University of Canberra Institute for Applied Ecology (2014) Wildlife Tissue and Distribution Database Records
- online databases (BioNet Atlas of NSW Wildlife (OEH 2014)).

All point-based occurrence surrogates were given 100% targets to support populations of frogs, freshwater fish, water-dependent reptiles and aquatic snails so that they could recruit and reproduce. The geographical records did not cover a large part of the floodplain landscape, and there was limited site-specific baseline ecological data that could enable setting of site-specific targets.

Table 6.4 lists point-based surrogates, their targets and their rationale for selection. Data presented in this table was sourced from the BioNet Atlas of NSW Wildlife (OEH 2014), Brooker and Wombey (1986), Davies et al. (2008, 2012), Growns and West (2008), NSW Department of Primary Industries – Fisheries NSW (2014), NPWS (2002), Ocock (2013), Shelly and NSW DIPNR (2005), Chessman (2014 unpublished data) and the University of Canberra Institute for Applied Ecology Wildlife Tissue and Distribution Database Records (2014). Records of freshwater aquatic snails were sourced from the Australian Museum (30 July 2014).

Table 6.4: Point-based fauna surrogates and number of occurrences in unique locations and their conservation targets used in Marxan analysis for the Macquarie Valley Floodplain

Category	Surrogate	Rationale for selection	Number of unique locations	Target (% of sites)
Observed native freshwater fish	Silver perch (*Bidyanus bidyanus*)^	• Recorded in the Macquarie Valley Floodplain by Harris and Edwards (1990). • Listed critically endangered under the EPBC Act in December 2013 (Department of the Environment 2014). • Listed as a vulnerable species in NSW under the *Fisheries Management Act 1994* (NSW DPI 2014a) and International Union for the Conservation of Nature (Wager 1996a). • Prefers fast-flowing, open waters, especially where there are rapids and races. • Modification of natural river flows has led to reduced opportunities for dispersal, spawning and migration (NSW DPI 2017) as this species requires flow pulses or floods for spawning (Humphries et al. 1999) and major spawning occurs when floodplains are inundated (Koehn and Crook 2013; Rogers and Ralph 2011). • Larvae and juveniles drift onto the floodplain after major flooding (Rogers and Ralph 2011). • Construction of barriers to migration and recolonisation is also likely to be a cause of its decline (NSW DPI 2014a). • The installation and operation of in-stream structures and mechanisms that alter natural flow regimes is a key threatening process that may adversely impact this species, as listed in Schedule 6 of the *Fisheries Management Act 1994* (NSW DPI 2014b).	3	100
Observed native freshwater fish	Un-specked hardyhead (*Craterocephalus stercusmuscarum fulvus*)^	• Recorded in the lowland zone of the Macquarie River valley (Davies et al. 2012). • Recorded by Cardno Pty Ltd (2011) in Crooked Creek. • Found around the margins of large, slow-flowing, lowland rivers, and in lakes, backwaters and billabongs (Lintermans 2007). • Associated with shallow vegetated areas with sandy or muddy substrate (Ralph et al. 2011). • Regarded as wetland opportunists, as it spawns and recruits in floodplain wetlands (and lakes, anabranches and billabongs) during in-channel flows (Young et al. 2003).	5	100
Observed native freshwater fish	Unidentified carp-gudgeon (*Hypseleotris* spp)^	• Recorded in the Macquarie Valley Floodplain by Jenkins et al. (2004). • Occurs in slow-flowing or still waters, normally associated with macrophyte beds or other aquatic vegetation (Lintermans 2007). • Regarded as a both a wetland and low-flow opportunist, since it tends to spawn and recruit during low flows and can utilise the main channels, floodplain wetlands and secondary channels during its life cycle (Young et al. 2003).	34	100

Category	Surrogate	Rationale for selection	Number of unique locations	Target (% of sites)
Observed native freshwater fish	Spangled perch (*Leiopotherapon unicolor*)^	• Recorded in the 2007–2008 and 2010–2011 surveys of the Macquarie Marshes (Rayner et al. 2009; Rayner et al. 2014). • Recorded by Cardno Pty Ltd (2011) in Crooked Creek. • Adapted to surviving in diverse environments including rivers, billabongs, lakes and waterholes in intermittent streams (Lintermans 2007). • Flooding maximises recruitment, and reduced flooding and access to floodplains are likely to disadvantage it (Lintermans 2007).	9	100
Observed native freshwater fish	Murray cod (*Maccullochella peelii*)^	• Listed as a vulnerable species under the EPBC Act. • Formally listed by the International Union for the Conservation of Nature (Wager 1996b) as Critically Endangered. • Recorded in the 2007–2008 and 2010–2011 surveys of the Macquarie Marshes (Rayner et al. 2009; Rayner et al. 2014). • A species important in Aboriginal beliefs associated with deep holes in rivers consisting of in-stream cover such as rocks, stumps and fallen trees (Lintermans 2007). • Flows are an important factor in the larval survivorship and subsequent recruitment of Murray cod (Cheshire and Ye 2008). • Changes such as river modification, clearing riparian vegetation, erosion, reduced river flows and de-snagging rivers have contributed to the decline of available habitat (Kalatzis and Baker 2010). • Appears to be exclusively restricted to riverine habitats across all stages of its life history (Humphries et al. 2002; King 2004; Koehn and Harrington 2005).	10	100
Observed native freshwater fish	Golden perch (*Macquaria ambigua*)^	• Recorded in the Macquarie Valley Floodplain by Harris and Edwards (1990), Swales and Curran (1995); in the 2007–2008 and 2010–2011 surveys of the Macquarie Marshes (Rayner et al. 2009; Rayner et al. 2014); and within the lowland zone of the Macquarie River valley (Davies et al. 2012). • A migratory fish species capable of upstream movements of more than 1,000 kilometres (Lintermans 2007). • River regulation, including barriers to migration and recolonisation, has disrupted migrations and breeding behaviour (Lintermans 2007) as this species requires flow pulses or floods for spawning (Humphries et al. 1999). • Commonly spawns in lowland river reaches; large numbers of juveniles then live in nurseries in inundated floodplains and shallow lake habitats before migrating long distance upstream (Gehrke and Harris 2004). • Eggs may drift onto the floodplain after major flooding (Koehn and Crook 2013).	16	100

Category	Surrogate	Rationale for selection	Number of unique locations	Target (% of sites)
Observed native freshwater fish	Murray–Darling rainbowfish (*Melanotaenia fluviatilis*)^	• Recorded in the Macquarie Valley Floodplain by Swales and Curran (1995) and in the 2007–2008 and 2010–2011 surveys of the Macquarie Marshes (Rayner et al. 2009; Rayner et al. 2014). • Prefers areas of in-stream vegetation in the slow-moving waters of rivers, billabongs and swamps (NSW DPI 2012; Lintermans 2007). • Loss of aquatic vegetation (spawning sites and cover) and cold-water pollution are potential threats (Lintermans 2007). • Tends to spawn and recruit during low flows in channels, but it can also use floodplain habitats (Young et al. 2003).	19	100
Observed native freshwater fish	Bony herring (*Nematalosa erebi*)^	• Recorded in the Macquarie Valley Floodplain by Swales and Curran (1995), Harris and Edwards (1990); in the 2007–2008 and 2010–2011 surveys of the Macquarie Marshes (Rayner et al. 2009; Rayner et al. 2014); and within the lowland zone of the Macquarie River valley (Davies et al. 2012). • Occurs in waterways of lowland and slope environments (NSW DPI 2006). • River regulation and cold-water pollution has reduced the abundance of the species (Lintermans 2007). • A main channel generalist and a wetland specialist since it tends to spawn and recruit in the main channel during high- and low-flow stages (Ralph et al. 2011). • It also uses anabranches, billabongs and wetlands during its life cycle (Young et al. 2003).	29	100
Observed native freshwater fish	Australian smelt (*Retropinna semoni*)^	• Recorded in the Macquarie Valley Floodplain by Swales and Curran (1995), and in the 2007–2008 and 2010–2011 surveys of the Macquarie Marshes (Rayner et al. 2009; Rayner et al. 2014). • Recorded by Cardno Pty Ltd (2011) in Crooked Creek. Barriers to fish passage may be fragmenting populations (Lintermans 2007).	12	100
Observed native freshwater fish	Freshwater catfish (*Tandanus tandanus*)^	• Recorded in the lowland zone of the Macquarie River valley (Davies et al. 2012). • Recorded by Cardno Pty Ltd (2011) in Crooked Creek. • Anecdotal information presented in the oral history component of Torrible and Wettin (2009) indicate historical occurrence in Duck and Marra creeks. • Found in lowland lakes and slow-flowing rivers (NSW DPI 2006; Lintermans 2007), it is an endangered population under the *Fisheries Management Act 1994*. • Cold-water pollution below dams, barriers to movement and changes to natural flow regimes (including loss of habitat due to alterations to flow patterns and flooding regimes) have contributed to the decline of this species (Lintermans 2007; NSW DPI 2014a).	10	100
Observed native freshwater fish	Flat-headed gudgeon (*Philypnodon grandiceps*)^	• Recorded in the Macquarie Valley Floodplain by Jenkins et al. (2004) and in the 2007–2008 surveys of the Macquarie Marshes (Rayner et al. 2009); however, it was not caught in the 2010–2011 surveys (Rayner et al. 2014). • Recorded by Cardno Pty Ltd (2011) in Crooked Creek. • Benthic species preferring slow-flowing areas of lowland streams, lakes and dams. • It is often found in weedy or muddy areas with abundant cover in the form or rocks or logs (Lintermans 2007).	6	100

Category	Surrogate	Rationale for selection	Number of unique locations	Target (% of sites)
Observed native freshwater fish	Mountain galaxias (*Galaxias olidus*)^	• Found in a variety of habitats and altitudes from small creeks to large rivers (Lintermans 2007).	1	100
Modelled freshwater fish biodiversity	High	• Freshwater fish sampling sites ranked with a high biodiversity score using a scoring system based on species diversity and abundance (Growns and West 2008).	2	100
Modelled freshwater fish biodiversity	Moderate	• Freshwater fish sampling sites ranked with a moderate biodiversity score using a scoring system based on species diversity and abundance (Growns and West 2008).	15	100
Modelled freshwater fish biodiversity	Low	• Freshwater fish sampling sites ranked with a low biodiversity score using a scoring system based on species diversity and abundance (Growns and West 2008).	3	100
Observed amphibious fauna	Eastern sign-bearing froglet (*Crinia parinsignifera*)	• Populations have a strong flood association, and their abundance is positively influenced by temporarily flooded marsh vegetation. • The species seeks shelter near damp places (Ocock 2013) occurring in rain-fed depressions, semi-permanent wetlands, oxbow lagoons, creeks and rivers, and man-made dams and infrastructure (Wassens 2011). • Favours water couch habitat (Healey et al. 1997) and may prefer to breed in deeper and more permanent pools than the common eastern froglet (Lintermans and Osborne 2002).	65	100
Observed amphibious fauna	Barking marsh frog (*Limnodynastes fletcheri*)	• Small to medium-sized non-burrowing ground frog. • May occur in the Macquarie Valley Floodplain near any water body, such as floodplain creeks, marshes and rain-filled ponds (Ocock 2011; Metcalfe et al. 1994). • Populations have a strong flood association, and their abundance is positively influenced by temporarily flooded marsh-vegetated habitat (Ocock 2013; Healey et al. 1997). • This species may be negatively affected by river regulatory activities (Ocock et al. 2014). • It has a strong preference for areas with emergent wetland vegetation (such as spike rush and cumbungi), particularly after flooding (Wassens 2010; Wassens 2011; Croft 2012; Healy et al. 1997).	118	100
Observed amphibious fauna	Broad-palmed frog (*Litoria latopalmata*)	• Non-burrowing ground frog. • Populations have a strong flood association, and their abundance is positively influenced by temporarily flooded marsh-vegetated habitat. • The species seeks shelter near damp places (Ocock 2013), restricted to areas near permanent and semi-permanent waters (Anstis 2013). • The broad-palmed frog occupies a range of habitats, including flood-dependent river red gum and black box (Wassens 2011).	57	100
Observed amphibious fauna	Common eastern froglet (*Crinia signifera*)	• Occurs in rain-fed depressions, semi-permanent wetlands, oxbow lagoons, creeks and rivers, and man-made dams and infrastructure (Wassens 2011).	2	100

Category	Surrogate	Rationale for selection	Number of unique locations	Target (% of sites)
Observed amphibious fauna	Sloanes's froglet (*Crinia sloanei*)	• Vulnerable species (*Biodiversity Conservation Act 2016*) occupying floodplain habitats. • Populations may be negatively affected by changes in flooding regimes, with 'Alteration to the natural flow regimes of rivers, streams, floodplains and wetlands' listed as Key • Threatening Processes under the *Threatened Species Conservation Act 1995* (OEH 2017). • Water requirements are very poorly known (Wassens 2011).	2	100
Observed amphibious fauna	Salmon striped frog (*Limnodynastes salmini*)	• Non-burrowing ground frog that may occur in the Macquarie Valley Floodplain (Ocock 2011). • Populations have a strong flood association where abundance is positively influenced by temporarily flooded marsh-vegetation (Ocock 2013). • During its breeding season, this species is associated with flooded grasses and dams. • The tadpoles prefer warmer, shallow water with vegetation cover (Anstis 2013).	59	100
Observed amphibious fauna	Spotted grass frog (*Limnodynastes tasmaniensis*)	• May occur in the Macquarie Valley Floodplain near any water body, such as floodplain creeks, marshes and rain-filled ponds (Ocock 2011; Metcalfe et al. 1994). • Populations have a strong flood association, and abundance is positively influenced by temporarily flooded marsh vegetation (Ocock 2013). • Prefers situations where there is considerable flooded vegetation such as tussocks and sedges (Lintermans and Osborne 2002). • This species will colonise any temporary or permanent pond or grassland soak (Anstis 2013). • During drought periods, adults congregate around permanent water (Wassens 2011).	116	100
Observed amphibious fauna	Desert tree frog (*Litoria rubella*)	• Arboreal species. • Populations have a moderate flood association (Ocock 2013). • Prefers temporary water bodies and is reliant on spring and summer flooding to create pools of water (Wassens 2011). • Males call from tussocks or vegetation near water (Anstis 2013).	53	100
Observed amphibious fauna	Common green tree frog (*Litoria caerulea*)	• Medium to large arboreal species occurring in a wide variety of habitats. • Populations have a moderate flood association (Ocock 2013). • This species has been recorded breeding in the Macquarie Marshes following spring and summer flooding (Wassens 2011).	91	100
Observed amphibious fauna	Peron's tree frog (*Litoria peronii*)	• Arboreal species more abundant in trees and fallen timber in woodland habitats within and around water bodies (Wassens 2011). • Populations in the Macquarie Marshes are characterised as moderately flood-associated (Ocock 2013).	84	100

Category	Surrogate	Rationale for selection	Number of unique locations	Target (% of sites)
Observed freshwater turtles	Eastern long-necked turtle (*Chelodina longicollis*)	• Water-dependent species occurring in the Macquarie Valley Floodplain (OEH 2012a; OEH 2012b; Shelly and NSW DIPNR 2005; Brooker and Wombey 1986; Metcalfe et al. 1994). • Occupies a broad range of freshwater aquatic environments, occurring in greatest abundance in shallow, ephemeral wetlands often remote from permanent rivers (Cogger 1983; Kennett et al. 2009). • Riverine habitat modification for agricultural industries and urban development, and changes in river flows and flood frequency, may threaten populations of this species (Kennett et al. 2009).	29	100
Observed freshwater turtles	Broad shelled turtle (*Chelodina expansa*)	• Water-dependent species occurring in the Macquarie Valley Floodplain (OEH 2012a; OEH 2012b; Shelly and NSW DIPNR 2005; Brooker and Wombey 1986; Metcalfe et al. 1994). • Prefers lacustrine habitats and slow-flowing water bodies, and is more frequently represented in permanent lakes and billabongs connected to main river channels (Bower and Hodges 2014). • Male turtles may be negatively influenced by aquatic barriers that impede movement, as the ecological health of the main river channel and backwaters are important to the species (Bower et al. 2012). • Females have been shown to have a reduced propensity for movement throughout their life cycle (Baggiano 2012; Bower et al. 2012).	7	100
Observed freshwater turtles	Murray turtle (*Emydura macquarii*)	• Water-dependent species occurring in the Macquarie Valley Floodplain (OEH 2012a; OEH 2012b; Shelly and NSW DIPNR 2005; Metcalfe et al. 1994). • Occurs primarily in rivers and water bodies associated with rivers such as backwaters, oxbows, anabranches and deep, permanent waterholes on floodplains (Chessman 1988; Brooker and Wombey 1986).	12	100
Observed water-dependent reptiles	Eastern water dragon (*Intellagama lesueurii*)	• Found in the Macquarie Valley Floodplain (Shelly and NSW DIPNR 2005; Metcalfe et al. 1994) on the slopes and ranges of eastern Australia (Cogger 2000). • Its presence in the Macquarie Valley Floodplain is likely to be associated with river and riparian habitats, as it predominately has an east coast and ranges distribution (Metcalfe et al. 1994).	2	100
Observed water-dependent reptiles	Eastern water skink (*Eulamprus quoyii*)	• Its presence in the Macquarie Valley Floodplain is associated with the river and riparian habitat, as it predominately has an east coast and ranges distribution (Metcalfe et al. 1994). • Usually found close to or on the shore of slow-flowing creeks and estuaries. • The eastern water skink is often seen basking besides small creeks, larger streams and rivers; however, it is not restricted to areas near fresh water (Cogger 1983; Cogger 2000). • Populations may be negatively affected by reductions in water availability, as abundance has been correlated with creek-side habitats and moist areas (Law and Bradley 1990).	2	100

Category	Surrogate	Rationale for selection	Number of unique locations	Target (% of sites)
Observed water-dependent reptiles	Red-bellied black snake (*Pseudechis porphyriacus*)	• Usually associated with streams, swamps and lagoons, occupying the riparian edge of rivers (Kingsford et al. 2010). • In the Macquarie Valley Floodplain, it has been observed to favour river red gum (*Eucalyptus camaldulensis*) woodlands close to water (Metcalfe et al. 1994). • It mostly feeds on frogs, but reptiles and small mammals are also eaten (Cogger 1983; Cogger 2000). • Predatory reptile that relies on the abundance of prey species in wetland environments (Ayers et al. 2004).	35	100
Observed water-dependent mammals	Water rat (*Hydromys chrysogaster*)	• Inhabits streams, rivers and wetlands throughout the Murray–Darling Basin (Scott and Grant 1997), where it is reliant on crustaceans, aquatic insects and fish, which form the bulk of its diet (CSIRO 2004; Woollard et al. 1978). • In the Macquarie Valley FMP, it has been associated with riverine vegetation including river red gum (*Eucalyptus camaldulensis*) woodlands and Cumbungi (*Typha* spp.) (Shelly and NSW DIPNR 2005); however, sightings are now rare. • It is once more commonly seen in the Macquarie Marshes (OEH 2012b). Anecdotal information presented in the oral history component of Torrible and Wettin (2009) indicates historical occurrence of water rats along Duck Creek and Crooked Creek. • This species may be found in permanent, swampy or lacustrine habitats associated with major drainages (Brooker 1983; Dickman 2004). • Water rats can occur in high numbers by permanent wetlands and prefer slower-moving waters and dense vegetation cover (Scott and Grant 1997; CSIRO 2004). • The water rat is often associated with irrigation infrastructure and may be a vagrant at ephemeral waters, travelling over 3 kilometres overland to exploit new resources (Scott and Grant 1997; Dickman 2004).	11	100
Observed aquatic snails	River snail (*Notopala sublineata*)^	• The river snail lives on mud, logs and rocks along river banks, usually in deep water (Cotton 1935; Johnston and Beckwith 1945). • The river snail is listed as an endangered species in NSW in Schedule 4 of the *Fisheries Management Act 1994* and International Union for the Conservation of Nature (Ponder 1996). • Populations may be negatively affected by river regulatory activities (NSW DPI 2007a) and altered flow regimes, principally weir and dam building (NSW DPI 2016). • The installation and operation of in-stream structures and mechanisms that alter natural flow regimes is a key threatening process that may adversely impact this species, as listed in Schedule 6 of the *Fisheries Management Act 1994* (NSW DPI 2005; NSW DPI 2014b).	2	100

Category	Surrogate	Rationale for selection	Number of unique locations	Target (% of sites)
Observed aquatic snails	Billabong banded snail (*Notopala kingi suprafasciata*)^	• Inhabits billabongs, swamps close to rivers, and waterholes in creeks, where it is found on mud and leaves and among aquatic plants. • The habitat of the billabong banded snail implies that it is dependent on frequent overbank flooding. • Populations may be negatively affected by reductions in flood frequency (Jones 2011).	2	100
Observed aquatic snails	Sculptured snail (*Plotiopsis balonnensis*)^	• The sculptured snail lives on rocks and water plants, where it grazes on detritus and biofilms (Jones 2011). • It is reliant on aquatic habitats and permanent waterholes, which provide refuge from droughts (Glaubrecht et al. 2009). • Little is known about the environmental tolerances of this species (Jones 2011).	3	100
Observed aquatic snails	Pouch snail (*Glyptophysa gibbosa*)^	• Occupies a wide range of habitats and ecological conditions, including floodplain wetlands and river littoral zones associated with water plants. • Populations may be negatively affected by reductions in flood frequency (Stevens 2007) or increases in flow velocity that reduce the amount of available habitat (Jones 2011).	7	100

^ Denotes the native animal species that form part of the endangered lowland catchment of the Darling River aquatic ecological community. These species are considered aquatic under the definition of the *Fisheries Management Act 1994*. The listing of the lowland Darling River aquatic ecological community has given all native fish and other aquatic animal life within its boundaries the status of endangered species (NSW DPI 2007b).

Appendix 8: Marxan prioritisation (constraint surface)

Marxan addresses the minimum-set problem, which is to meet a set of targets at the lowest cost. It minimises an objective function via a process of simulated annealing to select important parts of the landscape from a larger pool of potential areas (or planning units), taking into account planning-unit costs and the locations of the conservation features for protection (Ball et al. 2009). Efficiency is a core objective of Marxan. If efficiency is ignored, prioritisation is a simple procedure of conserving everything, which may be impractical (Possingham et al. 2007). The use of a constraint surface in ecological prioritisation, therefore, allows Marxan to create efficient planning solutions. A cost-efficient network of priority areas is comprehensive, representative and adequate, at the lowest possible cost, and is more likely to be defensible in light of competing interests (Wilson et al. 2009).

The cost constraint adopted for the Marxan analysis was based on the latest available land use data for the Macquarie Valley Floodplain (OEH 2011a), which was updated to include areas of recent cultivation mapped by Bowen and Fontaine (2014).

The different land use classes were allocated a constraint weighting, indicating the potential impacts of that land use on aquatic biodiversity and with consideration of the likely impact that land use types may have on the floodplain's hydrological processes (Table 8.1). Planning units with relatively natural conditions were preferentially weighted lower, while those that were highly modified were weighted higher. For example, existing wetland and riparian areas were allocated a lower constraint weighting compared to areas of cropping, and horticultural and intensive animal production. This approach is similar to that adopted in the freshwater conservation planning work of Rivers-Moore et al. (2011).

The constraint surface represented the ability to physically connect water to floodplain assets and was used to constrain the selection of planning units in the Marxan solution. Low constraint classes were most likely to be associated with a high likelihood of inundation; the central constraint class was more likely to indicate a moderate likelihood of inundation and the high constraint class was associated with a low likelihood of inundation.

For each planning unit, this constraint value was estimated using the Geospatial Modelling Environment (Spatial Ecology 2014) Intersect Polygons with Polygons tool to generate an area-weighted mean (AWM) of the constraint weighting for each planning unit (Figure 8.1).

Table 8.1: The land use categories used for computing the Marxan constraint surface and the weights given to each category

Land use NSW major category	Land use NSW detailed description	Land use ALUM* major category	Land use ALUM* detailed description	Constraint
Conservation Area	Private conservation agreement, National park, State forest	Nature conservation, Production forestry	Other conserved area, Production forestry, National park	0.35
Conservation Area	Crown reserve, Cultural heritage site - Aboriginal or European, Lands fenced and treated for land degradation problems	Nature conservation, Other minimal use	Residual native cover, Other conserved area, Rehabilitation	0.45
Conservation Area	Tree lot, Constructed grass waterway for water disposal, Part of a soil erosion control system carrying runoff from graded banks, Wide road reserve or TSR, with some grazing, Wide road reserve or TSR, with some grazing - with a woody vegetation cover of woodland	Plantation forestry, Other minimal use	Environmental forest plantation, Rehabilitation, Stock route	0.50
Conservation Area	Salt treatment or salt demonstration site (discharge and recharge sites)	Other minimal use	Rehabilitation	1.00

Land use NSW major category	Land use NSW detailed description	Land use ALUM* major category	Land use ALUM* detailed description	Constraint
Cropping	Fodder crop, Agricultural industry in a rural location e.g. cotton gin, Cotton – irrigated, Cotton - irrigated; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Cotton - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Cropping - continuous or rotation, Cropping - continuous or rotation – irrigated, Cropping - continuous or rotation - irrigated; irrigation practice - centre pivot, Cropping - continuous or rotation - irrigated; irrigation practice - drip irrigation, Cropping - continuous or rotation - irrigated; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Cropping - continuous or rotation - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Cropping - continuous or rotation - irrigated; irrigation practice - travel irrigator, Cropping - with a fixed irrigation system not used at the time of mapping, Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - drip irrigation, Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - travel irrigator, Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - centre pivot, Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Cropping of legumes for seed - chickpeas, lupins, vetches, field beans - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Fodder crop – irrigated, Fodder crop - with a fixed irrigation system not used at the time of mapping: irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Storage site for agricultural chemicals and products (e.g. fertiliser dumps, cotton bunkers and temporary grain storages)	Cropping, Manufacturing and industrial, Irrigated cropping	Hay & silage, Manufacturing and industrial, Irrigated cropping, Irrigated pulses, Irrigated hay & silage, Hay & silage	1.00
Grazing	Flood runners in western NSW - with a woody vegetation cover of woodland, Flood runners in western NSW (Vegetation is indicative of a more prolonged period of inundation or wetness.)	Grazing native vegetation	Grazing native vegetation	0.10
Grazing	Grazing within an ephemeral wetland - with a woody vegetation cover of woodland, Grazing within an ephemeral wetland (does not include cropping within an ephemeral lake - see classes 182 & 189), Grazing within bed of an ephemeral lake or watercourse; lake or watercourse are not regulated or above regulation level, Grazing within bed of an ephemeral lake or watercourse; lake or watercourse are not regulated or above regulation level with a dense shrub or tree cover	Grazing native vegetation	Grazing native vegetation	0.25
Grazing	Grazing of areas with a chequer-board treatment for scald reclamation	Grazing modified pastures	Grazing modified pastures	0.45
Grazing	Firebreak, Flood refuge (constructed features located within flood prone areas)	Grazing native vegetation, Land in transition	Grazing native vegetation, No defined use	0.50

Land use NSW major category	Land use NSW detailed description	Land use ALUM* major category	Land use ALUM* detailed description	Constraint
Grazing	Grazing of areas on the western floodplains with heavy clays and subject to prolonged wetness after floods, Grazing pastures within the Macquarie Marshes landscape, Grazing pastures within the Macquarie Marshes landscape - with more than 30% of ground area having regeneration of native tree species	Grazing native vegetation	Grazing native vegetation	0.50
Grazing	Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with more than 30% of ground area having native shrub regeneration, Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation, Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with a woody vegetation cover of open forest, Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with a woody vegetation cover of woodland, Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with more than 30% of ground area having regeneration of native tree species, Rangeland grazing, Rangeland grazing - with a woody vegetation cover of open forest, Rangeland grazing - with a woody vegetation cover of woodland, Rangeland grazing - with more than 30% of ground area having native shrub regeneration, Rangeland grazing - with more than 30% of ground area having regeneration of native tree species	Grazing native vegetation	Grazing native vegetation	0.60
Grazing	Degraded land (salt site, eroded area), Grazing - Residual strips (block or linear feature) of native grassland within cultivated paddock. Strips contain scattered to isolated trees only, Grazing of areas with water ponding treatments	Land in transition, Grazing native vegetation, Grazing modified pastures	Degraded land, Grazing native vegetation, Grazing modified pastures	0.65
Grazing	Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation, with previous evidence of cultivation, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - centre pivot, Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having native shrub regeneration, Volunteer, naturalised, native or improved pastures - with > 30% of ground area having regeneration of native tree species	Grazing native vegetation	Grazing native vegetation, Native/exotic pasture mosaic	0.75
Grazing	Irrigated pastures, Irrigated pastures; irrigation practice - centre pivot, Irrigated pastures; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Irrigated pastures; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Irrigated pastures; irrigation practice - sprinkler irrigation	Grazing irrigated modified pastures	Grazing irrigated modified pastures	0.85

Land use NSW major category	Land use NSW detailed description	Land use ALUM* major category	Land use ALUM* detailed description	Constraint
Grazing	Sown, improved perennial pastures, Volunteer, naturalised, native or improved pastures, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - contour irrigation, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Volunteer, naturalised, native or improved pastures, with previous evidence of cultivation, Recently cleared land (cleared of forest vegetation as yet not covered by crop or pasture), Saltbush plantings (for grazing purposes and not as part of a salinity control programme), Saltbush plantings (for grazing purposes and not as part of a salinity control programme): irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water	Grazing modified pastures, Grazing irrigated modified pastures	Native/exotic pasture mosaic, Woody fodder plants, Irrigated woody fodder plants	1.00
Horticulture	Abandoned orchard and vine lands; trees/vines not maintained and may be dying; regrowth of native shrubs and trees is occurring, Building associated with horticultural industry (winery, packing shed), Cut flowers & herbs, Nursery, Olives – irrigated, Olives - irrigated; irrigation practice - drip irrigation, Orchard - tree fruits – irrigated, Orchard - tree fruits - irrigated; irrigation practice - drip irrigation, Pecan, macadamia and other nuts, Pecan, macadamia and other nuts - irrigated; irrigation practice - drip irrigation, Shade house or glass house (includes hydroponic use), Vegetables, Vegetables – irrigated, Vegetables – irrigated, Vegetables irrigated; irrigation practice sprinkler irrigation, Vineyard - grape and other vine fruits, Vineyard - grape and other vine fruits – irrigated, Vineyard - grape and other vine fruits - irrigated; irrigation practice - drip irrigation	Land in transition, Manufacturing and industrial, Seasonal horticulture, Intensive horticulture, Irrigated perennial horticulture, Perennial horticulture, Irrigated seasonal horticulture,	Abandoned land, Manufacturing and industrial, Seasonal flowers & bulbs, Intensive horticulture, Irrigated oleaginous fruits, Irrigated tree fruits, Tree nuts, Irrigated tree nuts, Shade houses, Seasonal vegetables & herbs, Irrigated seasonal vegetables & herbs, Vine fruits, Irrigated vine fruits	1.00
Intensive Animal Production	Effluent ponds from intensive animal industries, Horse stud and/or horse breeding facilities, Intensive animal production - beef feedlot, Intensive animal production - dairy shed, Saleyard	Reservoir/dam, Intensive animal husbandry, Services	Effluent pond, Intensive animal husbandry, Cattle feedlots, Dairy sheds and yards, Commercial services	1.00
Mining & Quarrying	Derelict mining land, Mine site, Quarry, Restored mining lands	Land in transition, Mining, Land in transition	Degraded land, Mines, Quarries, Land under rehabilitation	1.00
Power Generation	Electricity substation	Utilities	Fuel powered electricity generation	1.00

Land use NSW major category	Land use NSW detailed description	Land use ALUM* major category	Land use ALUM* detailed description	Constraint
River & Drainage System	Flood chute (flood runners that are filled with water during and after floods) and designated floodway in irrigation districts, localities, Flood chute and designated floodway in irrigation districts, localities - with a woody vegetation cover of woodland, Lagoon or inland lake, River, creek or other incised drainage feature; includes cowals in western NSW	River	River	0.10
River & Drainage System	Reservoir	Reservoir/dam	Reservoir	0.15
River & Drainage System	Drainage depression in cropping paddock	Channel/aqueduct	Channel/aqueduct	0.20
River & Drainage System	Temporary water storage area (e.g. rice farming - opportunistic storage of water in natural depressions, Bore drain (active), Disposal dam, depression or lake bed for irrigation tail water, Drainage channel (from irrigation system or a channel draining a swamp; base of channel is lined), Drainage or water supply channel - base of channel is not lined	Reservoir/dam, Channel/aqueduct	Reservoir/dam, Channel/aqueduct, Evaporation basin, Drainage channel/aqueduct	1.00
River & Drainage System	Farm dam, Irrigation dam, Irrigation dam - not used at the time of mapping, Irrigation supply channel, Pump site, urban or irrigation supply, River diversion work (inland, not coastal)	Reservoir/dam, Channel/aqueduct, Utilities, River	Reservoir/dam, Supply channel/aqueduct, Utilities, River	1.00
Special category	Levee for flood protection around house and farm infrastructure Farm Infrastructure - house, machinery & storage sheds and garden areas Irrigation farm infrastructure; miscellaneous lands within farms including access roads, bund walls, buildings and services	Residential and farm infrastructure	Farm buildings/infrastructure	1.00
Transport & Other Corridors	Aerodrome/airport, Airstrip (local/farmer, grass or bare surface, not sealed), Communications facility, Railway, Railway - track no longer used, Road or road reserve, Roadside rest area	Transport and communication	Airports/aerodromes, Transport and communication, Navigation and communication, Railways, Roads	1.00
Tree & Shrub Cover	Dense shrub growth - limited to nil grazing capacity, Native forest, Native forest – regeneration, Windbreak or tree corridor	Other minimal use, Land in transition, Plantation forestry	Rehabilitation, Residual native cover, Land under rehabilitation, Environmental forest plantation	0.50
Urban	Rural recreation. Blocks are isolated and not associated with an urban area, Areas irrigated with effluent from sewage disposal ponds, Caravan park or mobile home village, Cemetery, Government and private facilities - gaol, training centre, school, religious institutions & training centres, religious retreats, Industrial/commercial, Landfill (garbage), Research facility, Residential, Residential, Rural residential, Sewage disposal ponds, Tourist development, Urban recreation	Services, Waste treatment and disposal, Services, Waste treatment and disposal, Residential and farm infrastructure	Recreation and culture, Sewage, Recreation and culture, Public services, Landfill, Research facilities, Urban residential, Rural residential with agriculture	1.00

Land use NSW major category	Land use NSW detailed description	Land use ALUM* major category	Land use ALUM* detailed description	Constraint
Wetland	Floodplain swamp, Floodplain swamp - back swamp, Floodplain swamp – billabong, Swamp	Marsh/wetland	Marsh/wetland	0.10
Wetland	Constructed wetland for conservation or water improvement	Reservoir/dam	Reservoir/dam	0.25
Wetland	Swampy and/or more moist landscapes within the western drainage system	Grazing native vegetation	Grazing native vegetation	0.25

These categories were generated by grouping the land use classes identified in detailed land use maps for the Macquarie Valley FMP Floodplain (OEH 2011a). The weights given to each category are scaled from 0 to 1 and indicate the potential impacts of that land use on aquatic biodiversity and hydrological processes.

* ALUM = Australian Land Use and Management Classification

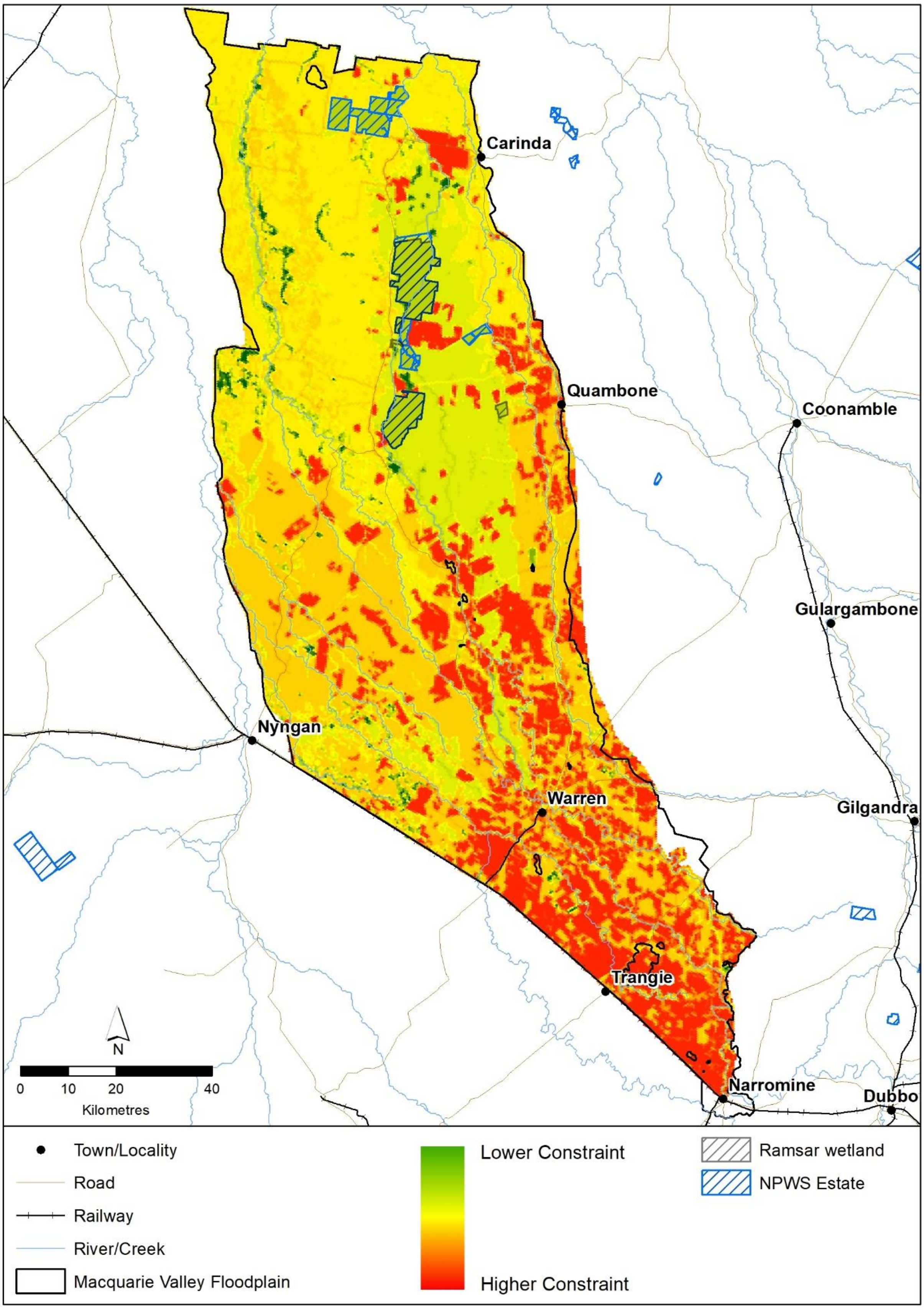

Figure 8.1: Land use–based constraints surface derived from detailed land use mapping (OEH 2011a) and data sourced from Bowen and Fontaine (2014) for the Macquarie Valley Floodplain

Appendix 9: Aboriginal Sites Decision Support Tool

The Aboriginal Sites Decision Support Tool (ASDST) was developed to meet a critical need in regional planning: whole-of-landscape data describing Aboriginal site issues. There are 2 key components of the ASDST:

- landscape visualisation through the provision of visual products (GIS layers) that fill in data gaps in the Aboriginal Heritage Information Management System (AHIMS) data
- analysis, by generating information products designed to meet the need of incorporating Aboriginal site heritage information into regional, park, land and natural resource management planning.

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

Landscape visualisation tool

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

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

Analytical tool

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

- accumulated impacts
- gap analysis
- representativeness.

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

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

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

Appendix 10: Socio-economic profile

Background

The water management principles of the WM Act require that planning on floodplains considers the socio-economic impacts of flood-work management strategies to:

- maximise the social and economic benefits to the community
- avoid and minimise the impacts of flood works on other water users
- minimise the existing and future flood risk to human life and property arising from occupation of floodplains.

The valley-wide floodplain management plans will contain management zones and rules that provide an equitable and consistent approach to controlling development on the floodplain. The management zones and rules will be designed to minimise the impact that flood-work development may have on neighbouring properties, which will help to minimise the risk to life and property from the effects of flooding.

A socio-economic profile of the floodplain area is required so that the social and economic impacts of development controls in the floodplain and the risk to life and property from the effects of flooding can be effectively considered.

In addition, it is important that, before options about future water resource management are developed, the floodplain area is understood and the ability of the community to absorb change is appreciated.

The focus of the profile of socio-economic factors is to assemble existing key data that will provide a general picture of the catchment in terms of its socio-demographic and socio-economic structures.

Developing the profile, or ‘snapshot’, involves documenting the biophysical, social and economic conditions of the valley to help understand the floodplain. The main types of socio-economic information that inform the baseline profile include:

- geographies that are relevant to the socio-economic discussion of the floodplain
- demographic profiles
- household income statistics
- employment statistics
- economic wellbeing indicators
- agricultural production statistics.

The socio-economic profile analysis informs Steps 7, 8 and 10 of the preparation of the Macquarie Valley FMP. Information from this profile will inform the development of management zones and rules for the valley (Steps 7 and 8). Information from this profile will also be drawn upon in the socio-economic impact analysis (Step 10) that identifies and considers the potential socio-economic impacts associated with the implementation of the FMP. The socio-economic impact analysis will be undertaken in coordination with the development of management zones and rules for the valley.

Study area geography

There are several geographies that are relevant to the socio-economic discussion of flood management within the Macquarie Valley FMP. The 3 areas examined are the:

- Macquarie floodplain economy
- Macquarie rural floodplain
- Macquarie urban floodplain.

The Macquarie floodplain economy (Figure 10.1) area includes the Macquarie rural and urban floodplains as well as the adjacent areas in the Barwon and Bogan River catchments that engage with the economy of the region. This area (3,698,800 hectares) is located between the regional centres of Dubbo and Brewarrina. Most goods and services consumed in the Macquarie floodplain economy area are sourced from the regional centres of Dubbo, Narromine, Warren, Nyngan and Trangie, or the smaller townships in this area.

The Macquarie rural floodplain is the floodplain area downstream of Narromine along the Macquarie River to the floodplain junction with the floodplain of the Barwon River. The Macquarie floodplain is bounded by the Bogan River floodplain in the west and the Castlereagh catchment in the east. This Macquarie rural floodplain area (1,245,600 hectares) will be directly impacted by the Macquarie Valley FMP (Figure 10.2). The community residents who live and work in this area are predominantly engaged in agriculture, but the community does include people who live in small rural towns. There are limited community services and infrastructure in this area; most of the required farm inputs and human services are provided from the local towns and the regional centre of Dubbo.

The Macquarie urban floodplain incorporates the townships of Narromine, Warren, Nyngan and Trangie. While this area is situated on or adjacent to the floodplain, and may be affected by Macquarie Valley FMP floodwater, floodwater management in urban areas of NSW is provided under the *Local Government Act 1993*. The communities that line in these towns are reliant upon the surrounding rural floodplain areas both as a source of employment and as a consumer of services.

Data sources

Demographic data on the Macquarie floodplain economy, the Macquarie rural floodplain and the Macquarie urban floodplain; on populations, including the Indigenous community; on sex and age ratios; on household weekly incomes; and on labour participation rates and employment by industry sector is drawn from the ABS Census of Population and Housing 2011 Statistical Area level 1 (SA1) data (ABS 2011a). The SA1 areas are the smallest unit for the release of Census data. The SA1 boundaries combine to form the boundary of the Macquarie floodplain economy and the urban floodplain areas. The rural floodplain area is defined as parts of 13 SA1 areas. Regional population trends for the local government areas (LGAs) have been drawn from the 2013 ABS Regional Population Growth data (ABS 2013).

Information on the relative socio-economic advantage and disadvantage rankings for the LGA and SA1 areas is drawn from the ABS Census of Population and Housing 2011 Socio-Economic Indexes for Areas (SEIFA) (ABS 2011b).

Agricultural production is a significant component of the floodplain economy. The ABS Agricultural Census 2011 (ABS 2011c) provides comprehensive data on both dry land and irrigated agriculture production at the Statistical Area level 2 (SA2). SA2 areas are general-purpose medium-sized areas built from whole SA1s. The SA2 communities of the floodplain economy include parts of the SA2 regions of Nyngan–Warren, Coonamble, Walgett–Lightning Ridge, Narromine and Bourke–Brewarrina.

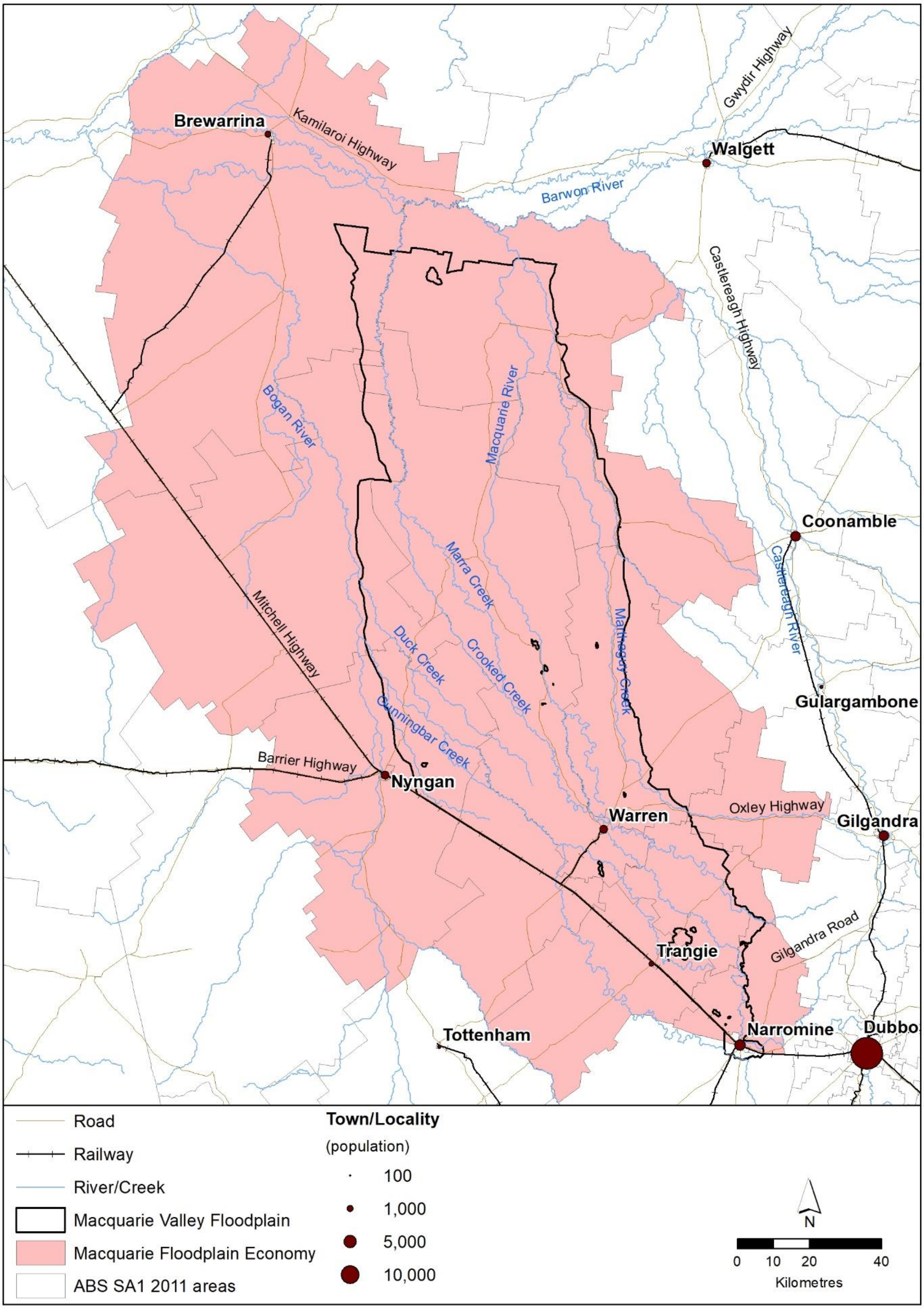

Figure 10.1: Macquarie Valley FMP and Macquarie floodplain economy area

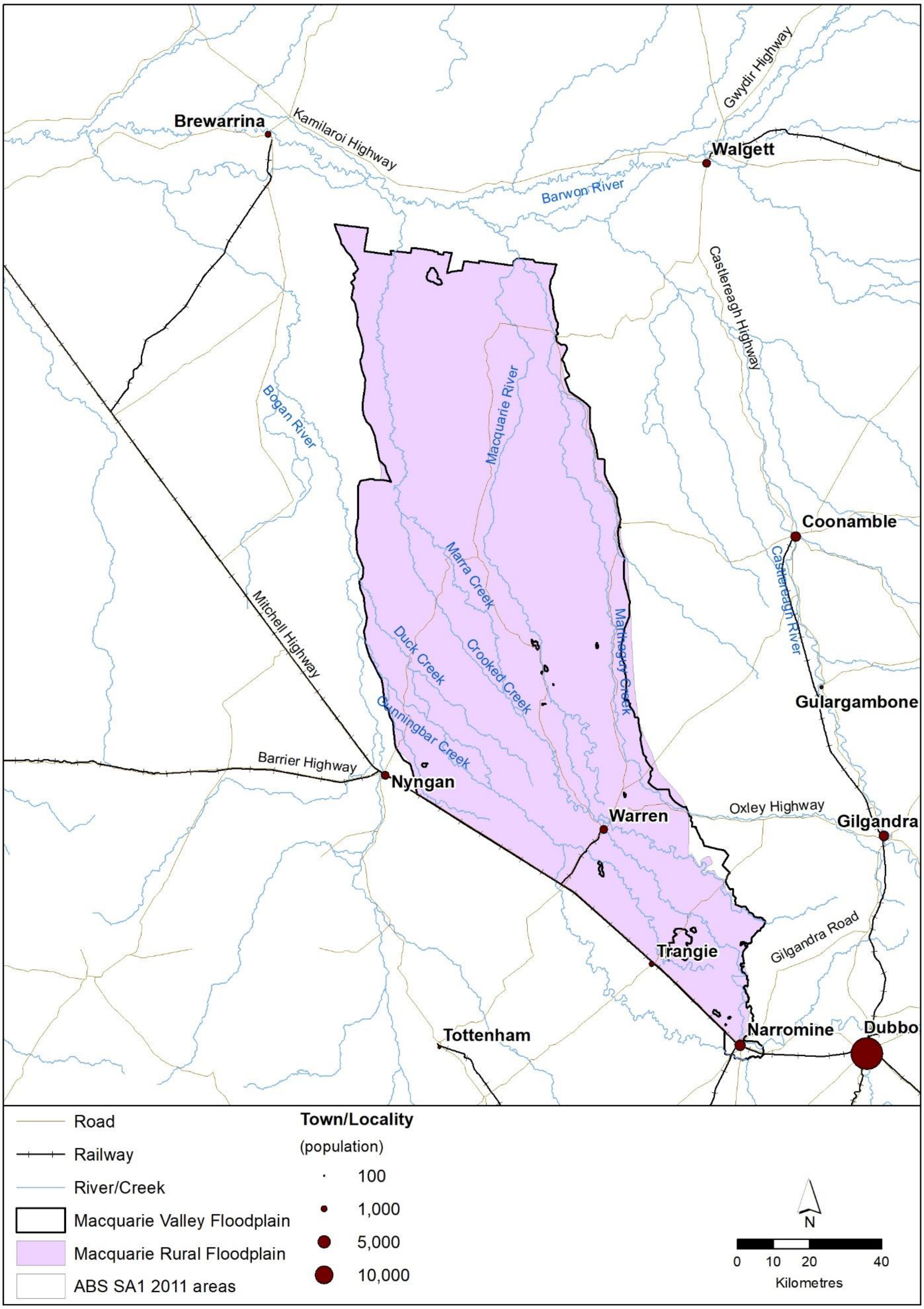

Figure 10.2: Macquarie Valley FMP and Macquarie rural floodplain area

Demographic profiles

In general, regional populations have experienced gradual decline; however, the populations of the 6 LGAs of the Macquarie Valley region have stabilised over recent years. Regional population trends for the 6 relevant LGAs are presented in Figure 10.3.

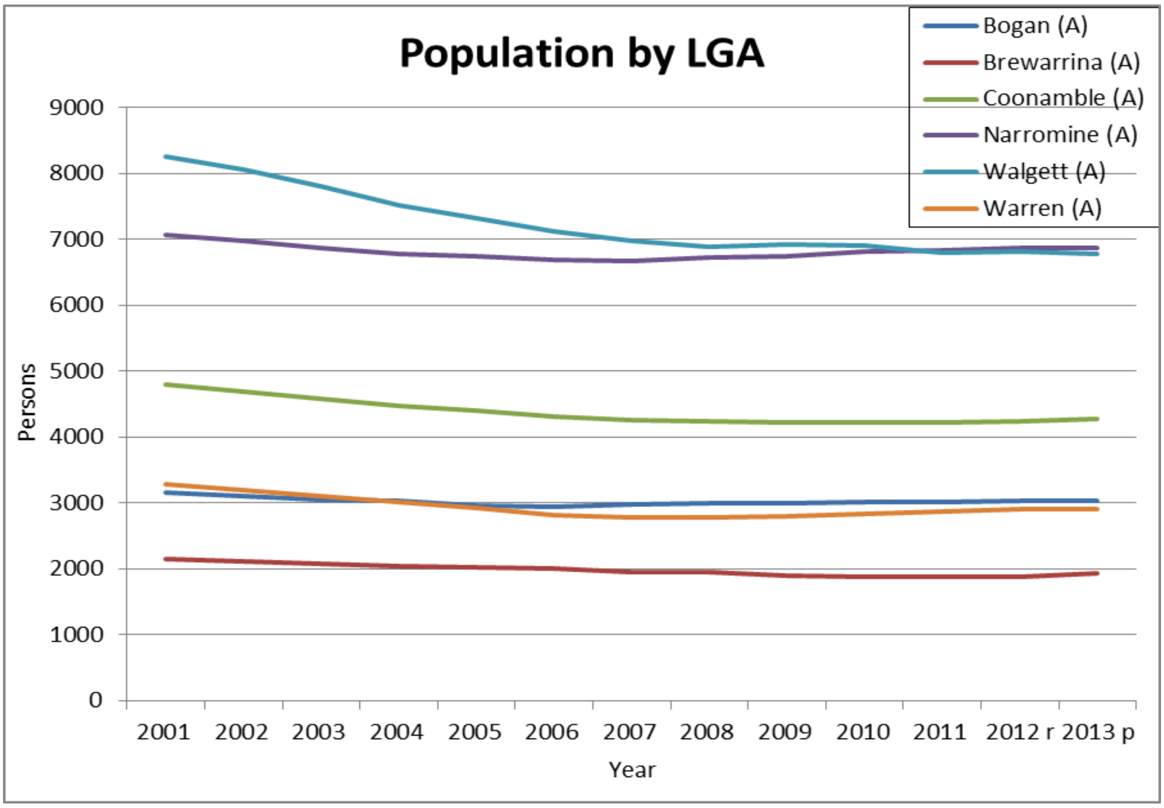

Figure 10.3: Macquarie Valley regional population trend by LGA, 2001–2013

Macquarie floodplain economy

The economy of the Macquarie Valley FMP area is interwoven with the economy of the adjacent community, drawing inputs from, passing outputs through and using services from the same business centres as the adjacent community. It is appropriate, therefore, to consider the socio-economic profile of the wider Macquarie floodplain economy (Figure 10.1).

The population of the Macquarie floodplain economy area (Figure 10.1) is estimated to be 12,700 people, of whom 65% live in towns. The major towns of this area are Narromine, Warren, Nyngan and Trangie. The Macquarie floodplain economy total population is greater than the total of the Macquarie rural floodplain and urban floodplain populations, as the boundary of the Macquarie floodplain economy area includes areas in addition to the rural floodplain and urban floodplain areas (see Figure 10.1 and Figure 10.2).

The Indigenous community makes up 22.2% of the Macquarie floodplain economy population, which is substantially higher than the NSW state proportion of 2.5%.

There is almost the same number of males and females living in the Macquarie floodplain economy area; the sex ratio (the number of males per 100 females) is 99.3.

The dependency ratio of the Macquarie floodplain economy is 66, a measure of the proportion of the population that is not of working age per 100 persons of working age (ages 15 to 64). This dependency ratio should be read with the understanding that there are a considerable number of farmers over the age of 64 who continue to work in the agriculture sector. The actual dependency ratio is likely to be closer to the NSW state ratio of 52. The age by sex distribution of this community reveals an under-representation in the 15 to 45 age groups, as compared to the under 15 and over 45 age groups of the NSW population. This under-representation is demonstrated to a greater extent in the Macquarie rural floodplain.

The age by sex distribution of the Macquarie floodplain economy is presented in Figure 10.4. The age by sex distribution of the NSW population is presented in Figure 10.5.

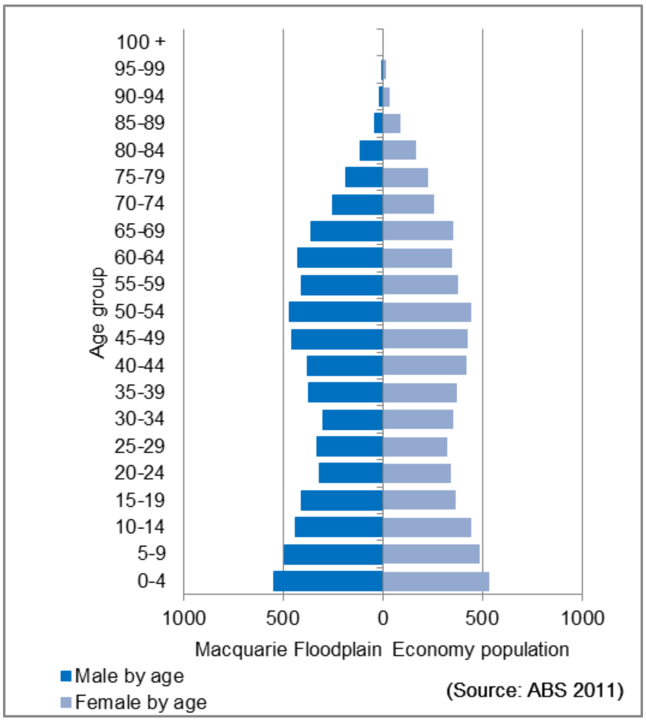

Figure 10.4: Floodplain economy by age group and sex, 2011

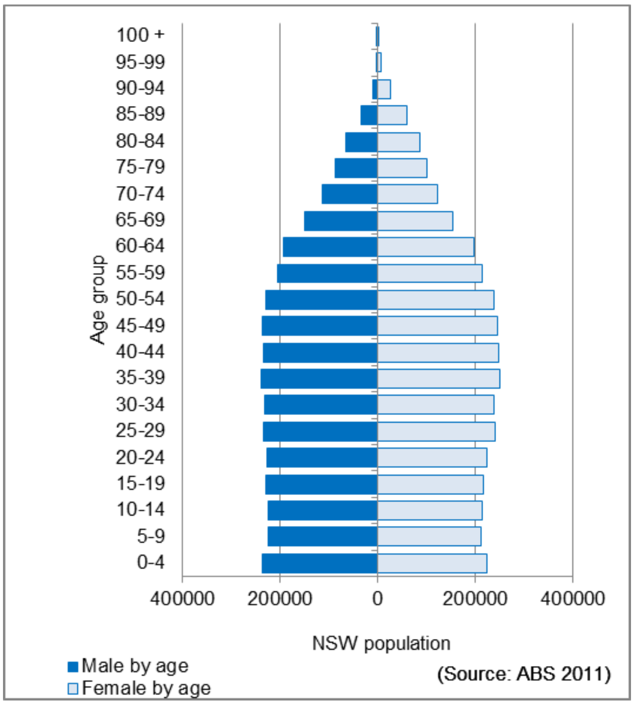

Figure 10.5: NSW by age group and sex, 2011

The Macquarie rural floodplain

The estimated population of the Macquarie rural floodplain, calculated on the area of 1,245,800 hectares, is 1,410 people. The population density of the rural floodplain is estimated to be 11 people per 10,000 hectares.

The Indigenous proportion of the Macquarie rural floodplain community is 8.3%, which is more than 3 times that of the NSW community, at 2.5%.

There are slightly more males than females in the Macquarie rural floodplain population, and the sex ratio of 105 is higher than the NSW state sex ratio of 97.

The dependency ratio of the Macquarie rural floodplain, at 55, is close to the NSW state dependency ratio of 52. As discussed regarding the dependency ratio calculated for the Macquarie floodplain economy, a considerable number of farmers over the age of 64 continue to work in the agriculture sector. The actual dependency ratio is likely to be lower than the NSW state ratio.

The population pyramid (age by sex) indicates a lower than expected proportion of the population in the 15 to 45 age groups. This is likely to be related to the inaccessibility of secondary and tertiary education opportunities, and associated employment, in this area.

The age by sex distribution of the Macquarie rural floodplain is presented in Figure 10.6.

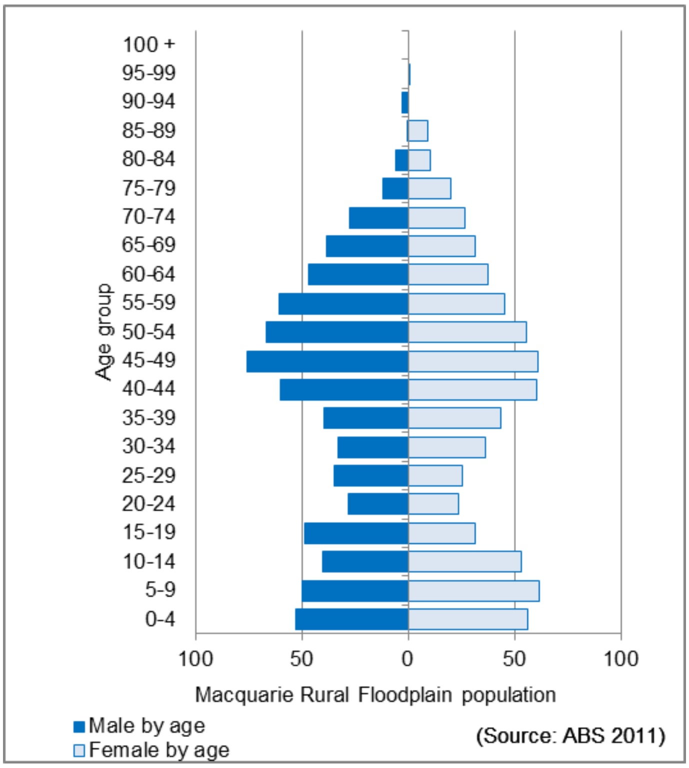

Figure 10.6: Macquarie rural floodplain population by age group and sex, 2011

The Macquarie urban floodplain

The Macquarie urban floodplain population of 8,230 people includes the urban centres of Narromine with a population of 3,790, Nyngan with 2,070, Warren with 1,520 and Trangie with 850 people.

The Indigenous community constitutes 22% of the Macquarie urban floodplain community, which is substantially higher than the Macquarie rural floodplain proportion of 8.3% and the NSW proportion of 2.5%.

The sex ratio of the Macquarie urban floodplain is 96, which is lower than the Macquarie rural floodplain sex ratio of 105 and close to the NSW state sex ratio of 97.

The dependency ratio of the Macquarie urban floodplain is 74, substantially higher than the adjacent Macquarie rural floodplain community dependency ratio of 55 and the NSW state dependency ratio of 52.

The demographic statistics are presented in Table 10.1 and the age by sex distribution is presented in Figure 10.7. It is interesting to note that the Macquarie Urban floodplain community reflects the under-representation in the 15 to 39 age groups, but to a lesser degree than that observed in the rural floodplain community.

Table 10.1: Macquarie Urban floodplain demographic statistics

Town	Area (ha)	Total population	Indigenous population	Indigenous proportion (%)	Dependency ratio
Narromine	1,340	3,790	910	24.0	72
Nyngan	1,163	2,070	370	17.9	74
Warren	298	1,520	300	19.7	70
Trangie	198	850	220	25.9	87
Macquarie urban floodplain total	3,000	8,230	1,800	21.9	74
NSW total	**n/a**	**6,917,700**	**172,600**	**2.5**	**52**

Source: ABS 2011a

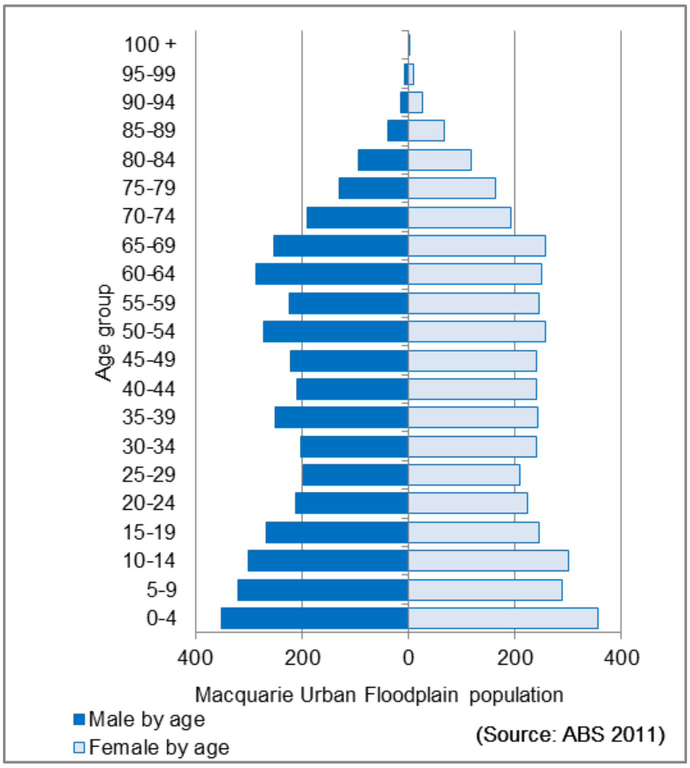

Figure 10.7: Macquarie urban floodplain population by age group and sex, 2011

Household income

Macquarie floodplain economy

The weekly household income in the Macquarie floodplain economy closely correlates with that of the Macquarie urban floodplain, and 65% of the population lives in the townships. The proportion of low-income households (with weekly incomes of $599 or below) in the Macquarie floodplain economy, at 34%, is well above the NSW state proportion of 23%. The proportion of medium-income households (with weekly incomes of $600 to $2,499 per week) in the Macquarie floodplain economy, at 57%, is close to the NSW proportion of 56%. Consequently, the high-income household proportion of 9% is well below the NSW state proportion of 21%.

The weekly household income proportions for NSW – and for the Macquarie floodplain economy, rural floodplain and urban floodplain – are presented in Figure 10.8.

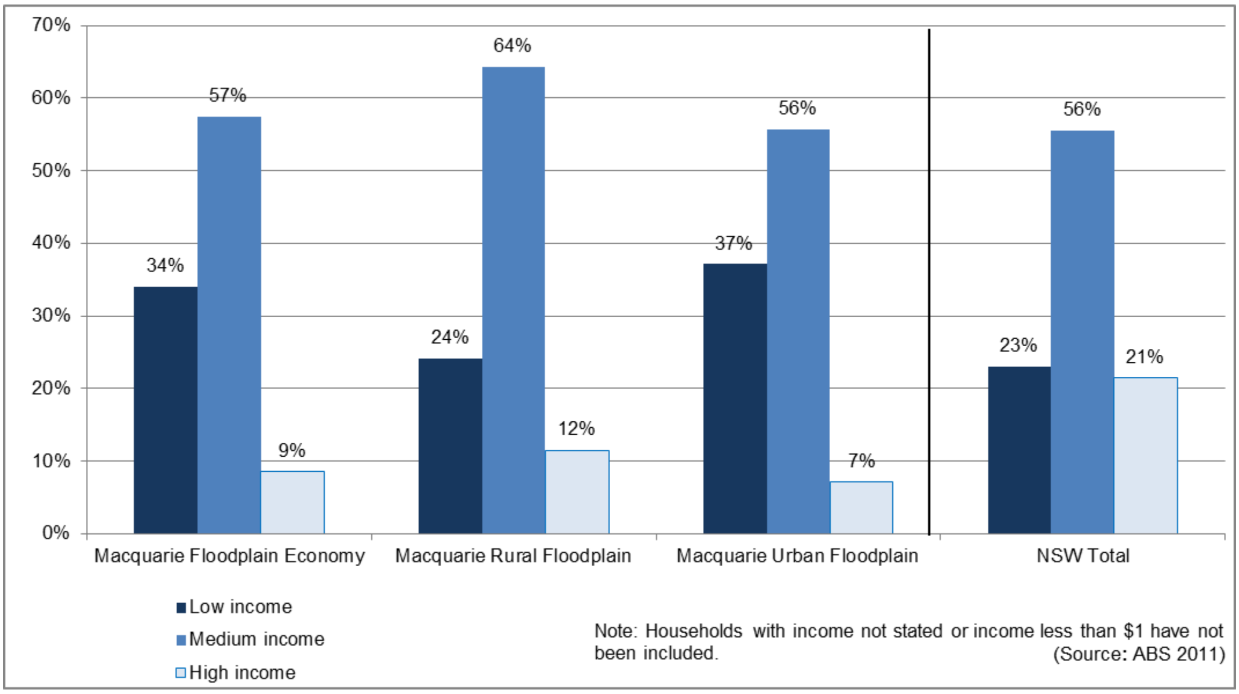

Figure 10.8: Distribution of households in low-, medium- and high-income categories (%)

Macquarie rural floodplain

The Macquarie rural floodplain households in 2011 are equally as prosperous as their NSW counterparts, with a similar proportion of households in the low-income category, at 24%, as the NSW proportion of 23%. The proportion of households in the medium-income range, at 64%, is greater than the NSW proportion of 56%. The high-income proportion of 12% is less than the state proportion of 21%.

Macquarie urban floodplain

The Macquarie urban floodplain community has a greater proportion of low-income households than NSW, at 37%. The proportion of medium-income households, at 56%, is the same as the NSW proportion. The proportion of high-income households, at 7%, is a third of the NSW proportion of 21%.

Employment

Macquarie floodplain economy

The labour force of the Macquarie floodplain economy is 5,390 persons. The number of persons 15 years and above is 9,770. The labour force participation rate, which is the number of persons in the labour force as a percentage of persons aged 15 years and over, at 55%, is very close to the NSW participation rate of 56%.

Employment in the Macquarie floodplain economy is predominantly within the agriculture, forestry and fishing sector, which engages 27.5% of the workforce (1,480 persons, with this number including employment in a large agricultural area that is not on the rural floodplain). In contrast, the NSW agriculture sector engages 2.2% of the workforce.

The next most significant employment sectors are health care and social assistance, education and training, and retail trade, which engage 10.8%, 8.9% and 8.3% of the workforce respectively.

There is a relatively even distribution of the remaining 44.5% of the workforce among the remaining sectors. Macquarie floodplain economy employment by sector, organised in order of the top 10 sectors in the Macquarie rural floodplain, is presented in Figure 10.9. Total employment by industry sector for NSW is presented in Figure 10.10.

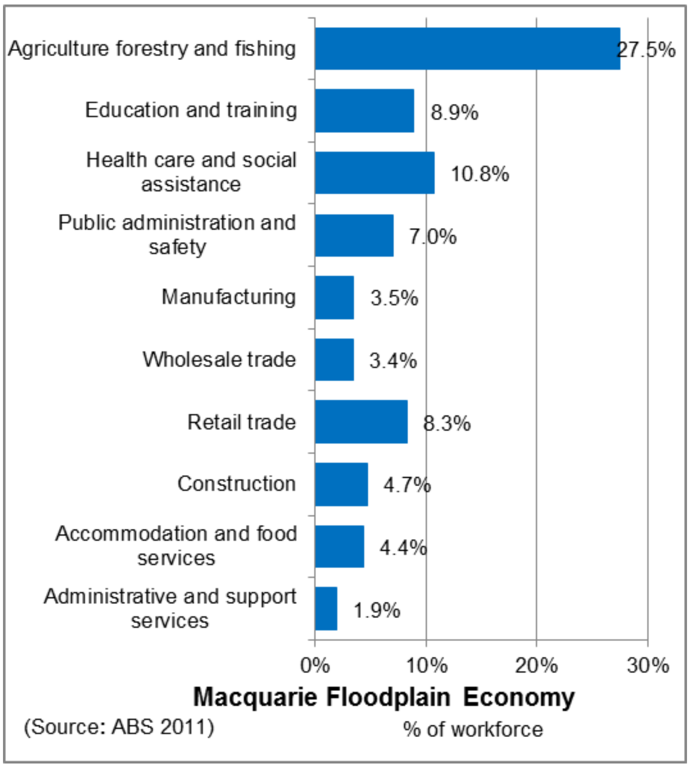

Figure 10.9: Macquarie floodplain economy employment by industry sector.

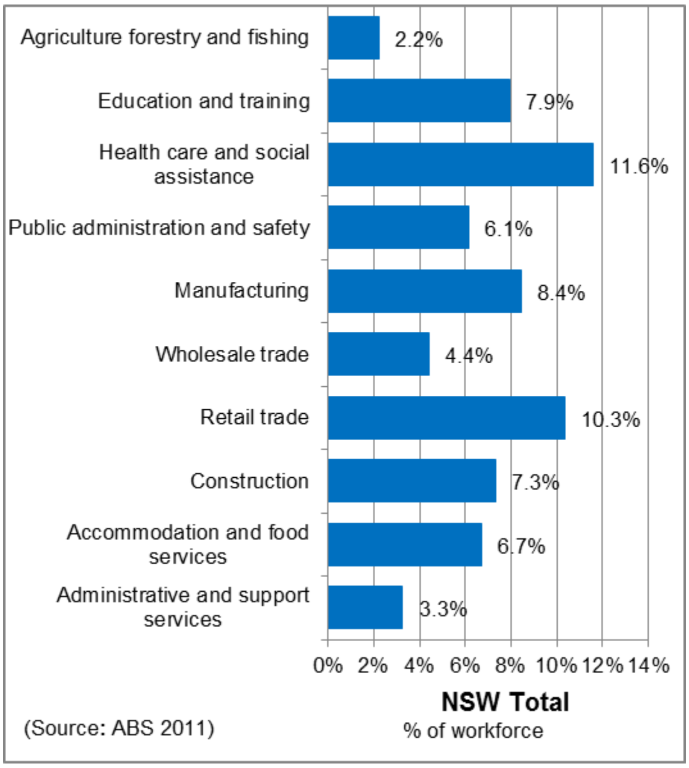

Figure 10.10: NSW economy employment by industry sector

Macquarie rural floodplain

The labour force of the Macquarie rural floodplain is 790 persons. The population 15 years and above is 1,100 persons. The labour force participation rate is 72%, markedly higher than the NSW participation rate of 56%.

Employment in the Macquarie rural floodplain is dominated by the agriculture, forestry and fishing sector, with 55.8% of the workforce, or 440 persons, working in the agriculture industry. This is in sharp contrast to the NSW agriculture sector, which engages only 2.2% of the workforce.

The next most significant employment sectors of the Macquarie rural floodplain are education and training, with 6.6% of the workforce, and health care and social assistance, with 5.5%. Employment by sector for the top 10 sectors in the rural floodplain is presented in Figure 10.11.

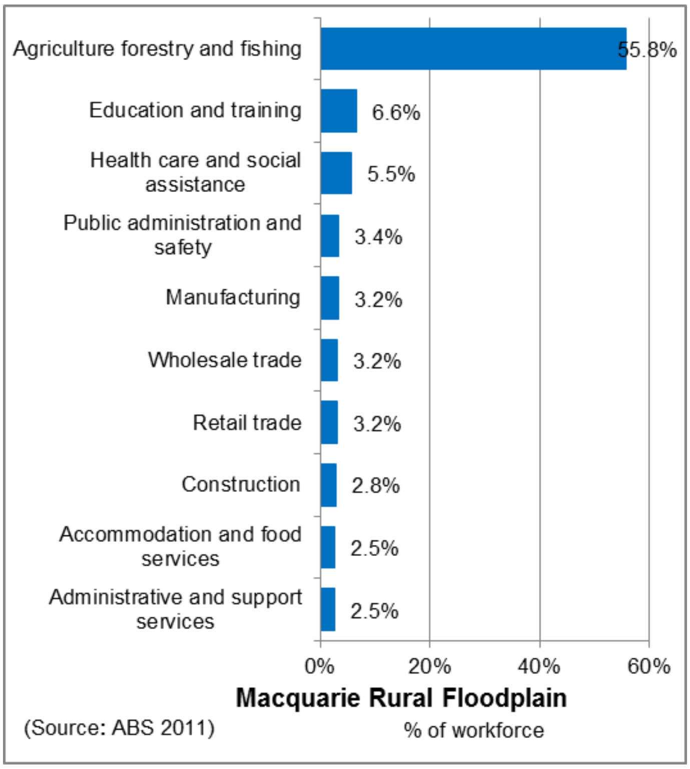

Figure 10.11: Macquarie rural floodplain employment by industry sector

Macquarie urban floodplain

The labour force of the Macquarie urban floodplain is 3,210 persons. The population 15 years and above is 6,310 persons. The labour force participation rate is 51%, below the participation rate in NSW and in the Macquarie rural floodplain, and substantially lower than the participation rate in the Macquarie floodplain economy.

In contrast with the surrounding rural community, employment in the Macquarie urban floodplain is reasonably evenly distributed across sectors. A significant proportion of the workforce is employed in the service sectors. The agriculture, forestry and fishing sector is the most significant employer, with 12.3% of the workforce (390 persons), closely followed by health care and social assistance, with 11.9%, and then by retail trade, with 11.2%. Macquarie urban floodplain employment by sector, organised in order of the top 10 sectors in the Macquarie rural floodplain, is presented in Figure 10.12.

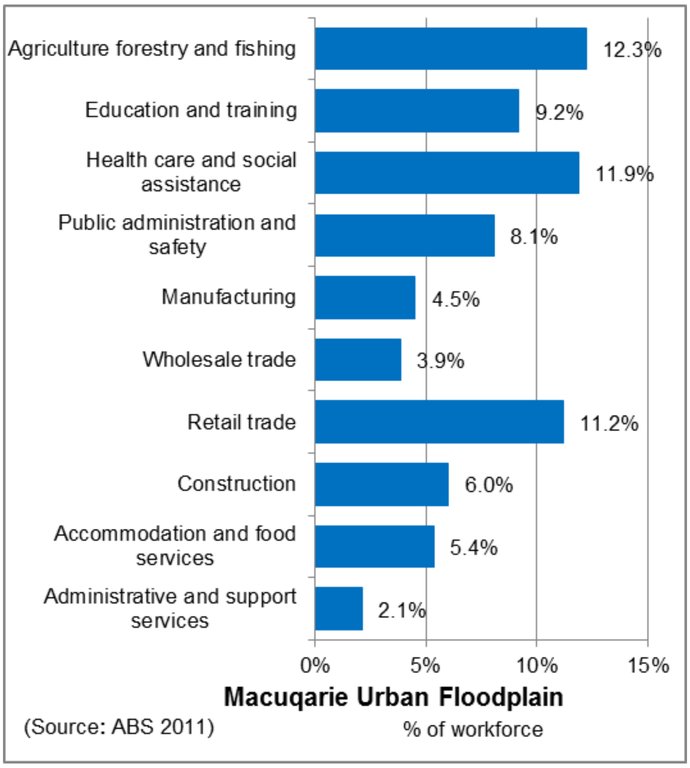

Figure 10.12: Macquarie Urban floodplain employment by industry sector

Estimated employment of the Macquarie Valley FMP area

The urban residents employed in the agriculture sector combined with the rural residents employed in the agriculture sector make up the employment directly impacted by the Macquarie Valley FMP. Given the location of the townships, it is assumed that all of the Warren residents (100) and half of the 290 remaining Macquarie urban floodplain residents employed in the agriculture sector work in the Macquarie Valley FMP area. Including the 440 persons employed in the agriculture sector in the Macquarie rural floodplain, the estimated total employment in the agricultural sector potentially impacted by the Macquarie Valley FMP is 685 persons.

Wellbeing indicators

Socio-Economic Indexes for Areas (SEIFA) is a product developed by the ABS that ranks areas in Australia according to relative socio-economic advantage and disadvantage (ABS 2011b). The indexes are based on information from the 5-yearly Census. The index scores are on an arbitrary numerical scale; the scores do not represent some quantity of advantage or disadvantage. As measures of socio-economic level, the indexes are best interpreted as ordinal measures. They can be used to rank (order) areas and illustrate the distribution of socio-economic conditions across different areas.

The Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) summarises 25 variables that indicate either relative advantage or disadvantage. This index ranks areas on a continuum from most disadvantaged to most advantaged. An area with a high score on this index has a relatively high incidence of advantage and a relatively low incidence of disadvantage.

The IRSAD scores for the LGAs of Bogan (A), Brewarrina (A), Coonamble (A), Narromine (A), Walgett (A) and Warren (A) are in the 1st to 4th decile of NSW, demonstrating distinct relative disadvantage.

At the SA1 level, the area with the lowest IRSAD score of 782 (ranked 542, decile 1 in the state) is located in the township of Narromine. The highest scoring area has a score of 1,091 (decile 8 in the state), which is the agricultural area in the north-east of Warren.

The range and distribution of the IRSAD scores for the floodplain area are presented in Figure 10.13. The dark green areas have a score that is among the lowest 10% of scores for the state, being the relatively more disadvantaged. The red areas are areas of advantage, while the yellow areas are relatively neither advantaged nor disadvantaged. The IRSAD scores for the smaller SA1 areas representing the townships of Narromine, Warren, Nyngan and Trangie (see insert in Figure 10.13) are all shaded green, indicating that they are relatively disadvantaged (being within deciles 1 to 3), except one SA1 in the south-east of Narromine. The Rural floodplain areas are generally shaded light green to orange (being within deciles 5 to 8), indicating that they are neither advantaged or disadvantaged, or are relatively advantaged, except the SA1 surrounding Brewarrina (decile 1), which is substantially disadvantaged.

Agricultural production

Agricultural production is the significant production activity of the region's economy, occupying 97% of the farm-holding area in the Macquarie Valley FMP area. Agricultural production is predominantly cropping, which is dominated by wheat. Irrigated production on the Macquarie rural floodplain is dominated by cotton production. The regional economy is structured to provide the inputs and services and handle the outputs of these industries. The performance of the regional economy responds in a large part to the fortunes of the wheat and cotton industries.

The ABS Agricultural Census 2011 provides agricultural production statistics for the 5 SA2 areas that cover the Macquarie Valley FMP (ABS 2011c) (Figure 10.14).

In the Macquarie Valley FMP region, broadacre cropping and livestock production are the predominant products. The value and area used for these products in the Macquarie Valley FMP area were estimated based on the following assumptions:

- Agricultural production and areas of housing are evenly distributed throughout SA2 areas of the region.
- The estimated percentages of area of each ABS SA2 within the Macquarie Valley FMP area are Nyngan–Warren: 32%, Coonamble: 19%, Walgett – Lightning Ridge: 6%, Narromine: 23% and Bourke–Brewarrina: 0.5%.
- The value and area of agricultural production of individual crops and products of each SA2 area within the Macquarie Valley FMP area, as a percentage of total production within these SA2 areas, are proportionate to the estimated percentage of area of each SA2 area within the Macquarie Valley FMP area.
- The estimated area and value of agricultural production of individual crops and products for the Macquarie Valley FMP area and the sum of the proportional estimates for the SA2 areas listed above.

As agricultural production is not evenly distributed across the area of these regions, the values derived and presented below provide estimates (only) of the value of production and the area of holding in the FMP area (Figure 10.14). Horticultural production and pig, goat and poultry production are not included in the estimated totals because they are not conventionally undertaken in the floodplain area.

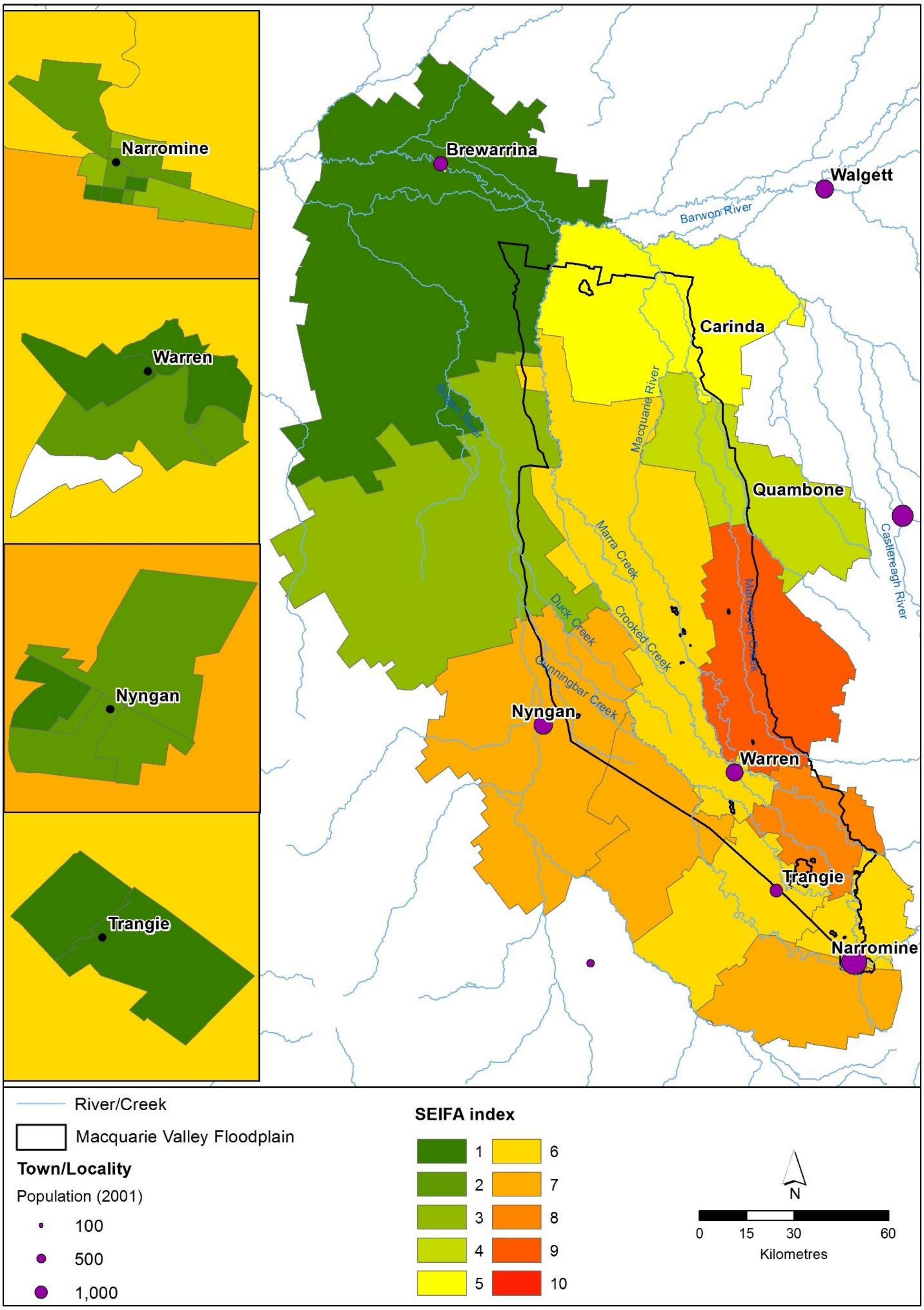

Figure 10.13: Index of Relative Socio-economic Advantage and Disadvantage, state decile

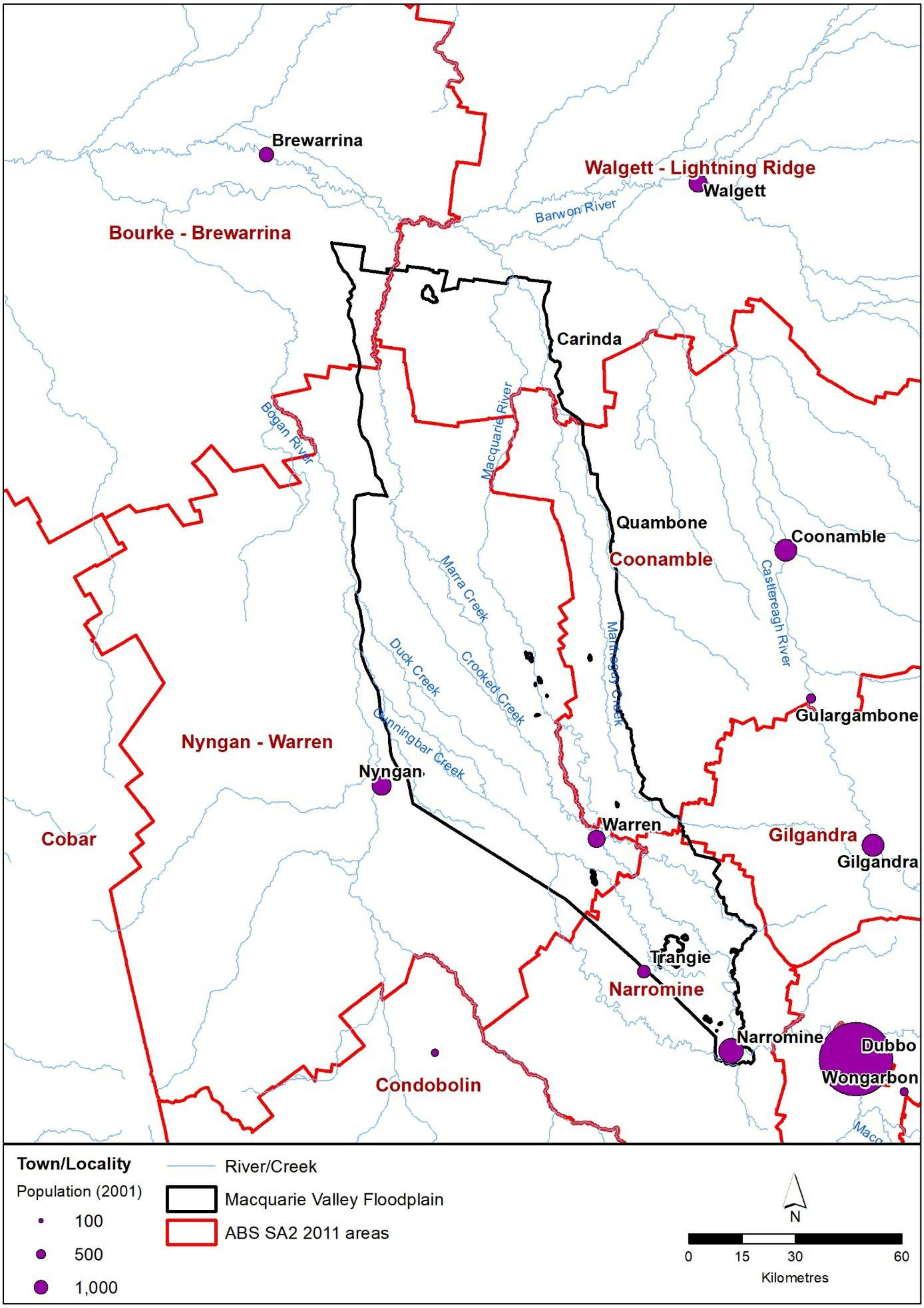

Figure 10.14: Macquarie Valley FMP and agricultural data area

The Gross Value of Agricultural Production (GVAP) in 2010–2011 in the Macquarie Valley FMP area, using a farm-holding area of 972,800 hectares, is estimated to be $180 million or 1.9% of total NSW GVAP. The gross value of broadacre cropping, estimated at $140 million, constitutes 78% of the GVAP of the FMP area, using 275,400 hectares or 28% of the area ('NA' means that this crop is unlikely to occupy floodplain land. Source: ABS Agricultural Census 2011 data. The ABS Agricultural Census 2011 identifies the area watered and the quantity of water used by irrigated agricultural production for the Bourke-Brewarrina, Coonamble, Narromine, Nyngan-Warren and Walgett-Lightning Ridge regions in 2010-2011 (ABS 2011a). 0.5% of the irrigated agriculture in the Bourke-Brewarrina region, 19.2% of the Coonamble region, 23.2% of the Narromine region, 31.9% of the Nyngan-Warren region and 6.4% of the Walgett-Lightning Ridge region were included in the Macquarie Valley Floodplain.

Table 10.3). The highest value producing individual broadacre crops are wheat yielding $79 million or 44 per cent, and cotton yielding $26 million or 14 per cent, of the total FMP area GVAP. Livestock and livestock products yield $40 million, accounting for 22% of GVAP while using 69% of the area. Data for GVAP and area of holding is presented in Table 10.2 and 'NA' means that this crop is unlikely to occupy floodplain land. Source: ABS Agricultural Census 2011 data. The ABS Agricultural Census 2011 identifies the area watered and the quantity of water used by irrigated agricultural production for the Bourke-Brewarrina, Coonamble, Narromine, Nyngan-Warren and Walgett-Lightning Ridge regions in 2010-2011 (ABS 2011a). 0.5% of the irrigated agriculture in the Bourke-Brewarrina region, 19.2% of the Coonamble region, 23.2% of the Narromine region, 31.9% of the Nyngan-Warren region and 6.4% of the Walgett-Lightning Ridge region were included in the Macquarie Valley Floodplain.

Table 10.3.

Irrigated agricultural production

The ABS Agricultural Census 2011 identifies the area watered and the quantity of water used by irrigated agricultural production for the 5 SA2 areas of the region in 2010–2011 (ABS 2011c).

The total area watered and the total quantity of water used in the Macquarie Valley FMP area were estimated based on the following assumptions:

- The areas of irrigated agriculture of each SA2 situated in the Macquarie Valley FMP area are Nyngan–Warren: 80%, Coonamble: 100%, Walgett – Lightning Ridge: 6%, Narromine: 50% and Bourke–Brewarrina: 0%.
- The total area watered and the total quantity of water used in the Macquarie Valley FMP area are the sum of the proportional estimates for the SA2 areas listed above.

Horticultural production is not included in the estimated totals because it is not conventionally undertaken in the floodplain area.

There was an estimated total of 15,800 hectares of irrigated land in the Macquarie Valley FMP area in 2010–2011. This area of irrigated land constitutes approximately 2% of the Macquarie Valley FMP farm-holding area.

It is estimated that 76,000 megalitres of water was extracted for agricultural irrigation across the regions in 2010–2011. The majority of the irrigation water used in 2010–2011 was applied to cotton, using 60,700 megalitres or 80%, at an estimated average rate of 5.9 megalitres per hectare. Irrigation for cotton used an estimated 10,200 hectares or 65% of the estimated Macquarie rural floodplain irrigated area. Data for irrigation activity is presented in 'NA' means that this crop is unlikely to occupy floodplain land. Source: ABS Agricultural Census 2011 data. The ABS Agricultural Census 2011 identifies the area watered and the quantity of water used by agricultural production for the Bourke-Brewarrina, Coonamble, Narromine, Nyngan-Warren and Walgett-Lightning Ridge regions in 2010-2011 (ABS 2011a). 0.5% of the irrigated agriculture in the Bourke-Brewarrina region, 19.2% of the Coonamble region, 23.2% of the Narromine region, 31.9% of the Nyngan-Warren region and 6.4% of the Walgett-Lightning Ridge region were included in the Macquarie Valley Floodplain

Table 10.4 and Table 10.5.

Table 10.2: Gross value of agricultural production (GVAP) 2011 ($M)

Gross Value of Agricultural Production ($M)	Bourke–Brewarrina ($M)	Coonamble ($M)	Narromine ($M)	Nyngan–Warren ($M)	Walgett – Lightning Ridge ($M)	Estimated Macquarie Valley Floodplain ($M)	NSW Total ($M)
Broadacre crops – Cereal crops – cereals for grain and wheat for grain	6	76	96	95	192	79	2,511
Broadacre crops – Cereal crops – cereals for grain, excluding wheat	0	15	13	15	24	12	998
Broadacre crops – Legumes for grain – legumes for grain	0	13	10	11	40	11	237
Broadacre crops – Oilseeds	–	10	17	13	4	10	438
Broadacre crops – Hay – Pasture and cereal and other crops cut for hay	–	2	3	2	2	2	284
Broadacre crops – Other crops – cotton	51	–	37	33	103	26	1,126
Broadacre crops – Other crops – excluding cotton	–	0	0	1	0	0	97
Total broadacre crops (ha)	**58**	**115**	**176**	**169**	**364**	**140**	**5,690**
Horticulture – Fruit	NA	NA	NA	NA	NA	NA	NA
Horticulture – Nurseries, cut flowers and cultivated turf	NA	NA	NA	NA	NA	NA	NA
Total horticulture	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Livestock products – Whole milk	–	1	4	–	–	1	505
Livestock products – Slaughtered and other disposals – cattle and calves	17	23	10	20	22	15	1,616
Livestock products – Wool	19	10	14	26	21	15	853
Livestock products – Slaughtered and other disposals – sheep and lambs	17	9	7	17	14	10	610
Livestock products – Slaughtered and other disposals – pigs	NA	NA	NA	NA	NA	NA	NA
Livestock products – Slaughtered and other disposals – goats	NA	NA	NA	NA	NA	NA	NA
Livestock products – Eggs produced for human consumption	NA	NA	NA	NA	NA	NA	NA
Livestock products – Slaughtered and other disposals – poultry	NA	NA	NA	NA	NA	NA	NA
Total livestock and livestock products (ha)	**53**	**43**	**35**	**63**	**57**	**40**	**3,583**
Agriculture – total value ($M)	**111**	**159**	**210**	**232**	**421**	**180**	**9,274**

'NA' means that this crop is unlikely to occupy floodplain land. Source: ABS Agricultural Census 2011 data. The ABS Agricultural Census 2011 identifies the area watered and the quantity of water used by irrigated agricultural production for the Bourke-Brewarrina, Coonamble, Narromine, Nyngan-Warren and Walgett-Lightning Ridge regions in 2010-2011 (ABS 2011a). 0.5% of the irrigated agriculture in the Bourke-Brewarrina region, 19.2% of the Coonamble region, 23.2% of the Narromine region, 31.9% of the Nyngan-Warren region and 6.4% of the Walgett-Lightning Ridge region were included in the Macquarie Valley Floodplain.

Table 10.3: Land mainly used for agricultural production, 2010–2011

Area (ha)	Bourke–Brewarrina (ha)	Coonamble (ha)	Narromine (ha)	Nyngan–Warren (ha)	Walgett – Lightning Ridge (ha)	Estimated Macquarie Valley Floodplain (ha)	NSW (ha)
Broadacre crops – Cereals – wheat for grain	19,114	143,061	148,605	181,118	354,100	142,335	3,814,726
Broadacre crops – Cereals – other than wheat for grain	1,203	44,271	28,020	41,019	64,472	32,197	1,637,949
Broadacre crops – Non-cereal – cotton	9,748	–	9,906	7,192	31,569	6,643	329,665
Broadacre crops – Non-cereal – other than cotton	673	64,546	47,232	48,293	133,505	47,253	1,262,087
Land mainly used for agriculture – crops (ha)	45,852	306,612	275,912	350,303	637,406	275,399	9,209,190
Horticulture – Orchard fruit and nut trees	NA	NA	NA	NA	NA	NA	NA
Horticulture – Grapevines for wine production	NA	NA	NA	NA	NA	NA	NA
Horticulture – Nurseries, cut flowers and cultivated turf	NA	NA	NA	NA	NA	NA	NA
Hay and silage – hay (ha)	15	2,781	3,886	3,221	4,620	2,757	312,513
Pasture seed production – clean pasture seed produced (ha)	–	–	50	233	–	86	18,280
Land mainly used for agriculture – total grazing (ha)	4,969,425	532,943	263,424	1,212,028	1,475,390	667,142	46,419,229
Land mainly used for agriculture – other agricultural purposes (ha)	–	40	188	66	53	76	29,377
Land mainly used for agriculture – forestry plantation (ha)	313	57	–	1	–	13	112,489
Area of holding – total area of holding (ha)	**5,110,778**	**868,702**	**559,366**	**1,614,343**	**2,160,269**	**972,846**	**58,326,346**

'NA' means that this crop is unlikely to occupy floodplain land. Source: ABS Agricultural Census 2011 data. The ABS Agricultural Census 2011 identifies the area watered and the quantity of water used by agricultural production for the Bourke-Brewarrina, Coonamble, Narromine, Nyngan-Warren and Walgett-Lightning Ridge regions in 2010-2011 (ABS 2011a). 0.5% of the irrigated agriculture in the Bourke-Brewarrina region, 19.2% of the Coonamble region, 23.2% of the Narromine region, 31.9% of the Nyngan-Warren region and 6.4% of the Walgett-Lightning Ridge region were included in the Macquarie Valley Floodplain

Table 10.4: Area of irrigated agricultural production, 2010–2011

Area watered (ha)	Bourke–Brewarrina (ha)	Coonamble (ha)	Narromine (ha)	Nyngan–Warren (ha)	Walgett – Lightning Ridge (ha)	Estimated Macquarie Valley Floodplain (ha)	NSW (ha)
Cereal crops – for grain or seed (e.g. wheat/oats/maize) (ha)	2,241	819	1,287	1,700	1,159	2,892	109,676
Other crops – broadacre other (e.g. canola/field beans/lupins/sunflowers/poppies) (ha)	–	19	1,153	2	1,035	659	96,129
Other crops – cotton (ha)	9,748	–	8,168	6,252	19,051	10,228	196,233
Cereal crops – cut for hay (inc. wheat/oats/forage sorghum) (ha)	1	0	1	6	–	5	6,809
Fruit or nut trees, and plantation or berry fruits (exc. grapes) (ha)	NA	NA	NA	NA	NA	NA	NA
Grapevines (ha)	NA	NA	NA	NA	NA	NA	NA
Nurseries, cut flowers and cultivated turf (ha)	NA	NA	NA	NA	NA	NA	NA
Pasture – cut for hay (ha)	–	–	255	–	–	127	25,420
Pasture – for grazing (ha)	25	438	675	433	26	1,123	130,380
Pasture – for seed (ha)	–	–	–	–	–	–	3,092
Total area watered and used – area watered (ha)	**12,221**	**1,285**	**12,083**	**8,991**	**21,310**	**15,798**	**674,064**

'NA' means that this crop is unlikely to occupy floodplain land. Source: ABS Agricultural Census 2011 data. The ABS Agricultural Census 2011 identifies the area watered and the quantity of water used by irrigated agricultural production for the Bourke-Brewarrina, Coonamble, Narromine, Nyngan-Warren and Walgett-Lightning Ridge regions in 2010-2011 (ABS 2011a). 0% of the irrigated agriculture in the Bourke-Brewarrina region, 100% of the Coonamble region, 50% of the Narromine region, 80% of the Nyngan-Warren region and 6% of the Walgett-Lightning Ridge region were included in the Macquarie Valley Floodplain

Table 10.5: Water used for irrigated agricultural production, 2010–2011 (ABS 2011c)

Water for agricultural production (ML)	Bourke–Brewarrina (ML)	Coonamble (ML)	Narromine (ML)	Nyngan–Warren (ML)	Walgett – Lightning Ridge (ML)	Estimated Macquarie Valley Floodplain (ML)	NSW (ML)
Cereal crops – cut for hay (inc. wheat/oats/forage sorghum) (ML)	1	0	2	14	–	12	13,989
Cereal crops – for grain or seed (e.g. wheat/oats/maize) (ML)	2,801	341	6,290	4,928	3,987	7,668	203,841
Other crops – broadacre other (ML)	–	49	2,889	6	5,594	1,834	809,027
Other crops – cotton, volume applied (ML)	54,655	–	43,574	40,576	106,920	60,662	1,073,849
Fruit or nut trees, and plantation or berry fruits (exc. grapes) (ML)	NA	NA	NA	NA	NA	NA	NA
Grapevines (ML)	NA	NA	NA	NA	NA	NA	NA
Nurseries, cut flowers and cultivated turf (ML)	NA	NA	NA	NA	NA	–	NA
Pasture – cut for hay (ML)	–	–	1,106	–	–	553	78,406
Pasture – for grazing (ML)	35	1,034	1,572	593	42	2,297	232,629
Pasture – for seed (ML)	–	0	–	–	–	0	6,281
Total area watered and used (ML)	**59,754**	**1,444**	**57,413**	**48,511**	**116,652**	**75,958**	**2,745,896**

'NA' means that this crop is unlikely to occupy floodplain land. Source: ABS Agricultural Census 2011 data. The ABS Agricultural Census 2011 identifies the area watered and the quantity of water used by irrigated agricultural production for the Bourke-Brewarrina, Coonamble, Narromine, Nyngan-Warren and Walgett-Lightning Ridge regions in 2010-2011 (ABS 2011a). 0% of the irrigated agriculture in the Bourke-Brewarrina region, 100% of the Coonamble region, 50% of the Narromine region, 80% of the Nyngan-Warren region and 6% of the Walgett-Lightning Ridge region were included in the Macquarie Valley Floodplain

Appendix 11: Quadrants of management zones

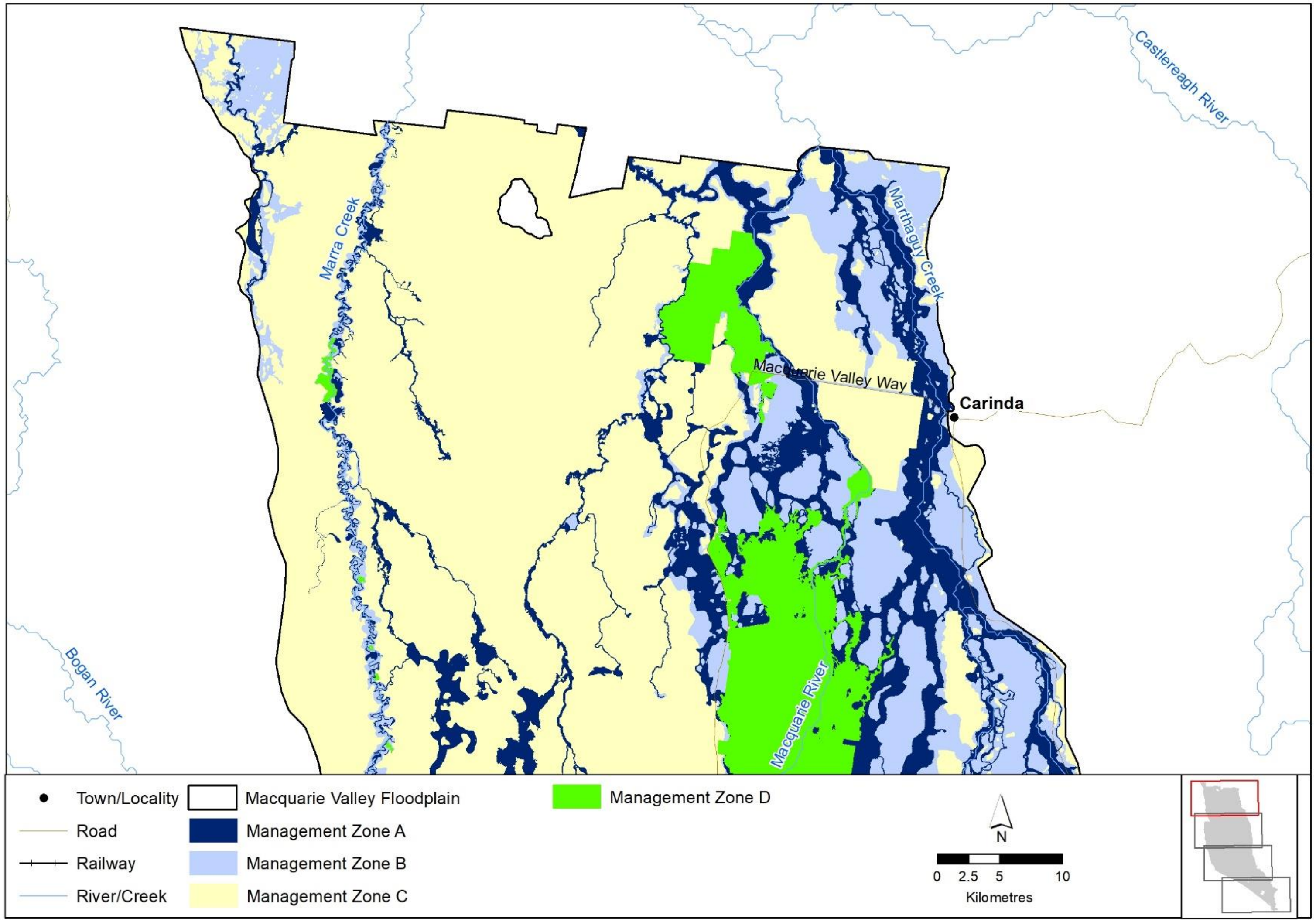

Figure 10.1: Management zones in the Macquarie Valley Floodplain – quadrant one of 4

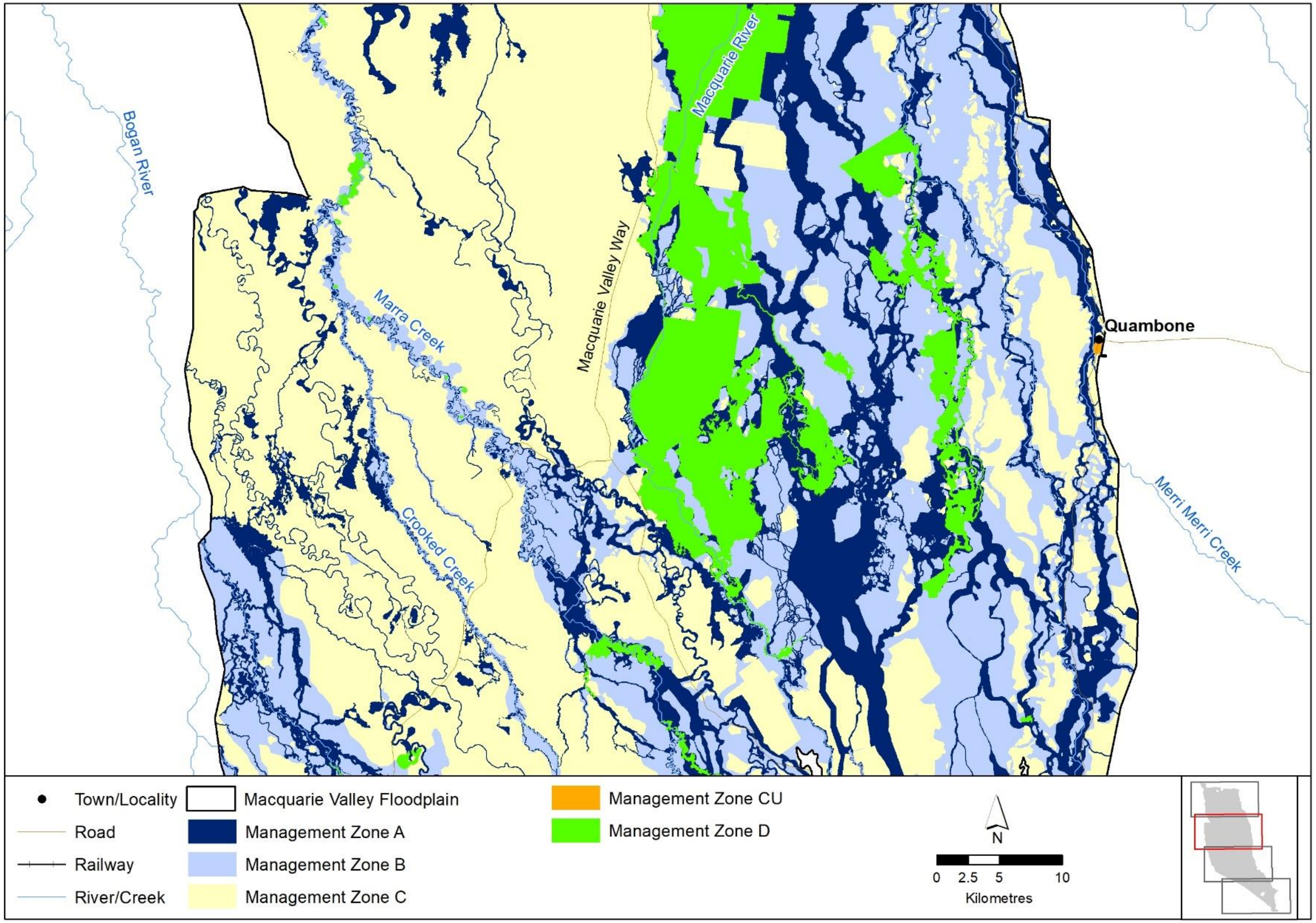

Figure 10.2: Management zones in the Macquarie Valley Floodplain – quadrant 2 of 4

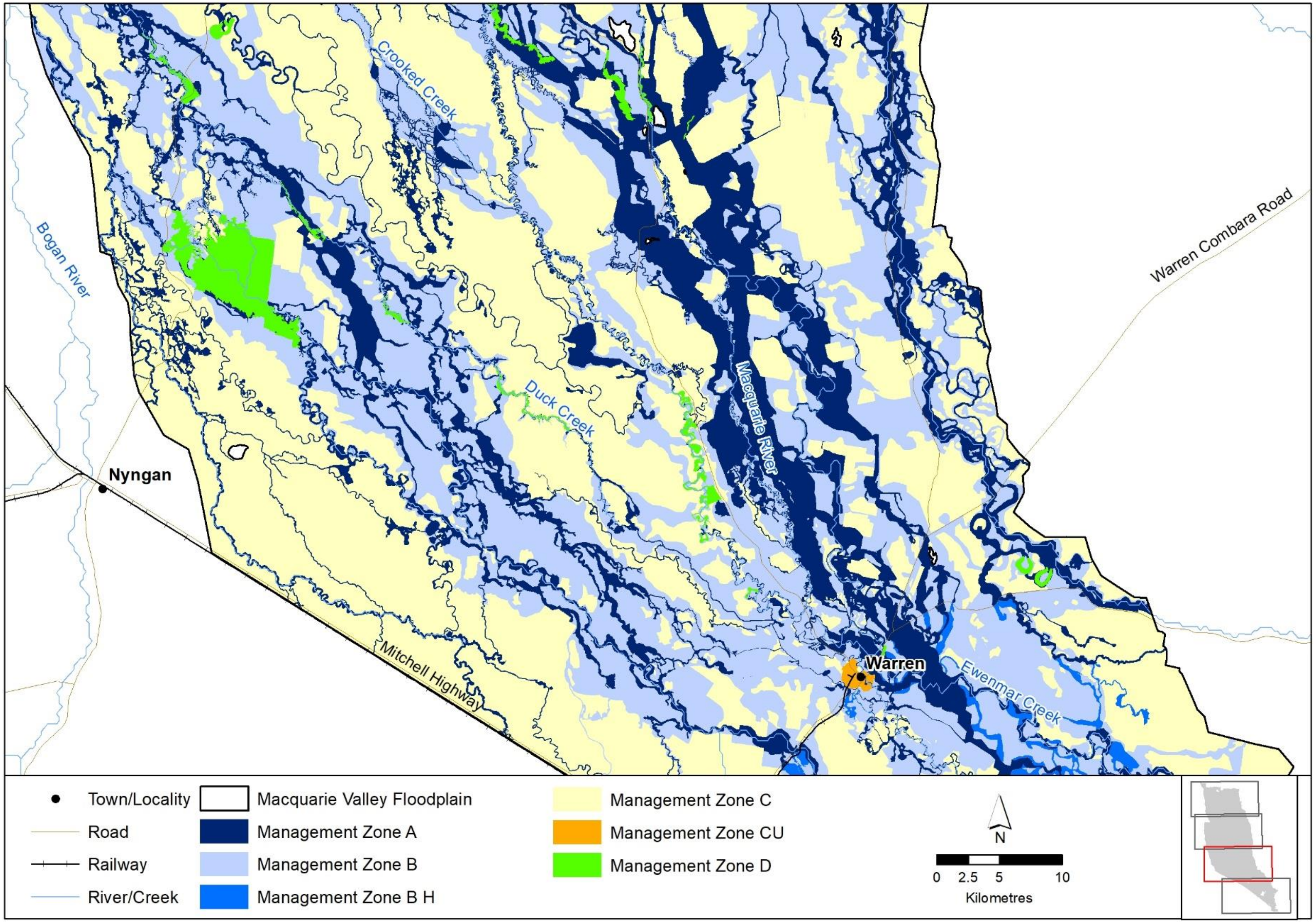

Figure 10.3: Management zones in the Macquarie Valley Floodplain – quadrant 3 of 4

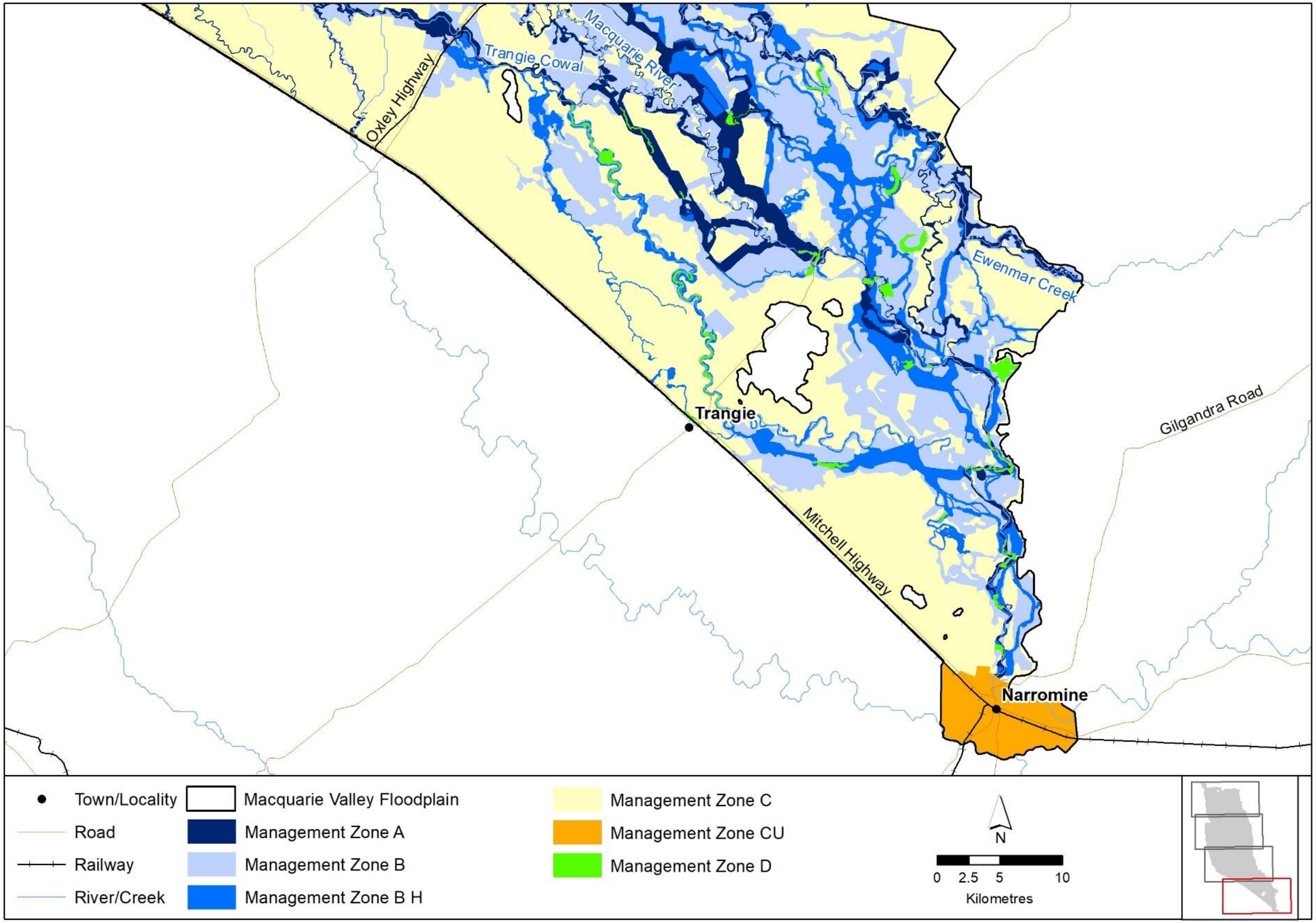

Figure 10.4: Management zones in the Macquarie Valley Floodplain – quadrant 4 of 4

Appendix 12: Management Zone D assets

Thirty floodplain assets of high ecological value were recommended to become MZ D (Table 12.1: List of Macquarie Valley Floodplain assets classified as Management Zone D and Figure 12.1: MZ D areas in Macquarie Valley Floodplain). The ecological significance of each asset is described below.

Table 12.1: List of Macquarie Valley Floodplain assets classified as Management Zone D

No.	Name	Description	*Ecological/ **Cultural significance	References
1	Ban Ban Lagoon	Open-water lagoon with the functional capacity to act as an aquatic drought refuge within Ban Ban Creek floodway. Fringed with flood-dependent vegetation including River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36) and Black Box woodland wetland on NSW central and northern floodplains, including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion. (PCT 37).	Functional capacity to act as an aquatic drought refuge	Named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013), Steenbeeke 1995
2	Buddah Lake	Large open-water lagoon fringed with shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains (PCT 53) and *Eucalyptus camaldulensis* Forests and Woodlands (Metcalfe et al 2003) used as off-river water storage for surrounding Buddah Lakes private irrigation scheme. Functional capacity to act as an aquatic drought refuge for a variety of waterbird species including Brolga, *Grus rubicunda*, (Conservation status in NSW – Vulnerable), Intermediate Egret, *Ardea intermedia*, Sharp-tailed Sandpiper, *Calidris acuminate,* Latham's Snipe, *Gallinago hardwickii,* Glossy Ibis, *Plegadis falcinellus* observed at the site (Bionet 2014, Michael Brooker data). Part of Boggy Cowal Swamps and Lagoons class (Bcl) DRP Upper Darling Bogan–Macquarie of Mitchell landscapes (Mitchell 2002).	Functional capacity to act as an aquatic drought refuge	Bionet (2014), DWE & DECC (2008), Named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013), Mitchell (2002)

No.	Name	Description	*Ecological/ **Cultural significance	References
3	Cowal Swamp	Large swamp adjacent to Monument Creek and Buckinguy Road with the functional capacity to act as an aquatic drought refuge. Fringed with flood-dependent vegetation, including Black Box woodland wetland on NSW central and northern floodplains, including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37).	Functional capacity to act as an aquatic drought refuge	Named swamp on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
4	Coxs Lagoon	Open-water lagoon with the functional capacity to act as an aquatic drought refuge. Surrounded by partly derived Windmill Grass - copperburr alluvial plains shrubby grassland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 49) and Poplar Box grassy woodland on alluvial clay-loam soils mainly in the temperate (hot summer) climate zone of central NSW (wheatbelt). (PCT 244).	Functional capacity to act as an aquatic drought refuge	Named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
5	Eastern Macquarie Marshes wetlands and streams	The Eastern Macquarie Marshes sub-system (DECCW 2010) contains a variety of wetland vegetation communities and habitat for flow-dependent fauna and flora including colonial waterbirds. Wetlands are primarily private areas, including Wilgara Wetlands portion of the Macquarie Marshes Ramsar site, the Ninia portion of the Macquarie Marshes Nature Reserve and various lagoons, woodlands and water couch meadows along the Gum Cowal and Terrigal Creek. The Eastern Macquarie Marshes support river red gum forest and woodland, river cooba, water couch marsh and lignum shrubland, and contains relatively deep and protected open water lagoons that function as aquatic drought refuge.	Recognition in or protection by a local, state or federal environmental policy and/or legislation	DECCW 2010 Driver and Knight (2007), OEH 2012

No.	Name	Description	*Ecological/ **Cultural significance	References
6	Euloon Cowal	Large cowal adjacent to Crooked Creek providing functional capacity to act as an aquatic drought refuge. Fringed with flood-dependent River Red Gum swampy woodland wetland on cowals (lakes) and associated flood channels in central NSW (PCT 249).	Functional capacity to act as an aquatic drought refuge	Named Cowal on Land and Property Information – SIX Maps/Topographic Map (LPI 2013) and NSW Wetlands Layer (Kingsford et al 2004).
7	Goan Waterhole	Small waterhole with functional capacity to act as an aquatic drought refuge. Fringed with Floodplain River Red Gum woodland (Steenbeeke 1995) adjacent to Trangie Cowal at Trangie township. Waterhole provides habitat for a variety of waterbird species including Grey Teal, *Anas gracilis*, Pacific Black Duck, *Anas superciliosa*, Eastern Great Egret, *Ardea modesta*, Australian Wood Duck, *Chenonetta jubata*, Yellow-billed Spoonbill, *Platalea flavipes*, Royal Spoonbill, *Platalea regia*, Straw-necked Ibis, *Threskiornis spinicollis* (Bionet 2014). Waterhole provides habitat for water-dependent molluscs – aquatic snails, reliant on aquatic vegetation within the waterhole, including the Pouch snail *Glyptophysa gibbosa* which has been observed at the site (W.F.Ponder & D.L.Beechey. Australian Museum Data 2014).	Functional capacity to act as an aquatic drought refuge	Bionet (2014), Named waterhole on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
8	Greenhide Swamp	Swamp (Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains – PCT 53) on Greenhide Creek just east of the Macquarie River fringed with River Red Gum woodland.	A high degree of floodwater dependency, a high degree of habitat complexity and a history of supporting a diversity or abundance of waterbird, native fish or frog populations	DWE & DECC (2008) Named swamp on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)

No.	Name	Description	*Ecological/ **Cultural significance	References
9	Horseshoe Waterhole	Small waterhole on Marra Creek fringed with River Red Gum open-forest on stream-banks and low flats (Kerr et al 2003) with functional capacity to act as an aquatic drought refuge for a variety species including Red-bellied Black Snake, *Pseudechis porphyriacus,* Long-thumbed Frog, *Limnodynastes fletcheri*, Spotted Grass Frog, *Limnodynastes tasmaniensis*, Green Tree Frog, *Litoria caerulea*, Peron's Tree Frog, *Litoria peronii*, Desert Tree Frog, *Litoria rubella*, observed (Bionet 2014, Darren J Shelly). Provides habitat for a variety of waterbird species, including Grey Teal, *Anas gracilis*, Pacific Black Duck, *Anas superciliosa*, Australian Wood Duck, *Chenonetta jubata*, Little Black Cormorant, *Phalacrocorax sulcirostris*, Eastern Great Egret, *Ardea modesta*, White-necked Heron, *Ardea pacifica*, White-faced Heron, *Egretta novaehollandiae*, and Yellow-billed Spoonbill, *Platalea flavipes* (Bionet 2014, Darren J Shelly data).	Functional capacity to act as an aquatic drought refuge	Bionet (2014), Named waterhole on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
10	Magawah Lagoon	Open water lagoon adjacent to Burlong Creek, providing the functional capacity to act as an aquatic drought refuge (Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains – PCT 53) fringed with flood-dependent River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 53).	Functional capacity to act as an aquatic drought refuge	Named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
11	Marra Creek Billabong 1	Billabong located on the northern side of Marra Creek providing the functional capacity to act as an aquatic drought refuge. Billabong fringed with flood-dependent Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37) and River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36).	Functional capacity to act as an aquatic drought refuge	n/a

No.	Name	Description	*Ecological/ **Cultural significance	References
12	Marra Creek Billabong 2	Billabong located on the eastern side of Marra Creek providing the functional capacity to act as an aquatic drought refuge. Billabong fringed with flood-dependent Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37) and River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36).	Functional capacity to act as an aquatic drought refuge	n/a
13	Marra Creek Billabong 3	Billabong located on the western side of Marra Creek providing the functional capacity to act as an aquatic drought refuge. Billabong fringed with flood-dependent Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37) and River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36).	Functional capacity to act as an aquatic drought refuge	n/a
14	Marra Creek Billabong 4	Billabong located on the northern side of Marra Creek providing the functional capacity to act as an aquatic drought refuge. Billabong fringed with flood-dependent Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37) and River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36).	Functional capacity to act as an aquatic drought refuge	n/a

No.	Name	Description	*Ecological/ **Cultural significance	References
15	Marra Creek Billabong 5	Billabong located on the eastern side of Marra Creek providing the functional capacity to act as an aquatic drought refuge. Billabong fringed with flood-dependent Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37) and River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36).	Functional capacity to act as an aquatic drought refuge	n/a
16	Marra Creek Billabong 6	Billabong located at Mundadoo Bridge (Books Road) on the eastern side of Marra Creek providing the functional capacity to act as an aquatic drought refuge. Billabong fringed with Coolabah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39), River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36) and Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37).	Functional capacity to act as an aquatic drought refuge	n/a
17	Marra Creek Billabong 7	Billabong located on the eastern side of Marra Creek providing the functional capacity to act as an aquatic drought refuge. Billabong fringed with Coolabah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39), River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36) and Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37).	Functional capacity to act as an aquatic drought refuge	n/a

No.	Name	Description	*Ecological/ **Cultural significance	References
18	Marra Creek Billabong 8	Billabong located on the eastern side of Marra Creek providing the functional capacity to act as an aquatic drought refuge. Billabong fringed with Coolabah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39) and Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37).	Functional capacity to act as an aquatic drought refuge	n/a
19	Northern Macquarie Marshes wetlands and streams	The North Macquarie Marshes sub-system (DECCW 2010) contains a variety of wetland vegetation communities and habitat for flow-dependent fauna and flora including colonial waterbirds. The Northern Macquarie Marshes contain relatively deep and protected open water lagoons that function as aquatic drought refuge. Wetlands are primarily private areas, including the Pillicawarrina portion of the Macquarie Marshes Nature Reserve. The Northern Macquarie Marsh area supports river red gum forest and woodland, extensive marshy grasslands of common reed and water couch, lignum shrubland, river cooba and cumbungi.	Recognition in or protection by a local, state or federal environmental policy and/or legislation	DECCW 2010 Driver and Knight (2007), OEH 2012

No.	Name	Description	*Ecological/ **Cultural significance	References
20	Paddys Cowal	Large cowal (Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains – PCT 53) fringed with Rats Tail Couch sod grassland wetland of inland floodplains (PCT 242) and river red gum swampy woodland wetland on cowals (lakes) and associated flood channels in central NSW (PCT 249) adjacent to Paddys River and Crooked Creeks providing the functional capacity to act as an aquatic drought refuge and providing habitat for a variety of species including Brolga, *Grus rubicunda* (Conservation status in NSW – Vulnerable), Black Swan, *Cygnus atratus,* White-necked Heron, *Ardea pacifica,* Australian White Ibis, *Threskiornis molucca*, Straw-necked Ibis, *Threskiornis spinicollis*, and Swamp Harrier, *Circus approximans* observed at the site (Bionet 2014, Atlas of Australian Birds 1 data).	Functional capacity to act as an aquatic drought refuge	Bionet 2014, Named Cowal on Land and Property Information – SIX Maps/Topographic Map (LPI 2013) and NSW Wetlands Layer (Kingsford et al 2004).
21	Raby billabong (lagoon) anabranch	Open water billabong/lagoon (anabranch) at Raby property which is essentially a permanent waterbody filled and maintained via a regulator previously stocked with juvenile freshwater catfish and Murray cod. Fringed with flood-dependent river red gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36) providing habitat for freshwater turtles, waterbirds and aquatic species that require deeper water for feeding (Cardno Pty Ltd 2011). Functional capacity to act as an aquatic drought refuge.	Functional capacity to act as an aquatic drought refuge	Cardno Pty Ltd (2011)

No.	Name	Description	*Ecological/ **Cultural significance	References
22	Southern Macquarie Marshes wetlands and streams	The Southern Macquarie Marshes sub-system (DECCW 2010) contains a variety of wetland vegetation communities and habitat for flow-dependent fauna and flora including colonial waterbirds. Wetlands are primarily private areas, including the Mole Marsh, Monkey Swamp and Buckiinguy Swamp portion of the Macquarie Marshes Nature Reserve. The Southern Macquarie Marshes support river red gum woodland, river coobah, water couch marsh and common reed, and contains large, relatively deep and protected open-water lagoons that function as aquatic drought refuge.	Recognition in or protection by a local, state or federal environmental policy and/or legislation	DECCW 2010 Driver and Knight (2007), OEH 2012
23	The Big Lagoon	Large open water floodplain lagoon on Kaloola property adjacent to Marra Creek, fringed with flood-dependent Coolabah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCY 39) and Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion.(PCT 37) providing the functional capacity to act as an aquatic drought refuge. Provides habitat for a variety of waterbird species including Grey Teal, *Anas gracilis*, Pacific Black Duck, *Anas superciliosa*, Australian Wood Duck, *Chenonetta jubata*, Australian Pelican, *Pelecanus conspicillatus*, Eastern Great Egret, *Ardea modesta*, Yellow-billed Spoonbill, *Platalea flavipes*, Australian White Ibis, *Threskiornis molucca* (Bionet 2014, Aerial Waterbird Survey of Eastern Australia Data).	Functional capacity to act as an aquatic drought refuge	Bionet 2014, Named lagoon on OEH NSW TopoMosaic and NSW Wetlands Layer (Kingsford et al 2004).

No.	Name	Description	*Ecological/ **Cultural significance	References
24	The Overflow (Confluence of Gunningbar and Bena Billa Creeks)	Large swamp providing diversity of wetland types including Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains (PCT 53), Rats Tail Couch sod grassland wetland of inland floodplains (PCT 242), Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion (PCT 247), at the confluence of Bena Billa and Gunningbar Creek's. Part of Rare ephemeral Pleistocene circular or sinuous swamps and lagoons in depressions in the alluvial plains forming part of Bugwah Swamps and Lagoons (Bwl) DRP Upper Darling Bogan – Macquarie class of Mitchell landscapes mapping version 3 (Mitchell 2002). Functional capacity to act as an aquatic drought refuge, supporting a diversity of frog species, including Eastern Sign-bearing Froglet, *Crinia parinsignifera*, Long-thumbed Frog, *Limnodynastes fletcheri*, Spotted Grass Frog, *Limnodynastes tasmaniensis*, Green Tree Frog, *Litoria caerulea*, Broad-palmed Frog, *Litoria latopalmata*, Desert Tree Frog, *Litoria rubella,* Spotted Grass Frog, *Limnodynastes tasmaniensis* (Bionet 2014, Darling Riverine Plains - Autumn 2000 survey data). Provides habitat for a variety of waterbird species including Australian Wood Duck, *Chenonetta jubata*, Little Pied Cormorant, *Microcarbo melanoleucos*, White-necked Heron, *Ardea pacifica*, White-faced Heron, *Egretta novaehollandiae* and Sacred Kingfisher, *Todiramphus sanctus* (Bionet 2014, Darling Riverine Plains - Autumn 2000 and Birds Australia Atlas of Australian Birds 2 survey data).	Functional capacity to act as an aquatic drought refuge	Bionet 2014, Steenbeek 1995, Mitchell (2002)

No.	Name	Description	*Ecological/ **Cultural significance	References
25	Trailgang Cowal	Large cowal of Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains (PCT 53), forming part of Boggy Cowal Swamps and Lagoons (Bcl) DRP Upper Darling Bogan – Macquarie of Mitchell landscapes mapping version 3 (Mitchell 2002). Surrounding vegetation associated with the cowal has been extensively cleared. Remaining cowal may provide functional capacity to act as an aquatic drought refuge when filled from overbank flows.	A high degree of floodwater dependency, a high degree of habitat complexity and a history of supporting a diversity or abundance of waterbird, native fish or frog populations	DWE & DECC (2008) Named Cowal on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
26	Wonrobbie Lake and unnamed lagoon	Two large lagoons (Open water and Mixed Marsh, Steenbeeke 1995) and Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains (PCT 53 – OEH 2015) adjacent to Marthaguy Creek providing the functional capacity to act as an aquatic drought refuge. Provides habitat for a variety of waterbird species including Brolga, *Grus rubicunda* (Conservation status in NSW – Vulnerable), Grey Teal, *Anas gracilis*, Australian Wood Duck, *Chenonetta jubata*, Little Pied Cormorant, *Microcarbo melanoleucos*, Australian Pelican, *Pelecanus conspicillatus*, Intermediate Egret, *Ardea intermedia*, White-necked Heron, *Ardea pacifica*, Yellow-billed Spoonbill, *Platalea flavipes*, Royal Spoonbill, *Platalea regia*, and Australian White Ibis, *Threskiornis molucca* observed at the site (Bionet 2014, Birds Australia Data).	Functional capacity to act as an aquatic drought refuge	Bionet 2014
27	Unnamed Swamp (Buena Vista)	Large swamp (river red gum swampy woodland wetland on cowals/lakes and associated flood channels in central NSW – PCT 249 and river red gum riparian tall woodland/open forest wetland in the Nandewar Bioregion and Brigalow Belt South Bioregion – PCT 78), adjacent to Macquarie River at junction of Pineview and Burroway Roads. Functional capacity to act as an aquatic drought refuge.	Functional capacity to act as an aquatic drought refuge	-

No.	Name	Description	*Ecological/ **Cultural significance	References
28	Unnamed lagoon (Ferndale Stud Park)	Large open water lagoon (Ferndale Stud Park) adjacent to Ewenmar Creek fringed with River Red Gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36). Functional capacity to act as an aquatic drought refuge.	Functional capacity to act as an aquatic drought refuge	-
29	Wamboin Lagoon	Large open water lagoon with the functional capacity to act as an aquatic drought refuge, fringed with river red gum tall to very tall open forest/woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36, black box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37) and Coolabah - River Coobah - lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39).	Functional capacity to act as an aquatic drought refuge	n/a

Note: As a guide, the spatial extent of Management Zone D ecological assets was determined depending on the nature of the asset. For some assets such as lagoons, waterholes and billabongs, contours were derived from LiDAR to represent the high-water mark for these assets, and a 40-metre buffer was applied to the high watermark where the asset was on waterfront land. The spatial extent of other assets was determined using the extent of the 5-year ARI Macquarie Marshes Landsat inundation mapping (Thomas et al. 2016).

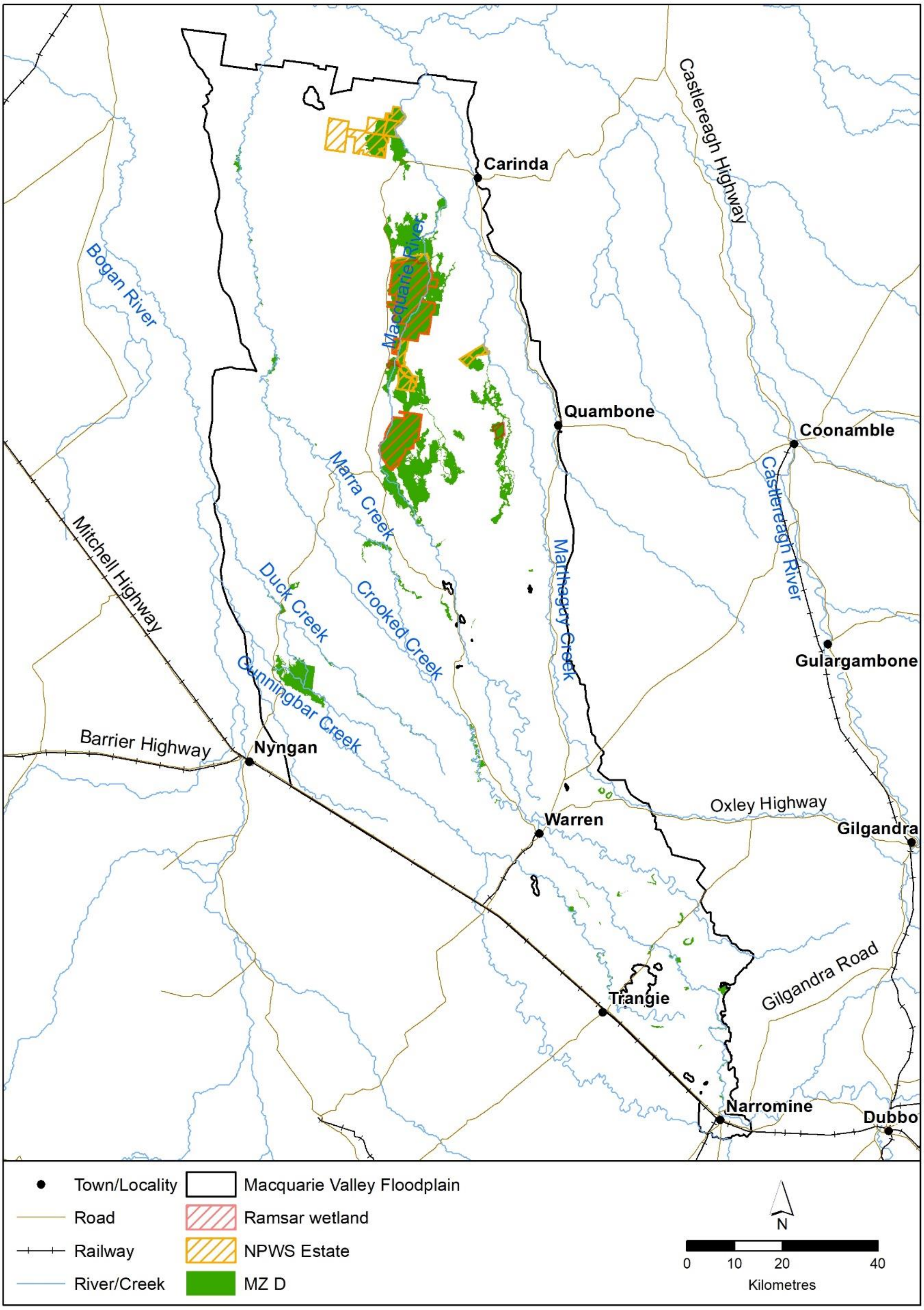

Figure 12.1: MZ D areas in Macquarie Valley Floodplain

Appendix 13: Existing flood works decisions tree

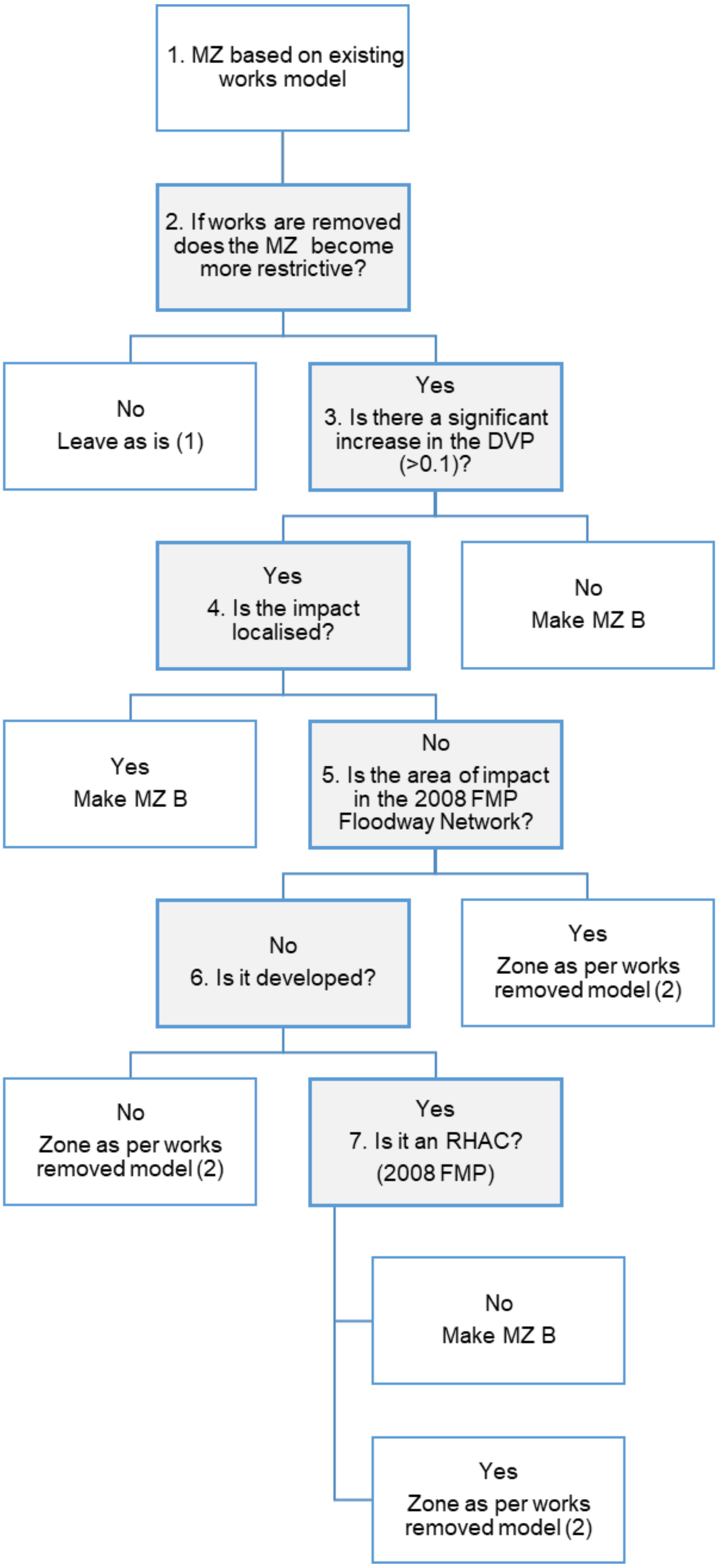

Figure 13.1: Decision tree for adjusting management zones (MZs) based on works removed modelling

Appendix 14: Peak discharge calculation points

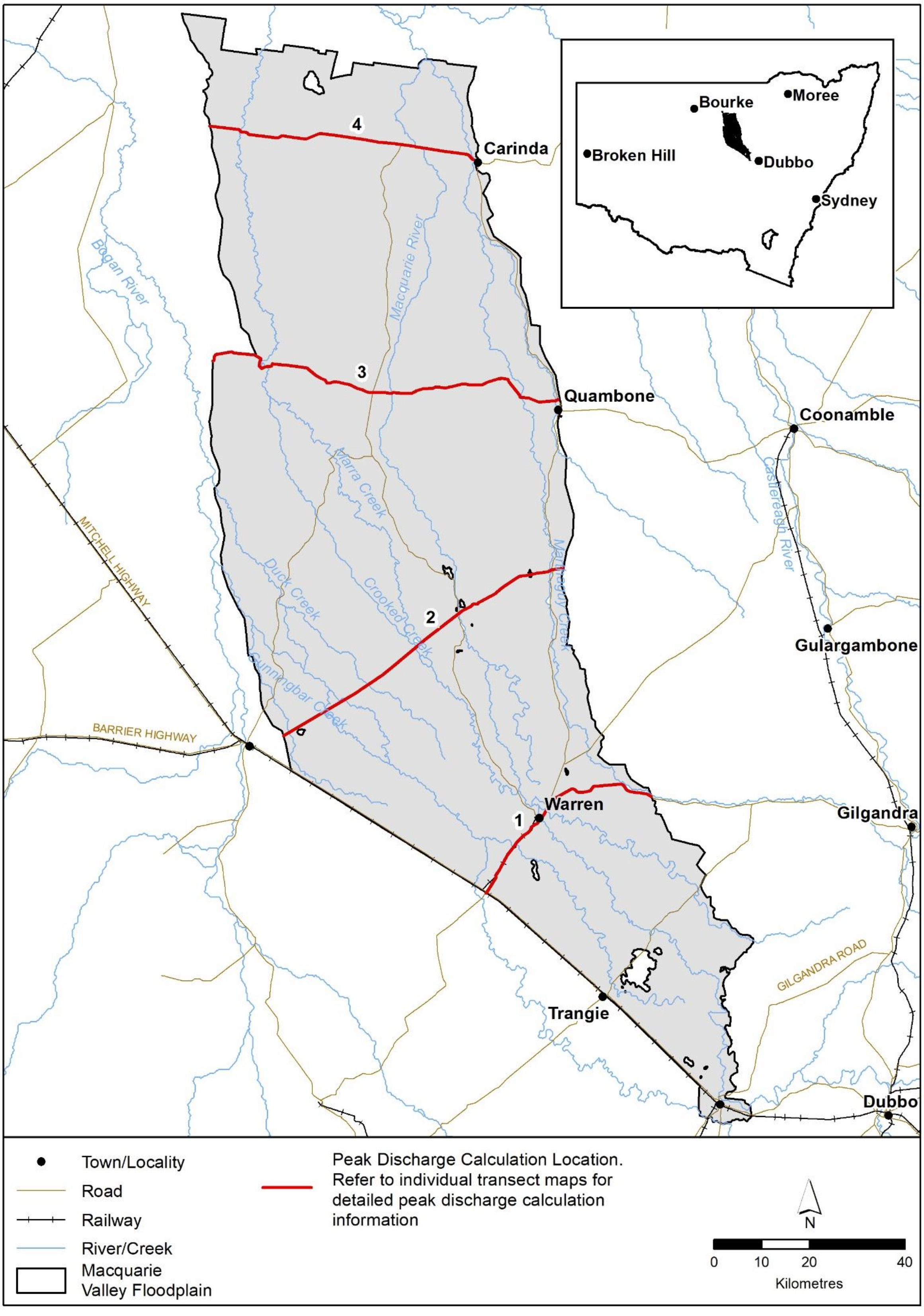

Figure 14.1: Peak discharge calculation locations across the Macquarie Valley Floodplain (refer to individual maps for detailed peak discharge calculation information)

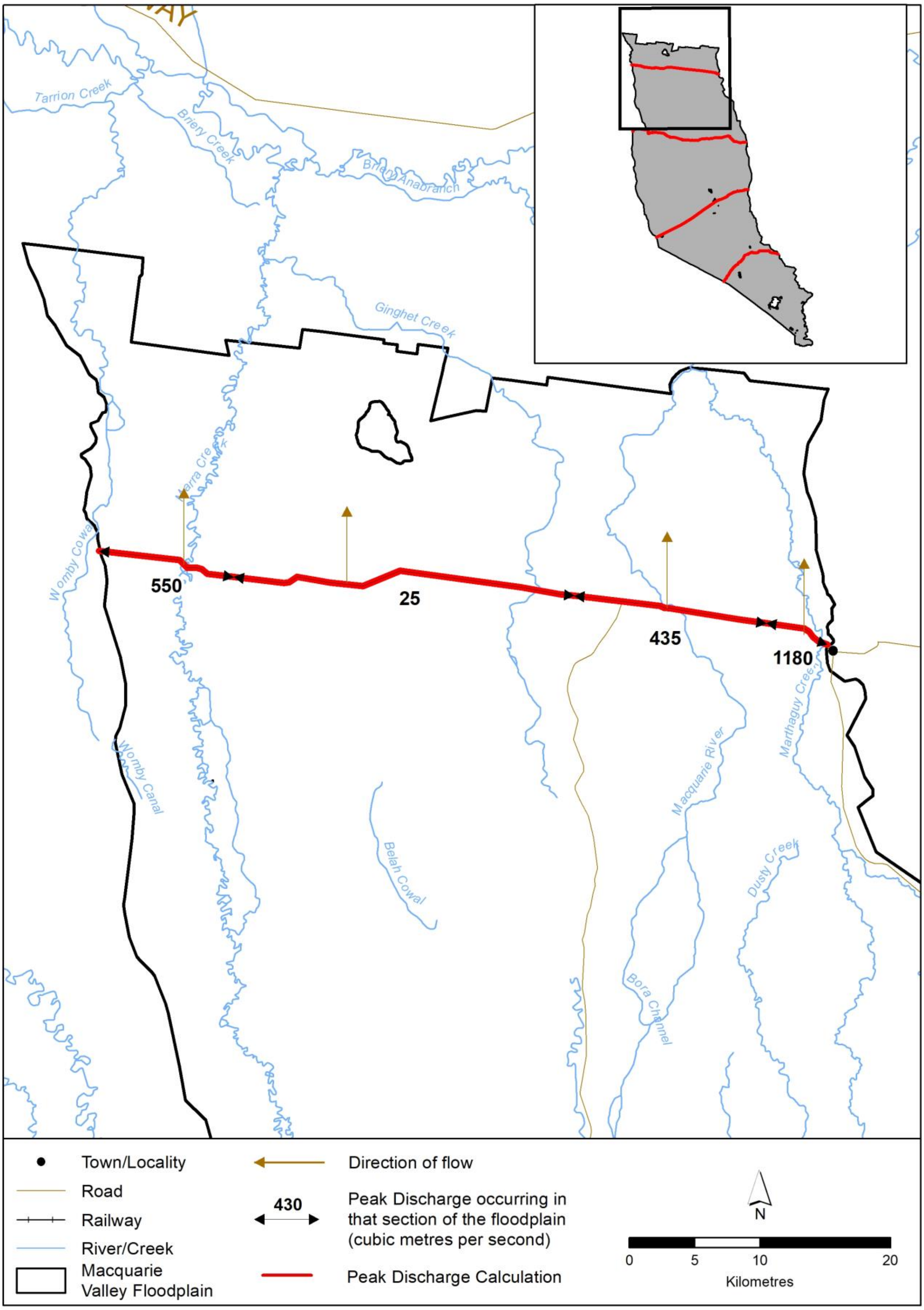

Figure 14.2: Peak discharge calculation location near Carinda

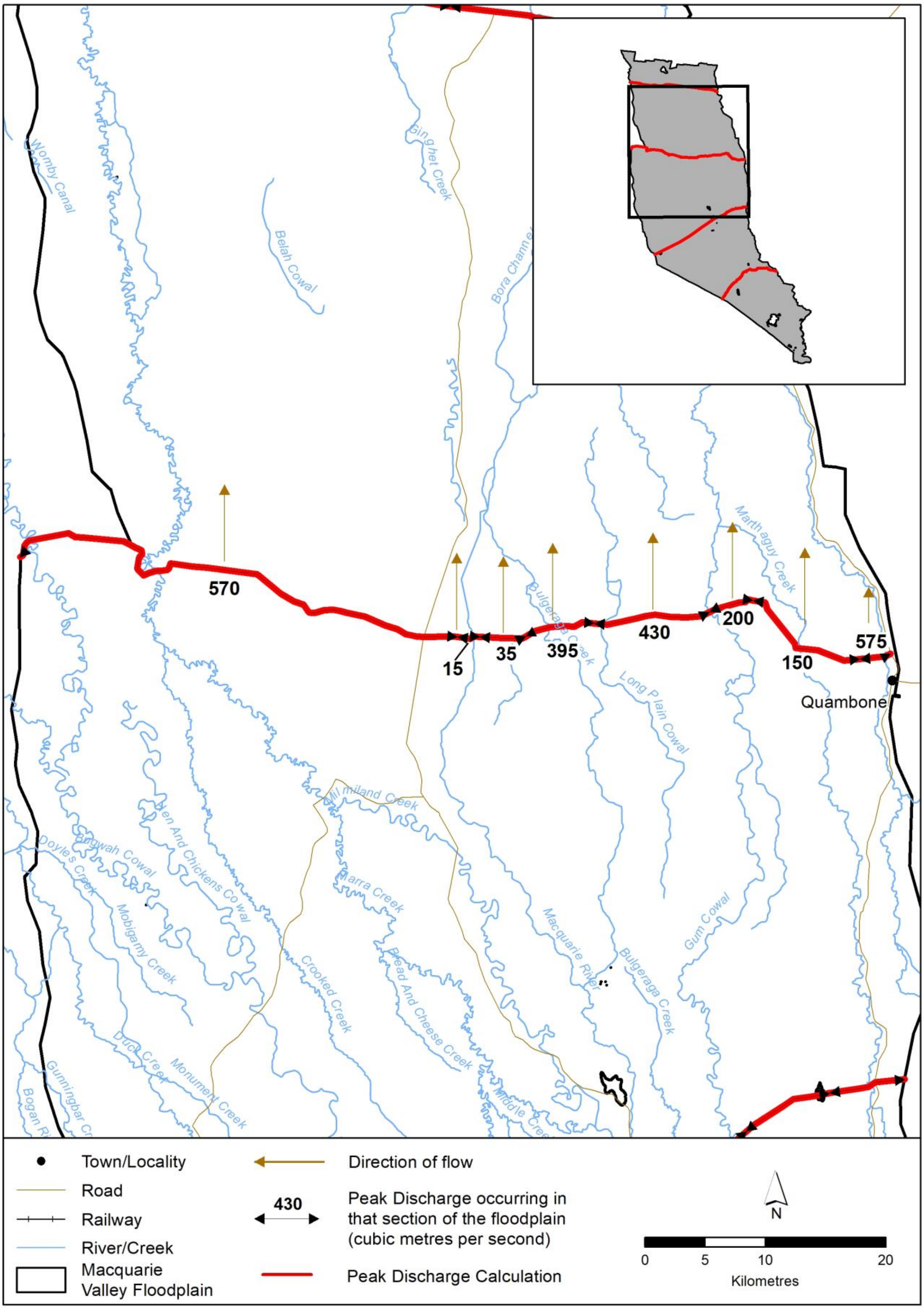

Figure 14.3: Peak discharge calculation location near Quambone

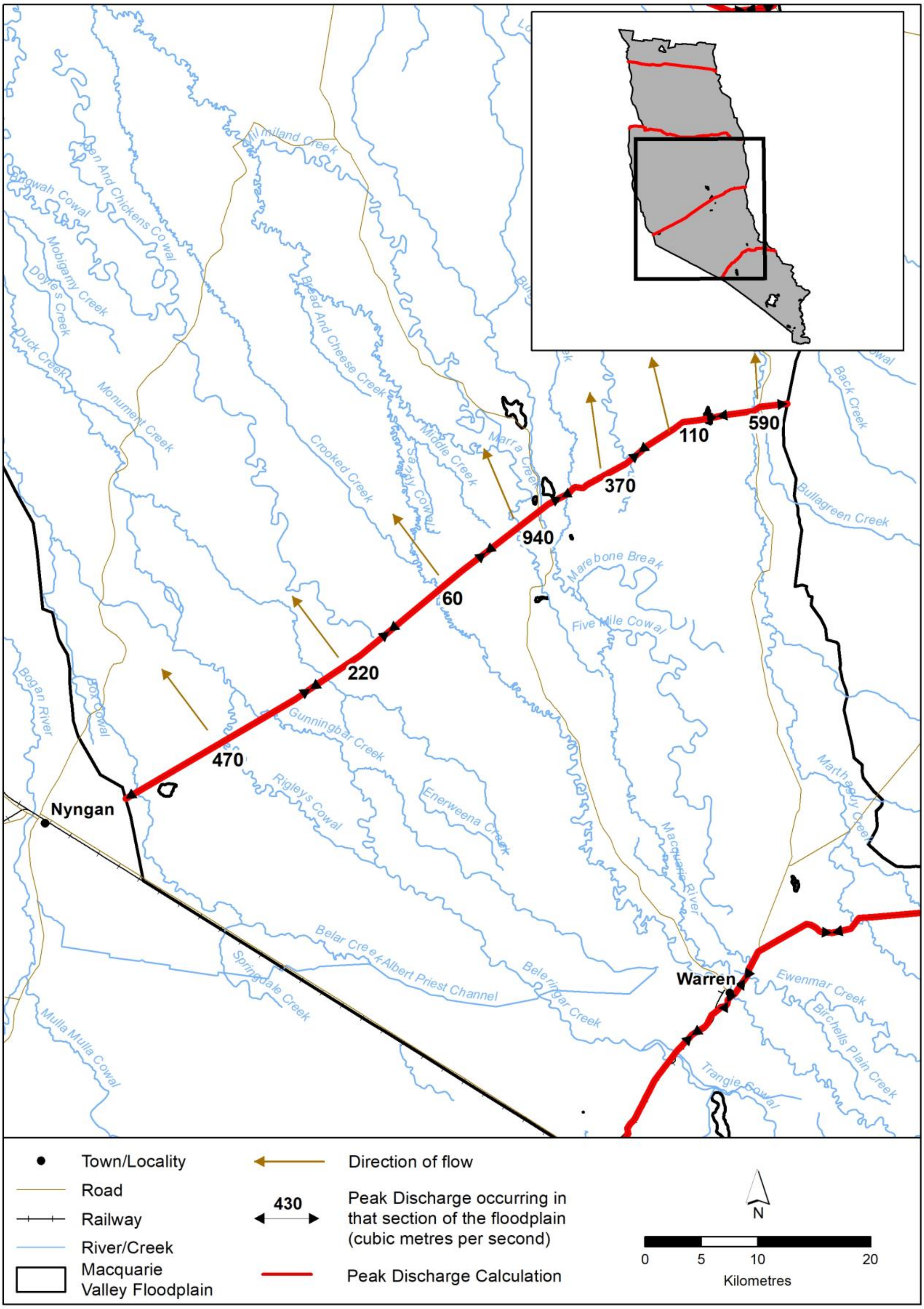

Figure 14.4: Peak discharge calculation location near Nyngan and Warren

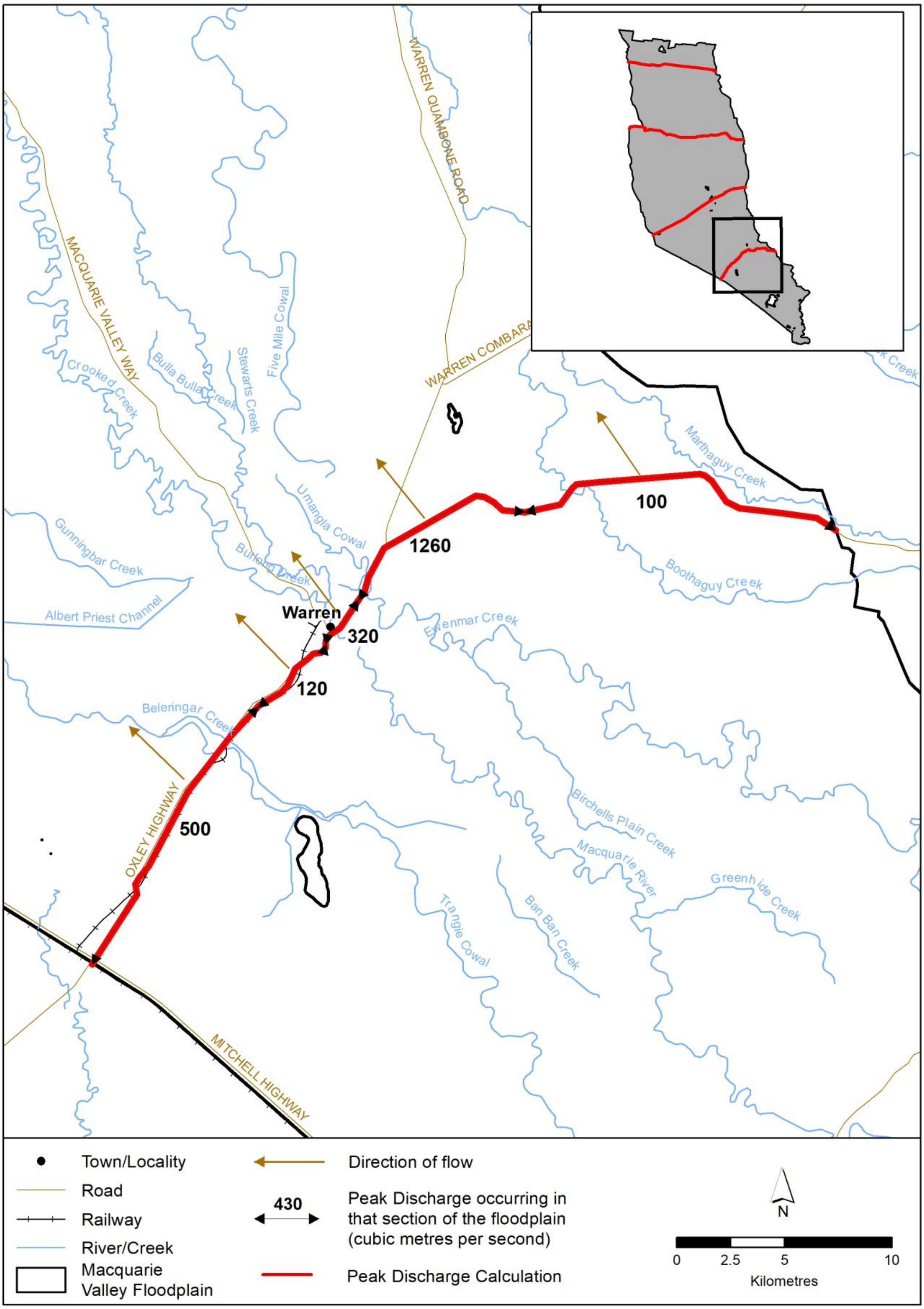

Figure 14.5: Peak discharge calculation location near Warren

Appendix 15: Approach for consulting with Aboriginal stakeholders

As the First Peoples of Australia, Aboriginal people have certain inherent rights, including the right to maintain culture, which requires the ability to maintain links with Country (including traditional lands and seas). Aboriginal stakeholders include individuals of First Nations descent who have a cultural connection to the Macquarie Valley Floodplain. Aboriginal stakeholders and interests may be represented by communities, formal or informal working groups or committees and Aboriginal Land Councils.

The NSW Department of Planning, Industry and Environment (the department), worked closely with the former Office of Environment and Heritage (OEH) when consulting with Aboriginal stakeholders because the former OEH undertook many environmental protection, natural resource management and conservation activities that have direct relevance to and effects on Aboriginal communities. As a result, OEH produced principles and frameworks to guide the implementation of meaningful community engagement that ensures the needs of Aboriginal communities are met in relation to the conservation and continuation of their cultural heritage and values. These documents include:

- *Aboriginal People, the Environment and Conservation* (APEC) principles (Department of Environment and Conservation NSW 2006)
- *An Aboriginal Community Engagement Framework for DECC* (unpublished, 2007)
- *Working to protect Aboriginal cultural heritage* (OEH 2011b).

The APEC principles guide the inclusion of the rights and interests of Aboriginal people into the department's work by supporting OEH and Aboriginal people to jointly and openly identify the level of involvement that Aboriginal communities would like in OEH's environmental management and conservation activities. The 5 principles are:

1. Spirituality and connection
2. Cultural resource use
3. Wellbeing
4. Caring for country
5. Doing business with Aboriginal people.

Aboriginal Community Engagement Framework for DECC and *Working to protect Aboriginal cultural heritage* both support the implementation of APEC principles.

The Aboriginal cultural heritage and contemporary cultural values and connections of the Macquarie Valley Floodplain are rich and vibrant. Many of the cultural values of the Aboriginal peoples of the Macquarie are linked to flooding and floodwater. The FMP aims to help protect cultural, heritage and spiritual features of the floodplain that are significant to Aboriginal people and other stakeholders.

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