Commonwealth Environmental Water Office Long Term Intervention Monitoring Project Lachlan River System

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UNIVERSITY OF CANBERRA

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Long Term Intervention Monitoring Project

Lachlan river system

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Acronyms and abbreviations

Accepted Acronym	Standard Term (capitalisation as specified)
ANAE	Australian National Aquatic Ecosystem
CED	Cause and effect diagram
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
CPUE	Catch per unit effort
GS	General Security
HS	High Security
IMEF	Integrated Monitoring of Environmental Flows
LAP	Land Access Protocol
LLS	Local Land Services
LRWG	Lachlan River Working Group
LTIM Project	Long Term Intervention Monitoring Project
MDBA	Murray-Darling Basin Authority
MERI Framework	Monitoring, Evaluation, Reporting and Improvement Framework
M&E Adviser	Monitoring and Evaluation Adviser
M&E Plan	Monitoring and Evaluation Plan
M&E Provider	Monitoring and Evaluation Provider
M&E Requirements	Monitoring and Evaluation Requirements
MDMS	Monitoring Data Management System
NOW	NSW Office of Water
SOP	Standard Operating Procedure
QA/QC	quality assurance / quality control
WRP	Water Resource Plans
WSP	Water Sharing Plan

1 Background

The Commonwealth Environmental Water Holder (CEWH) is responsible under the *Water Act 2007* (Cth) for managing Commonwealth environmental water holdings. The holdings must be managed to protect or restore the environmental assets of the Murray-Darling Basin, and other areas where the Commonwealth holds water, so as to give effect to relevant international agreements. The Basin Plan (Commonwealth of Australia 2012) further requires that the holdings must be managed in a way that is consistent with the Basin Plan's Environmental Watering Plan. The *Water Act 2007* (Cth) and the Basin Plan also impose obligations to report on the contribution of Commonwealth environmental water to environmental objectives of the Basin Plan.

Monitoring and evaluation are critical for supporting effective and efficient use of Commonwealth environmental water. Monitoring and evaluation also provides important information to ensure the CEWH meet their reporting obligations.

The Long-Term Intervention Monitoring Project (LTIM Project) is the primary means by which the Commonwealth Environmental Water Office (CEWO) will undertake monitoring and evaluation of the ecological outcomes of Commonwealth environmental watering. The LTIM Project will be implemented at seven Selected Areas over a five year period from 2014-19 to deliver five high-level outcomes (in order of priority):

1. Evaluate the contribution of Commonwealth environmental watering to the objectives of the Murray-Darling Basin Authority's (MDBA) Environmental Watering Plan.
2. Evaluate ecological outcomes of Commonwealth environmental watering at each of the seven Selected Areas.
3. Infer ecological outcomes of Commonwealth environmental watering in areas of the Murray-Darling Basin not monitored.
4. Support the adaptive management of Commonwealth environmental water.
5. Monitor the ecological response to Commonwealth environmental watering at each of the seven Selected Areas.

This Monitoring and Evaluation Plan (M&E Plan) details the monitoring and evaluation activities that will be implemented under the LTIM Project for the Lachlan Selected Area. This M&E Plan includes:

- A description of the Lachlan river catchment and Selected Area (Section 2).
- A description of current and proposed environmental watering (Section 3).
- Evaluation questions relevant to the Selected Area (Section 4).
- Monitoring indicator methods and protocols (Section 5 and Standard Operating Procedures in Appendix 1).
- A monitoring schedule (Section 6).
- A communication and engagement plan (Section 7 and Appendix 2).
- A project management plan, including project governance; risk assessment; quality planning; and health, safety and environmental planning, (Section 8 and Health and Safety Appendix 3).

A budget for the implementation of the M&E Plan is submitted as a separate document.

2 Lachlan River catchment – Selected Area

The headwaters of the Lachlan River are located on the Breadalbane Plain in New South Wales between Yass and Goulburn. The river flows west for approximately 1,400 km depending on environmental conditions. In most years it terminates at Great Cumbung Swamp. In years of high flows however, water from the Lachlan River can spill over the swamp through to the Murrumbidgee River.

The Wyangala Dam is the major water storage on the Lachlan River, and is used to regulate the supply of water to irrigation industries downstream. Other regulating weirs include Carcoar Dam, Lake Cargelligo and Lake Brewster. The flows released from these dams and weirs support irrigation along almost the entire length of the catchment.

The area of the Lachlan river system identified as the focus for the LTIM Project is referred to as the 'Selected Area'. The Selected Area is located at the western end of the Lachlan River from the outlet of Lake Brewster to the terminal Great Cumbung Swamp. It encompasses associated anabranches, flood runners and billabongs, including terminal wetlands, such as Merrowie Creek, Lachlan Swamp and Booligal Wetlands. However it excludes Middle Creek and other creeks to the north (see Figure 1).

The Booligal wetlands are low-gradient braided channels situated on Muggabah-Merrimajeel Creek, a distributary from Torriganny Creek which in turn is an anabranch of the Lachlan River. Lachlan swamp is a large group of wetlands that includes Lake Waljeers, Lake Ryans, Lake Bullogal, Lake Ita, Peppermint Swamp and Baconian Swamp.

A wide range of aquatic habitats such as pools, backwaters and billabongs, in-stream woody habitat and aquatic plants are provided by the Lachlan River and its floodplains (Gawne et al. 2013). In addition, the Great Cumbung Swamp is one of the most important waterbird breeding areas in eastern Australia, and supports one of the largest stands of river red gums in New South Wales. The Lachlan River catchment also supports many flora and fauna listed as vulnerable or endangered by federal or NSW state legislation, including the Sloane's froglet, Australian painted snipe, osprey, blue-billed duck and the fishing bat.

Of the 470,000 hectares of wetlands in the Lachlan region, 95% occur in the Selected Area including numerous nationally and regionally significant wetlands such as the Great Cumbung Swamp, Lachlan Swamp and Booligal Wetlands. These wetlands contain important ecological, cultural and social values, and are particularly valuable as waterbird and migratory bird habitats (Environment Australia 2001).

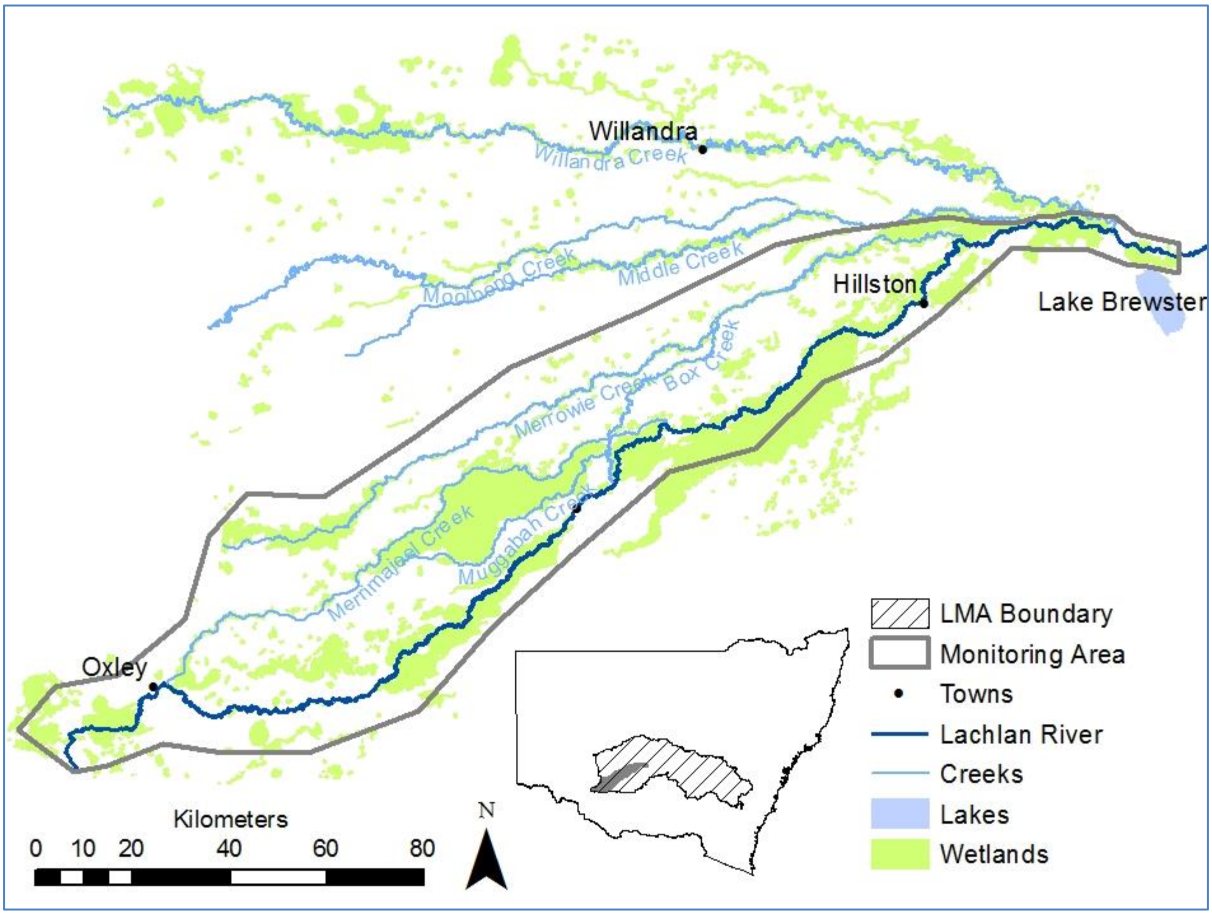

Figure 1. Map of the Lower Lachlan river system showing the region that is the focus for the LTIM Project

3 Commonwealth environmental watering

3.1 Current environmental watering in the Lachlan River

Current environmental water in the Lachlan River comprises both Commonwealth government holdings of water entitlements (Commonwealth environmental water) and NSW Government-held licensed environmental water (NSW Environmental Water Holdings). At present, a combined total of almost 115 GL of environmental water is held for the Lachlan River Valley (Table 1).

Each jurisdiction has decision-making rights over the use of individual environmental water holdings. Commonwealth environmental watering options are determined through an annual planning process. This process takes into consideration:

- Statutory obligations (particularly the Water Act and the Basin Plan).
- Basin wide demands for environmental water.
- Area priorities defined in Water Resource Plans (WRPs).
- Operational constraints as well as catchment and climate conditions.

The NSW Government makes provision for environmental flows through the *Water Sharing Plan for the Lachlan Regulated River Water Source* (WSP) (NSW Government 2003). This process involves the accumulation of water, based on dam inflows or announced allocation levels.

Table 1: Environmental water holdings in the Lachlan River Valley as at 20 March 2014

	WATER HOLDINGS (GL) BY ENTITLEMENT TYPE		
WATER HOLDER	HIGH SECURITY	GENERAL SECURITY	UNREGULATED
CEWH	0.90	86.92	
NSW Riverbank	1.0	24.10	
Rivers Environmental Restoration Program	0.93	0.47	0.18
TOTAL	**2.8**	**111.39**	**0.18**

The use of Commonwealth held environmental water, relevant to monitoring under the LTIM Project, can occur in the context of other flows and sources of environmental water in the valley. In addition, water from multiple sources may be used in a single watering event. Therefore all sources of water have been considered in identifying what is expected for the Lachlan river system over the next five years.

General Security (GS) licences in the Lachlan operate under continuous accounting. This means water is allocated to GS licences throughout the year as inflows occur and there is no forfeiture of water in accounts below 200% of entitlement. Volumes of water credited to GS accounts remain available until used or transferred. In order to maintain total long-term average annual extraction below the Water Sharing Plan (WSP) limit an annual Take Limit is applied to all GS accounts. The Take Limit is expressed as a percentage of entitlement and for the past two years NSW Office of Water (NOW) has determined the Take Limit for GS accounts to be 100% of entitlement. Large scale watering events, such as the action recently completed in the lower Lachlan in 2013, require more water than is available under any one year's Take Limit. This is achieved by scheduling the event to run across two water accounting years by accessing carried-over allocation.

3.1.1 Environmental conditions in 2008/9-2012/13

Environmental conditions experienced in the Lachlan River catchment for the five years between July 2008 and June 2013 can be summarised by:

- Eighteen months of extreme drought conditions: drought contingency management of the river culminating in a period of cease to flow conditions in the lower Lachlan River, no access to GS accounts, and very limited volumes available in High Security (HS) accounts.
- Drought breaking rains and floods in the river, with twelve months of wet conditions, and allocations into GS accounts lagging behind the improving conditions but eventually exceeding 100%.
- Twelve months of dry conditions, with no new allocations and declining flows in the lower river.
- Significant catchment-wide rainfall leading to localised flooding and filling of floodplain wetlands and depressions. This was followed by whole of system flooding, dam spills, accounts reset to 136%, translucent releases following floods, and over-bank flows in lower Lachlan over a nine month period despite drought condition.
- Twelve month period of below average rainfall resulting in static or declining water storages, no GS allocations but significant volumes carried over in GS accounts.

The hydrograph for Booligal (Figure 2) is broadly representative of the climatic conditions experienced in the catchment. The pattern of GS account allocation and holdings broadly follow the trends seen in storage levels in Wyangala Dam (Figure 3).

Interventions that have occurred under these conditions include:

- One large-scale action in 2012/13 targeting the whole of the lower Lachlan River and wetland system. This action incorporated multiple sites to support vegetation recovery, with subsidiary objectives to address the unnatural winter low-flow conditions occurring in the lower Lachlan River under current river management practises, to provide flushing flows and to replenish water in key floodplain wetlands.
- Two medium-scale actions in 2010/11 (Merrowie Creek) and 2010/2011 to 2011/2012[1] (Merrimajeel Creek) targeting a whole creek/creek system. Along these systems discrete target wetland sites supporting ongoing vegetation recovery, with subsidiary objectives of supporting threatened frog habitat and recovery/maintenance of waterbird breeding habitat, occur.
- Seven small-scale actions targeting specific sites:
    - Four actions were primarily targeted at supporting colonial breeding waterbirds with subsidiary objectives of supporting vegetation recovery (2010/2011 two Cuba Dam ibis breeding events; 2010/2011 and 2012/2013 Booligal Swamp ibis breeding).

[1] Watering event ran over two water years (i.e. through winter).

- Three actions were targeted to support vegetation recovery and to support recovery of waterbird breeding habitat (2010/2011 Cuba Dam vegetation recovery; mid 2011 to Murrumbidgil swamp for vegetation recovery; 2011/12 Muggabah Creek for habitat for bird foraging and frogs).

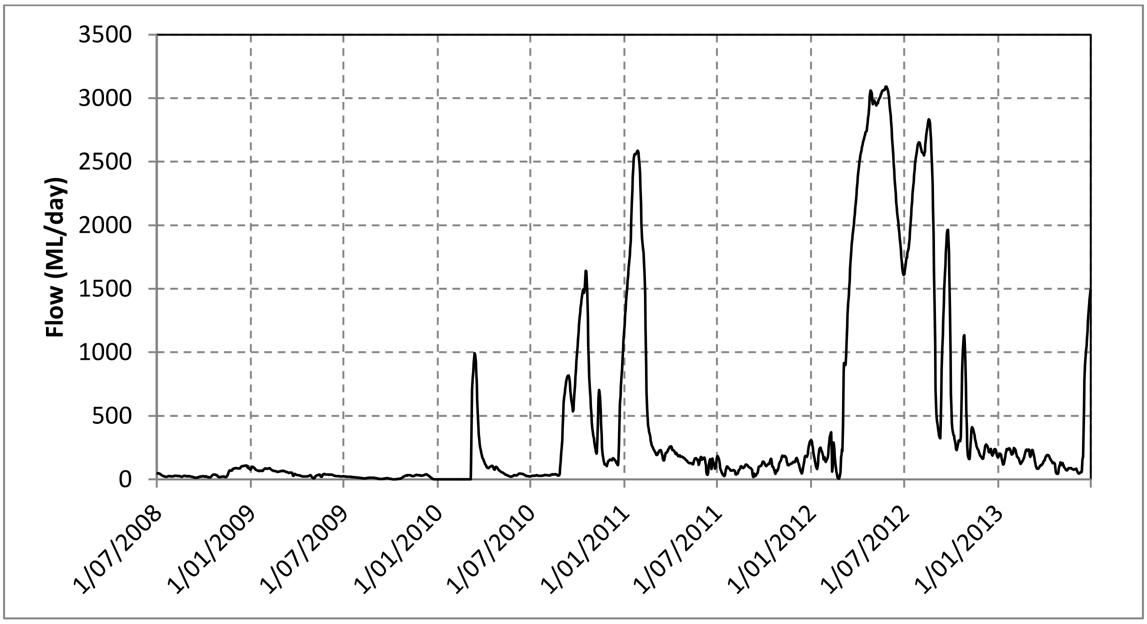

Figure 2. Hydrograph for the Lachlan River at Booligal illustrating the climatic conditions experienced in the catchment between July 2008 and June 2013.

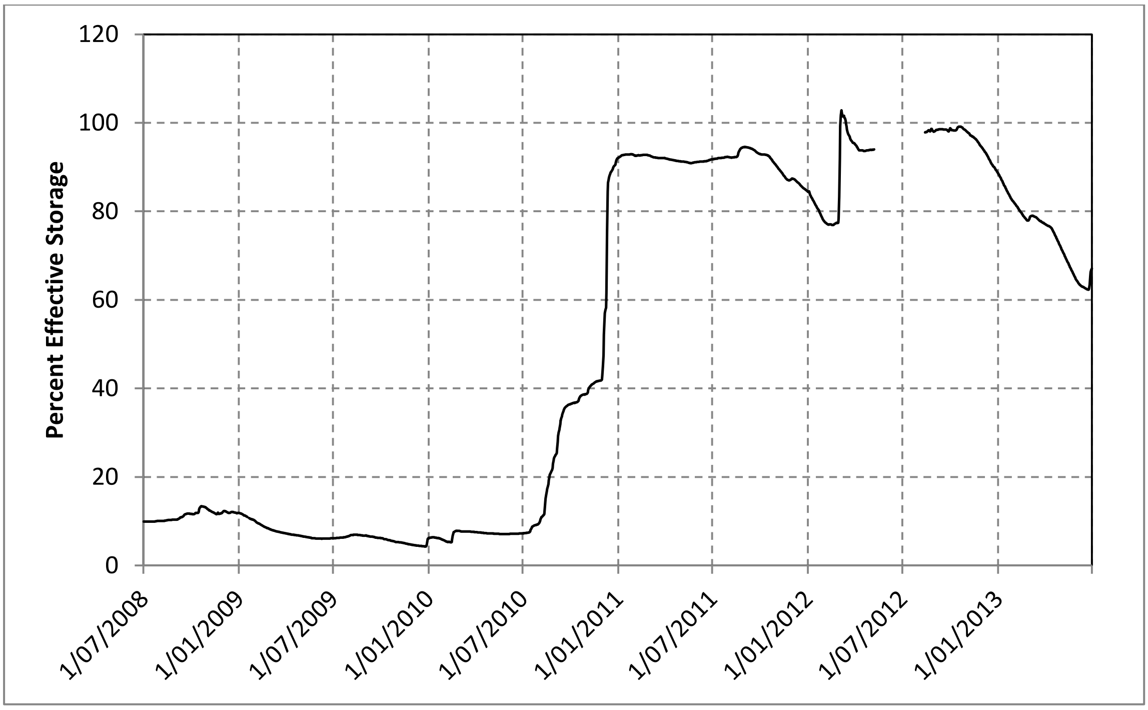

Figure 3. Storage levels (as percent effective storage) in Wyangala Dam between July 2008 and June 2013. Note that data are missing in mid 2012.

3.2 Proposed watering

3.2.1 Assumptions for watering options

Appropriate environmental watering options are based on a range of variables. A number of these are easily defined, for example current water holdings, watering priorities and catchment constraints. However, identifying variables such as Basin wide demands, catchment condition, and climate conditions are more difficult. Thus for the purposes of developing the LTIM Project a number of assumptions have been defined by CEWH, OEH, and University of Canberra[2], and include:

- Carryover provisions of GS licences combined with strategic management of environmental water holdings mean the forward five year period starts with substantial purchased water available for environmental purposes (between 44 and 124 GL was available for 2013-14 (CEWH 2013)).
- Rainfall, water storage, and water account allocations experienced over the past five years are likely representative of the range of circumstances to be experienced over the five year period of the LTIM Project.
- Rainfall, water storage, and water account allocations experienced over the next five years allow the triggering of the translucent environmental flow account, the largest single source of environmental water in the Lachlan during wet years.
- Environmental water management actions taken over the past five years are representative of the range and scale of interventions likely to be undertaken over a five year period for the LTIM Project.
- The quantum of entitlement held for the environment will not change substantially from the current level, although actual volumes of water in accounts will change depending on water allocations and water use.
- Annual take limit (currently 100% of entitlement) will not change.
- There will be one or more dam spills and GS account reset events during the five year period – Wyangala Dam has been at or above 100% (the point at which a GS account reset to 136% is likely) more than 20 times over the past 40 years, although over the past 20 years this has only occurred six times.
- Maximum release capacity of Lake Brewster is 3,000 ML/day.
- Rate of vegetation recovery and condition will differ and some areas may require less/more intensive intervention during the recovery process.

3.2.2 Expected watering within the next five years

Given the assumptions and observations described above, the expected watering over the next five years include:

- 1-2 large-scale whole of system/multi-site actions. For example, this would be similar to the recent whole of system watering.

[2] These have been informed by 1) Mr Paul Packard, Senior Environmental Water Manager, Regional Operations Group OEH.

- 2-3 medium-scale actions targeting a whole creek or creek/wetland complex. For example, watering of Merrowie Creek to Lake Tarwong or Merrimajeel Creek to Merrimajeel Lagoon.
- 7-9 small-scale actions targeting specific sites or events: For example Merrowie Creek to Cuba Dam or Merrimajeel Creek to Booligal wetlands.

Catchment condition and climatic drivers for these environmental watering actions mean that it is unlikely that these actions will be undertaken at evenly distributed intervals throughout the five year period. Rather, they may be "clumped" to coincide with favourable conditions. In addition, it is likely that watering will be distributed across the assets with repeat watering of sites limited to only a few sites and a few times during the five year period.

3.3 Target sites and expected outcomes

The project team have identified 21 target sites for environmental watering (Table 2). For each of these sites, the scale of watering action, flow component, and expected number of waterings have been identified along with the expected outcomes from the watering (Table 2). These have been informed by CEWH 2013; Commonwealth Environmental Water Office 2013; Gawne et al. 2013; Lachlan Riverine Working Group 2013 and discussions with area water managers.

Expected short and long term outcomes as a result of the proposed waterings cover a broad suite of attributes including waterbirds, fish, frogs, turtles, vegetation, water quality and instream productivity. Gawne et al. 2013 noted that priority regional scale outcomes are dominated by improvements in native fish populations and diversity; floodplain and wetland vegetation condition and extent and improvements in waterbird populations

Table 2. Target sites for environmental watering, scale of watering action required to deliver them, and the number of times the targets are expected to be watered in the next 5 years.

LOCATION CODE	TARGET/SITES	SCALE OF WATERING ACTION			FLOW COMPONENT	EXPECTED WATERINGS IN NEXT 5 YRS	OUTCOMES
		SM	**MED**	**LG**			
LOWER LACHLAN RIVER CHANNEL							
LLR1	Lower Lachlan River Channel to Lachlan Swamp	X			Baseflow Fresh	1	• Biodiversity: fish breeding & habitat; riparian extent & growth • Resilience: fish, habitat • Ecosystem function: fish connectivity, biofilm production • Water quality: chemical for fish, frogs & macroinvertebrates
LLR2	Lower Lachlan River channel		X		Baseflow Fresh	1	• Biodiversity: fish breeding & habitat; riparian extent & growth • Resilience: fish, habitat • Ecosystem function: fish connectivity, biofilm production • Water quality: chemical for fish, frogs & macroinvertebrates
LOWER LACHLAN SWAMPS							
LLS-PS	Peppermint Swamp			X	Bankfull	1	• Biodiversity: frog habitat; instream, wetland & floodplain vegetation • Ecosystem resilience: seedbank rhizones & long lived vegetation; frog habitat
LLS-LW	Lake Waljeers			X	Bankfull	1	• Biodiversity: frog habitat; instream, wetland & floodplain vegetation • Ecosystem resilience: seedbank rhizones & long lived vegetation; frog habitat
LLS-LB	Lake Boologal			X	Bankfull	1	• Biodiversity: frog habitat; instream, wetland & floodplain vegetation • Ecosystem resilience: seedbank rhizones & long lived vegetation; frog habitat
LLS-EB	Erins Billabong			X	Bankfull	1	• Biodiversity: frog habitat; instream, wetland & floodplain vegetation • Ecosystem resilience: seedbank rhizones & long lived vegetation; frog habitat
LLS-V	The Ville			X	Bankfull	1	• Biodiversity: frog habitat; instream, wetland & floodplain vegetation • Ecosystem resilience: seedbank rhizones & long lived vegetation; frog habitat
LLS-SC	Southern Creeks			X	Bankfull	1	• Biodiversity: frog habitat; instream, wetland & floodplain vegetation • Ecosystem resilience: seedbank rhizones & long lived vegetation; frog habitat
OTHER WETLANDS							
MMS	Moon-moon swamp			x	Bankfull	1	• Biodiversity: fish habitat protection; habitat for frogs, turtles & other vertebrates • Ecosystem resilience: seedbank rhizones & long lived vegetation; habitat for frogs, turtles & other vertebrates
WL	Whealbah Lagoon			X	Bankfull	1	• Biodiversity: fish habitat protection; • Ecosystem resilience: seedbank rhizones & long lived vegetation
MERRIMAJEEL CREEK SYSTEM							
MCS-BW1	To Booligal wetland	X	X	X	Bankfull Overbank	2	• Biodiversity: waterbird breeding & recruitment; waterbird habitat; instream, wetland & floodplain vegetation • Ecosystem resilience: seedbank rhizones & long lived vegetation

LOCATION CODE	TARGET/SITES	SCALE OF WATERING ACTION			FLOW COMPONENT	EXPECTED WATERINGS IN NEXT 5 YRS	OUTCOMES
		SM	MED	LG			
MCS-BW2	To Booligal wetland		X	X	Bankfull, Overbank Infrastructure assisted	1	• Biodiversity: frog habitat; waterbird breeding & recruitment • Ecosystem resilience: frog habitat
MCS-MS	To Murrumbidgal Swamp	X	X	X	Bankfull Infrastructure assisted	3	• Biodiversity: instream, wetland & floodplain vegetation; fish breeding & recruitment • Ecosystem resilience: habitat for frogs, turtles & other vertebrates; seedbank rhizones & long lived vegetation
MCS-LM	To Lake Merrimajeel		X	X	Bankfull Infrastructure assisted	1	• Ecosystem resilience: habitat for frogs, turtles & other vertebrates
MCS-MC	Muggabah Creek	X	X		Bankfull	3	• Biodiversity: frog habitat; instream, floodplain & wetland vegetation
MERROWIE CREEK SYSTEM							
MCS2-CD	To Cuba Dam	X	X		Bankfull Infrastructure assisted	2	• Biodiversity: fish breeding & recruitment; fish habitat protection; wetland & floodplain vegetation; riparian extent & growth • Ecosystem resilience: seedbank rhizomes & long lived vegetation
MCS2-LT	To Lake Tawong		X		Bankfull Infrastructure assisted	1	• Biodiversity: fish breeding & recruitment; floodplain, wetland-stream & riparian vegetation • Ecosystem resilience: seedbank rhizomes & long lived vegetation
GREAT CUMBUNG SWAMP							
GCS-1	Whole swamp (reed beds, open water, red gums and black box fringe)			X		1	• Biodiversity: frog habitat; instream, floodplain & wetland vegetation • Ecosystem resilience: seedbank rhizomes & long lived vegetation
GCS-2	Reed beds, open water, red gums		X	X		2	• Biodiversity: frog habitat; instream, floodplain & wetland vegetation • Ecosystem resilience: seedbank rhizomes & long lived vegetation
GCS-3	Reed beds, open water		X	X		2	• Biodiversity: frog habitat; instream, floodplain & wetland vegetation • Ecosystem resilience: seedbank rhizomes & long lived vegetation
GCS-4	Reed beds		X			1	• Biodiversity: frog habitat; instream, floodplain & wetland vegetation • Ecosystem resilience: seedbank rhizomes & long lived vegetation

3.4 Watering practicalities

3.4.1 Delivery of environmental water

The Lower Lachlan river system is a very low gradient system comprising numerous anabranches and distributary creeks that terminate in wetlands. Flow variability is high, with common low flow and cease to flow periods. High flows producing overbank flooding and the connection of floodplain wetlands, swamps, and off channel wetlands are irregular events. In addition, flow attenuation is high, and travel times are long – taking weeks to travel from Lake Brewster to the Great Cumbung Swamp. River regulation has reduced the median monthly discharge of spring floods by one third (Gawne et al. 2013). The natural variability means watering does not need to occur every year, and will therefore be both temporally and spatially variable.

Delivery of water is complicated by a network of regulating structures. These can be used to provide infrastructure assisted watering, and include the Block Bank Regulator which can be used to extend watering duration in Booligal Wetland; and the Torringanny Regulator which can be used to assist in the delivery of water to the lower reaches of the Merrimajeel Creek system.

Delivery is also constrained by release capacities from storages, channel capacities, risks to private infrastructure and the timing of irrigation deliveries within the system, including:

- A maximum release capacity of Lake Brewster of 3,000 ML/day.
- Flows above 2,400 ML/day in the Lachlan River upstream of Willandra Weir resulting in flows commencing in Willandra Creek.
- Flows exceeding 2,800 ML/day at Hillston may inundate private irrigation infrastructure.

3.4.2 Typical watering action

Watering actions are defined within an annual planning cycle and draw on MDBA’s watering priorities, as well as antecedent watering conditions, seasonal, operational and local management considerations. Commonwealth environmental water can be delivered alone or in concert with NSW environmental water.

Environmental water can be delivered as:

1) ‘Stand alone’ events: with water gravity fed from Lake Brewster and regulated using the existing infrastructure to target sites.
2) Augmented events: with water gravity fed from Lake Brewster to enhance or extend a natural flow event.
3) “Piggy-backed” events: where water is ‘piggy-backed’ on water delivered for stock and domestic or irrigation purposes.

3.5 Information needed to inform monitoring activities

The monitoring activities proposed for the Lachlan river system Selected Area comprise a mix of annual monitoring at fixed sites, and event based monitoring that captures response to watering in any one year. This allows the monitoring program to operate effectively when the watering will be both spatially and temporally variable. Monitoring will be guided by information at a range of scales and timeliness of delivery, see Table 3 for additional information.

Table 3. Information that informs annual watering activities and monitoring plans

	PRACTICAL INFORMATION	LIKELY TIMING OF AVAILABILITY
Outcomes from water planning	MDBA watering priorities	Now
	CEW annual watering priorities	Published 9 months in advance
	NSW watering priorities	Prior to the water year: end June
Antecedent conditions	Previous years watering	Ongoing
	Water holdings	Ongoing
	Climate conditions	Historical data - now
Implementation plans	Implementation activities (including watering targets/objectives and timing of releases)	End June/July and throughout watering year
	Travel times	Now
On ground	Site access	Now
	Climate/flow data	Consider immediate forecasts and 3-6 month Bureau of Meteorology outlook

4 Basin Evaluation

This section describes the contribution monitoring in the Lachlan river system Selected Area will make to Basin Evaluation. It briefly outlines the evaluation questions for Basin Evaluation (see Section 4.2). It is important to note that Basin Evaluation is being led by the M&E Advisors, and the approach to Basin Evaluation is described in more detail in Gawne et al. 2014.

Basin evaluation questions have been developed to assess the extent to which Commonwealth environmental water contributes to achieving Basin Plan objectives. These follow the hierarchical structure of the Outcomes Framework (Commonwealth Environmental Water Office 2013_ENREF_7_ENREF_18):

1. Basin Plan objectives (Level 1 evaluation questions).
2. Basin Outcomes (Level 2 evaluation questions).
3. Expected Outcomes (Level 3 evaluation questions).

The Basin evaluation questions applicable to the Lachlan river system Selected Area are outlined in Table 4.

4.1 Basin indicators

Evaluating outcomes involves monitoring a set of ecosystem attributes, the response of which demonstrates the achievement (or otherwise) of an outcome. These attributes are known as indicators. Eight indicators were identified as being required to inform Basin Evaluation for the Lachlan river system Selected Area, including:

- Ecosystem type.
- Vegetation diversity.
- Fish (river).
- Fish (larvae).
- Waterbird breeding.
- Stream metabolism.
- Hydrology (river).
- Hydrology (wetland).

4.2 Basin Evaluation approach

The approach to Basin Evaluation is described in the Basin Evaluation Plan (Gawne et al. 2014) and involves both quantitative and qualitative analysis techniques.

Table 4. List of evaluation questions for the Lachlan river system Selected Area to be used in Basin Evaluation

LEVEL 1 EVALUATION QUESTIONS	LEVEL 2 EVALUATION QUESTIONS	LEVEL 3 EVALUATION QUESTIONS	
		LONG-TERM (5YR)	SHORT-TERM (ONE YEAR)
What has Commonwealth environmental water contributed to biodiversity?	What did Commonwealth environmental water contribute to Ecosystem diversity?	What did Commonwealth environmental water contribute to sustainable ecosystem diversity? Were ecosystems to which Commonwealth environmental water was allocated sustained? Was water delivered to a representative suite of ecosystem types?	
		What did Commonwealth environmental water contribute to the condition of floodplain and riparian trees?	What did Commonwealth environmental water contribute to the condition of floodplain and riparian trees?
		What did Commonwealth environmental water contribute to vegetation community diversity? What did Commonwealth environmental water contribute to vegetation species diversity?	What did Commonwealth environmental water contribute to vegetation community diversity? What did Commonwealth environmental water contribute to vegetation species diversity?
		What did Commonwealth environmental water contribute to vegetation extent?	
	What did Commonwealth environmental water contribute to Species diversity?	What did Commonwealth environmental water contribute to native fish populations? What did Commonwealth environmental water contribute to native fish species diversity? What did Commonwealth environmental water contribute to fish community resilience? What did Commonwealth environmental water contribute to native fish survival?	What did Commonwealth environmental water contribute to native fish reproduction? What did Commonwealth environmental water contribute to native larval fish growth and survival?
			What did Commonwealth environmental water contribute to waterbird breeding? What did Commonwealth environmental water contribute to waterbird chick fledging? What did Commonwealth environmental water contribute to waterbird survival?
		What did Commonwealth environmental water contribute to waterbird populations? What did Commonwealth environmental water contribute to waterbird species diversity?	What did Commonwealth environmental water contribute to waterbird survival?

LEVEL 1 EVALUATION QUESTIONS	LEVEL 2 EVALUATION QUESTIONS	LEVEL 3 EVALUATION QUESTIONS	
		LONG-TERM (5YR)	SHORT-TERM (ONE YEAR)
		What did Commonwealth environmental water contribute to other vertebrate populations? What did Commonwealth environmental water contribute to other vertebrate species diversity?	What did Commonwealth environmental water contribute to other vertebrate reproduction and recruitment? What did Commonwealth environmental water contribute to other vertebrate survival?
What has Commonwealth environmental water contributed to ecosystem function?	What did Commonwealth environmental water contribute to ecosystem connectivity?	What did Commonwealth environmental water contribute to hydrological connectivity?	What did Commonwealth environmental water contribute to hydrological connectivity?
		What did Commonwealth environmental water contribute to biotic dispersal?	What did Commonwealth environmental water contribute to biotic dispersal?
	What did Commonwealth environmental water contribute to ecosystem processes?	What did Commonwealth environmental water contribute to patterns and rates of primary productivity?	What did Commonwealth environmental water contribute to patterns and rates of primary productivity?
		What did Commonwealth environmental water contribute to patterns and rates of primary productivity? What did Commonwealth environmental water contribute to patterns and rates of decomposition?	What did Commonwealth environmental water contribute to patterns and rates of primary productivity? What did Commonwealth environmental water contribute to patterns and rates of decomposition?
		What did Commonwealth environmental water contribute to patterns and rates of nutrient cycling?	What did Commonwealth environmental water contribute to patterns and rates of nutrient cycling?
What has Commonwealth environmental water contributed to ecosystem resilience?	What did Commonwealth environmental water contribute to ecosystem resilience?	What did Commonwealth environmental water contribute to populations of long-lived organisms?	
		What did Commonwealth environmental water contribute to refuges?	What did Commonwealth environmental water contribute to refuges?
		What did Commonwealth environmental water contribute to recovery?	What did Commonwealth environmental water contribute to recovery?
	What did Commonwealth environmental water contribute to species resilience?	What did Commonwealth environmental water contribute to fish community resilience?	What did Commonwealth environmental water contribute to fish community resilience?

LEVEL 1 EVALUATION QUESTIONS	LEVEL 2 EVALUATION QUESTIONS	LEVEL 3 EVALUATION QUESTIONS	
		LONG-TERM (5YR)	SHORT-TERM (ONE YEAR)
What has Commonwealth environmental water contributed to water quality?	What did Commonwealth Environmental water contribute to chemical water quality?	What did Commonwealth environmental water contribute to temperature regimes? What did Commonwealth environmental water contribute to dissolved oxygen levels?	What did Commonwealth environmental water contribute to temperature regimes? What did Commonwealth environmental water contribute to dissolved oxygen levels?

5 Selected Area Evaluation

This section describes the approach to the evaluation of the outcomes of Commonwealth environmental water in the Lachlan river system Selected Area.

The one and five year expected outcomes for the Lachlan river system Selected Area (Table 5) have been used to set the context for the definition of the Selected Area evaluation questions. The development of outcomes were guided by the hierarchical structure of the Outcomes Framework (Commonwealth Environmental Water Office 2013_ENREF_7) linking the Basin Plan objectives (Level 1 evaluation questions) to Basin outcomes (Level 2 evaluation questions) and then expected Outcomes (Level 3 evaluation questions). While all outcomes listed in Table 5 are possible, it is unlikely to be practical to evaluate all of them within the LTIM Project. The priorities for the Lachlan river system Selected Area were established through a three stage process. Firstly, a list of expected outcomes for the Selected Area was reviewed to determine the fit with stakeholder priorities and ecosystem outcomes (see Section 5.1). Secondly, a set of indicators that could be used to evaluate the outcomes were identified and ranked according to the practicality and cost effectiveness of a monitoring program (see Section 5.2). This produced a list of indicators (and hence evaluation questions) that could form the basis for the M&E Plan. Thirdly, the available budget was used to select a set of indicators that would be monitored during the Monitoring and Evaluation period (see Section 5.3).

5.1 Selected Area outcomes

Selection of outcomes to be the focus of the Selected Area Evaluation for the Lachlan river system Selected Area was guided by stakeholder priorities and the need to understand ecosystem responses not just taxa responses.

5.1.1 Stakeholder priorities

A stakeholder workshop in February 2013 identified priority outcomes for the Lachlan river system as improvements in native fish populations and diversity; floodplain and wetland vegetation condition and extent and improvements in waterbird populations (Gawne et al., 2013a). A review of these priorities involving representatives from NSW Office of Water, NSW Office of Environment and Heritage and the Central Tablelands Local Land Services (LLS)[3] proposed that frogs and other vertebrates (specifically turtles) be added as regional priorities because of the value placed on these by the local community.

Societal values are often strongly linked to iconic species, use values, or recreational values within freshwater systems. Public interest in fish and water quality by Australians drive investment to protect such favoured attributes. Frogs, turtles and yabbies (decapods) also form a part of the social fabric of country life – with most people having fond memories of collecting tadpoles, watching

[3] At a scoping workshop at the University of Canberra in August 2013.

turtles and catching yabbies from local wetlands and creeks. Turtles and yabbies also play a significant role in indigenous culture. Downstream of the Lower Lachlan Swamps, the fish populations are dominated by invasive species (e.g. Growns 2001; Price 2009), yet frog populations are diverse, yabbies can be abundant, and turtles are widespread. As such the community continues to value these as important and their inclusion as priority outcomes is recommended.

Other comments

The Lachlan Riverine Working Group have identified that the infilling of pools and the scouring of channels is something of considerable interest in the management of local environmental watering. The project team consider that the complexity associated with sediment movement in the region means that this is best addressed through some targeted research and the University of Canberra will offer a PhD project to investigate sediment movement within the Lower Lachlan river system to help address some of the knowledge gaps in this area.

5.1.2 Understanding ecosystem responses

The MDBA's environmental watering objectives (Commonwealth of Australia 2012, Chapter 8) are articulated in terms of:

- Biodiversity.
- Ecosystem function.
- Resilience.
- Water quality

The Outcomes framework (Commonwealth Environmental Water Office 2013_ENREF_7) describes these objectives in terms of taxa specific responses, which confines the monitoring to taxon responses and provides limited information about ecosystem function. Given a further outcome of the LTIM Project is "*to infer ecological outcomes of Commonwealth environmental watering in areas of the Murray-Darling Basin not monitored*', the M&E Providers for the Lachlan river system Selected Area consider that evaluating outcomes that enable a whole of ecosystem responses to be understood is a key feature for generalising responses to other regions. Consequently, additional priority outcomes for the Lachlan river system Selected Area include:

- Aquatic micro-invertebrates as they are a key component of food chains that support indicators of significant interest (particularly fish).
- Primary productivity, as it forms the basis of aquatic food webs.

5.1.3 Summary

Outcomes that are both stakeholder priorities and relate to understanding whole of ecosystem responses are identified in Table 5.

Table 5. The expected 1 and 5 year outcomes for watering actions in the Lower Lachlan River. Outcomes that meet both stakeholder priority and ecosystem response criteria are shaded in blue.

FLOW COMPONENT	<1 YEAR EXPECTED OUTCOMES	1-5 YEAR EXPECTED OUTCOMES	STAKEHOLDER PRIORITY	ECOSYSTEM RESPONSE	INDICATOR
Overbank terminal wetland inundation infrastructure assisted	Contribute to restoration/protection of frog diversity and populations through provision of habitat to support breeding and recruitment	As for 1-year outcome	Y	Y	Frogs: population and diversity
Terminal wetland inundation	Support breeding and recruitment of waterbirds	Maintain or increase waterbird populations and landscape diversity of waterbirds	Y	Y	Breeding: Nests, eggs, chicks, fledgelings
	Contribute to the maintenance or improvement of wetland habitat to support the growth and survival of waterbirds	Maintain or increase waterbird populations and landscape diversity of waterbirds	Y	Y	Waterbird diversity
	Maintain viability of seedbank rhizones and long lived vegetation	As for 1-year outcome	Y		Tree stand condition
	Provide refuge habitat for frogs, turtles and other vertebrates	As for 1-year outcome	Y		Frogs: populations and diversity Turtle: populations and diversity (wetlands) Decapod: populations and diversity
	Contribute to in-stream vegetation population viability particularly extent and condition	Maintained condition and extent of floodplain and wetland vegetation	Y	Y	Condition and extent of instream vegetation Vegetation Diversity (and Condition)
Bankfull, Overbank Infrastructure assisted	Contribute to breeding and recruitment of native fish	Improved native fish population, diversity and condition	Y	Y	Larval fish
Bankfull, Overbank	Contribute to protection of native fish diversity and abundance through maintaining suitable habitat	Increase in native fish populations and diversity	Y	Y	Riverine Fish: diversity and abundance; Size frequency; Wetland fish: diversity and abundance; size frequency
Bankfull, Overbank Infrastructure assisted	Contribute to restoration protection of frog diversity and populations through provision of habitat to support breeding and recruitment	As for 1-year outcome	Y		Frogs: population and diversity
Overbank Infrastructure assisted	Support breeding and recruitment of waterbirds	Maintain or increase waterbird populations and landscape diversity of waterbirds	Y	Y	Waterbird diversity
Overbank Infrastructure assisted	Contribute to the maintenance or improvement of wetland habitat to support the growth and survival of waterbirds`	Maintain or increase waterbird populations and landscape diversity of waterbirds	Y	Y	Waterbird Diversity
Overbank Infrastructure assisted	Maintain viability of seedbank rhizones and long lived vegetation	As for 1-year outcome	Y		Tree stand condition
Overbank Infrastructure assisted	Provide refuge habitat for frogs	As for 1-year outcome	Y		Frogs: population and diversity
Overbank Infrastructure assisted	Contribute to in-stream and riparian native vegetation population viability particularly extent and condition	Maintained condition and extent of floodplain and wetlain-stream and riparian vegetation	Y	Y	Condition and extent of instream vegetation Vegetation Diversity (and Condition)

FLOW COMPONENT	<1 YEAR EXPECTED OUTCOMES	1-5 YEAR EXPECTED OUTCOMES	STAKEHOLDER PRIORITY	ECOSYSTEM RESPONSE	INDICATOR
Fresh	Contribute to native wetland vegetation population viability particularly extent and condition	Maintained condition and extent of floodplain and wetland vegetation	Y	Y	Condition and extent of instream vegetation Vegetation Diversity (and Condition)
Baseflow **Fresh**	Contribute to protection of native fish diversity and abundance through maintaining suitable habitat	Increase in native fish populations and diversity	Y		Wetland fish: diversity and abundance; size frequency
Baseflow	Provide refuge habitat for native fish (pools)	As for <1 year outcome	Y		Riverine Fish: diversity and abundance; Size frequency; Wetland fish: diversity and abundance; size frequency
Fresh, Bankfull	Contribute to native riparian vegetation population viability particularly extent and condition	Maintained condition and extent of riparian vegetation	Y	Y	Condition and extent of instream vegetation Vegetation Diversity (and Condition)
Fresh	Contribute to opportunities for dispersal of threatened fish from Lake Brewster	Improved dispersal of threatened fish from Lake Brewster			Riverine Fish: Dispersal of threatened/native fish
Fresh **Bankfull**	Contribute to breeding and recruitment of native fish	Improved native fish population, diversity and condition	Y	Y	Larval fish Riverine Fish: diversity and abundance; Size frequency; Wetland fish: diversity and abundance; size frequency
Fresh **Bankfull**	Maintain production biofilms through provision of scour disturbance	As for <1 year outcome		Y	River channel metabolism (primary productivity and decomposition)
Fresh **Bankfull**	Contribute to maintenance of pool depth via scour of sediments	Maintenance of pool refugia at landscape scale			Pool depth
Bankfull	Contribution to opportunities for the dispersal of native fish	Improved dispersal of native fish			Riverine Fish: Dispersal of threatened/native fish
Overbank	Improve biofilm productivity through the return of nutrient rich water from floodplains	As for <1 year outcome		Y	River channel metabolism (primary productivity and decomposition)
All	Contribute to the maintenance or improvement of aquatic habitat (water quality) to support the recruitment, growth and survival of native fish, frogs and invertebrates	Increased availability of physical habitat for fish, frogs and macroinvertebrates			Riverine Fish: diversity and abundance; Size frequency; Wetland fish: diversity and abundance; size frequency Frogs: population and diversity

5.2 Selected Area indicators

Evaluating the outcomes of Commonwealth environmental water involves monitoring a set of ecosystem attributes (indicators), the response of which demonstrates the achievement (or otherwise) of an outcome. Establishing a monitoring program requires that the indicators selected meet the needs of the evaluation program and are practical and cost effective to monitor. Identifying and prioritising Selected Area indicators has therefore been guided by:

- The overarching objectives of the LTIM Project.
- Indicators prescribed for quantitative Basin Evaluation.
- The likelihood of detecting a response to watering (based on the expected size of the response).
- The specificity of the response to watering.
- Value for money.
- The available budget.

Some of these features were used to inform the selection of indicators, others were used to assign a weighting that was used to score and prioritise the indicators but ultimately, the final suite of indicators was defined by the available budget. Details are provided in the following sections.

5.2.1 Indicator selection

Objectives of the LTIM Project

Evaluating the ecological outcomes from Commonwealth environmental water for the Lachlan river system Selected Area contributes to delivering the high-level outcomes of the LTIM Project. Hence, only indicators that could be demonstrated to have a direct link to the expected ecological outcomes (Table 5) of Commonwealth environmental water for the Lachlan river system Selected Area and, through the expected outcomes framework, to the objectives of the MDBA's Environmental Watering Plan were selected. The initial suite of possible indicators that were selected covered a broad range of attributes including waterbirds, fish, frogs, turtles, vegetation, water quality and instream productivity. These were grouped thematically for the Lachlan river system Selected Area (Table 6).

5.2.2 Prioritisation

Indicators prescribed for quantitative Basin Evaluation

In addition to the potential indicators for the Selected Area Evaluation, eight indicators were prescribed for the Lachlan river system to inform quantitative Basin Evaluation. These are identified in Table 6. The greatest return on monitoring effort comes from being able to monitor indicators that contribute to both Basin and Selected Area Evaluation. To facilitate prioritisation, a numerical weighting was assigned to indicators as follows:

- #1 – Basin or Selected Area Evaluation only.
- #2 – Both Basin and Selected Area Evaluation.

Likelihood of detecting a response

The magnitude of ecological response to watering is an important consideration in the selection of both indicators and monitoring sites (Roberts & Dyer 2007) i.e. size of response is central to the likelihood of detecting a response. In prioritising indicators, we have adopted the premise that if it is difficult or impractical to detect a response to watering then the indicator has limited value in the monitoring program. The likelihood of detecting a response can be informed by historical monitoring programs in the Lachlan river system, information from other areas, as well as expert opinion.

The likelihood of detecting a response of the indicators has been ranked using the M&E Provider team to assign the scores (Table 6) where the following numerical weighting has been applied:

- #1 – low (difficult to detect a response).
- #2 – medium.
- #3 – high (easy to detect a response).

Specificity of the response

Ecosystems respond to a range of environmental drivers and it is often difficult to disaggregate the effects of these drivers to establish clear flow ecology relationships (Poff & Zimmerman, 2010). The objectives of the LTIM Project are to evaluate the contribution of Commonwealth environmental water to the ecological outcomes. The specificity of ecological response to watering and the ability to design a monitoring strategy that detects the flow-ecology responses was seen as a significant component of prioritising the indicators.

The ability to detect an ecological response *specifically* to Commonwealth environmental water was ranked using the M&E provider team to assign the scores (Table 6) where the following numerical weighting has been applied:

- #1 – low (difficult e.g. major confounding factors likely to affect outcomes).
- #2 – medium.
- #3 – high (easy to determine specific responses)

Table 6. Ranking of indicators for the Lachlan river system Selected Area. Indicators shaded green are considered the highest priority for the Selected Area.

THEME	INDICATORS	EVALUATION OF PRIORITY OUTCOME	BASIN / AREA (B/A)	LIKELIHOOD OF DETECTION	SPECIFICITY OF RESPONSE	SCORE
Fish	Riverine Fish: diversity and abundance; Size frequency	Y	2	3	2.5	**7.5**
	Wetland fish: diversity and abundance; size frequency	Y	1	3	2.5	**6.5**
	Larval Fish	Y	2	3	3	**8**

THEME	INDICATORS	EVALUATION OF PRIORITY OUTCOME	BASIN / AREA (B/A)	LIKELIHOOD OF DETECTION	SPECIFICITY OF RESPONSE	SCORE
	Riverine Fish: Dispersal of threatened/native fish		1	1.5	3	**5.5**
Invertebrates	Microinvertebrate abundance (wetlands)	Y	1	3	3	**7**
Waterbirds	Breeding: Nests, eggs, chicks, fledglings	Y	2	3	3	**8**
	Diversity		1	2	1	**4**
Frogs and other vertebrates	Frogs: populations and diversity	Y	1	3	3	**7**
	Turtle: populations and diversity (wetlands)		1	3	2	**6**
	Decapod: populations and diversity	Y	1	2	2	**5**
Vegetation	Diversity (and Condition)		1	3	3	**7**
	Tree stand condition		1	2	2	**5**
	Condition and extent of instream vegetation	Y	1	1	2	**4**
Water quality and channel metabolism	River channel metabolism (primary productivity and decomposition)	Y	2	2	2	**6**
	Nutrient and carbon cycling	Y	1	2	2	**5**
	Water quality	Y	1	3	1	**5**
Geomorphology	Pool depth		1	1	1	**3**
Hydrology	Riverine: duration, depth, timing and type of connection	Y	2	3	3	**8**
	Wetland: duration, depth, timing and type of connection		2	3	3	**8**

5.2.3 Selected Area priority indicators

On the basis of this assessment, the highest priority indicators (with scores of >7) for the Selected Area Evaluation for the Lachlan river system Selected Area are:

- Riverine adult and larval fish.
- Waterbird breeding.
- Frog populations and diversity.
- Vegetation diversity and condition.

- Microinvertebrate abundance.
- Riverine and wetland hydrology.

5.2.4 Funding

The monitoring program for the Lachlan river system Selected Area is, by necessity, constrained by funding. This means that the final suite of indicators must be confined to those that represent the best investment for the LTIM Project and for which the monitoring can be undertaken within the available budget. Of the priority indicators for the Lachlan river system Selected Area, the fish monitoring is the most expensive and stream metabolism the least expensive.

Following negotiation with the Commonwealth Environmental Water Office, the indicators that are required to be monitored to inform Basin Evaluation for the Lachlan river system Selected Area were defined as:

- Ecosystem type.
- Fish (river).
- Fish (larvae).
- Stream metabolism.
- Hydrology (river).

The indicators that were subsequently negotiated for the Selected Area Evaluation were defined as:

- Vegetation condition and diversity.

Decapods, which are likely to be by-catch from implementing the Fish (river) monitoring, will be included in the Selected Area Evaluation and Turtles may also be similarly included if time and resources permit.

The monitoring of waterbird breeding and frog populations and diversity are to be implemented if and when required by the Commonwealth Environmental Water Office.

Thus, the indicators that will inform the Lachlan river system Selected Area Evaluation have been identified and are mapped to the relevant Selected Area evaluation questions and cause and effect diagrams in Table 7.

Table 7. Lachlan river system Selected Area evaluation questions, indicators and cause and effect diagrams

Theme	LEVEL 3 EVALUATION QUESTIONS	SHORT-/LONG-TERM	INDICATORS	RELEVANT CAUSE AND EFFECT DIAGRAM
Ecosystem type (Basin Evaluation only)	What did Commonwealth environmental water contribute to sustainable ecosystem diversity?	Long	Ecosystem type	Landscape ecosystem diversity
	Were ecosystems to which Commonwealth environmental water was allocated sustained?	Long		
	Was water delivered to a representative suite of ecosystem types?	Long		
Vegetation	What did Commonwealth environmental water contribute to vegetation community diversity?	Short Long	Vegetation diversity Hydrology (river and wetland)	Landscape vegetation diversity
	What did Commonwealth environmental water contribute to vegetation species diversity?	Short Long		
	What did Commonwealth environmental water contribute to vegetation extent?		Tree community and extent Hydrology (river)	Vegetation recruitment and extent
Fish	What did Commonwealth environmental water contribute to native fish populations?	Long	Fish (species, abundance and size frequency in rivers) Hydrology (river) Water quality (temperature and dissolved oxygen)	Landscape fish diversity
	What did Commonwealth environmental water contribute to native fish species diversity?	Long		
	What did Commonwealth environmental water contribute to fish community resilience?	Long		
	What did Commonwealth environmental water contribute to native fish survival?	Long		Fish condition
	What did Commonwealth environmental water contribute to native fish reproduction?	Short		Fish reproduction
	What did Commonwealth environmental water contribute to native larval fish growth and survival?	Short		Fish larval growth and survival
	What did Commonwealth environmental water contribute to fish community resilience?	Short Long		
Waterbirds (Option)	What did Commonwealth environmental water contribute to waterbird breeding?	Short	Waterbirds – breeding (colonial nesting species) Hydrology (wetlands) Vegetation type and condition	Waterbird recruitment and fledging
	What did Commonwealth environmental water contribute to waterbird chick fledging?	Short		
	What did Commonwealth environmental water contribute to waterbird survival?	Short		Waterbird reproduction
	What did Commonwealth environmental water contribute to waterbird survival?	Short		Waterbird survival and condition
Stream Metabolism	What did Commonwealth environmental water contribute to patterns and rates of primary productivity?	Short Long	Stream metabolism Hydrology (river)	Primary production
	What did Commonwealth environmental water contribute to patterns and rates of decomposition?	Short Long	Stream metabolism Hydrology (river)	Decomposition
	What did Commonwealth environmental water contribute to patterns and rates of nutrient cycling?	Short Long	Stream metabolism Hydrology (river)	Nutrient cycling
Water Quality	What did Commonwealth environmental water contribute to temperature regimes?	Short Long	Water quality (dissolved oxygen, temperature) Hydrology (river and wetland)	
	What did Commonwealth environmental water contribute to dissolved oxygen levels?	Short Long		
Other Vertebrates	What did Commonwealth environmental water contribute to other vertebrate populations?	Long	Frogs Turtles (species and	Other vertebrate growth and

Theme	LEVEL 3 EVALUATION QUESTIONS	SHORT-/LONG-TERM	INDICATORS	RELEVANT CAUSE AND EFFECT DIAGRAM
	What did Commonwealth environmental water contribute to other vertebrate species diversity?	Long	abundance) Hydrology (river)	survival Other vertebrate reproduction
	What did Commonwealth environmental water contribute to other vertebrate reproduction and recruitment?	Short		
	What did Commonwealth environmental water contribute to other vertebrate survival?	Short		
	What did Commonwealth environmental water contribute to refuges?	Short Long		
Hydrology	What did Commonwealth environmental water contribute to hydrological connectivity?	Short Long	Hydrology (river and wetland)	Hydrological connectivity Hydrology

5.3 Area Evaluation approach

The Selected Area Evaluation will focus on assessing the achievements of Commonwealth environmental watering in relation to the one and five year expected outcomes specific to the Lachlan river system Selected Area. The evaluation is based on analysis of the monitoring data collected and information/data about the watering action to answer the Level 3 evaluation questions (Table 7). The following sections outline the approach to answering these questions. Each section is based around a thematic group of indicators. Additional details are included in each of the Standard Operating Procedures (SOP’s) for monitoring the indicators (Appendix 1).

5.3.1 Zones and sites

The LTIM Project has adopted a hierarchical approach to the spatial elements of sampling design (Gawne et al. 2013) that involves Zones and Sites nested within the Selected Area. Zones are a subset of the Selected Area that represent a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. A site is the unit of assessment nested within a zone. The Lachlan river system Selected Area has been divided into Zones specific to the indicators measured. This recognises that temporal and spatial differences in specific flow-ecology responses (cf Roberts & Dyer 2007) means that Zones are best established based on knowledge of indicator responses to flow/landscape interactions within the Selected Area. Sites within each zone have been chosen to sample key environmental assets identified by the project team and priority has been given to sites for which historical data are available to aid the interpretation of ecological responses.

The delineation of zones within the Selected Area based on spatial differences in flow-ecology relationships means that the evaluation of outcomes for the Selected Area will be spatially explicit. It also means that without sampling multiple zones, it is not possible to provide a composite evaluation for the Selected Area. Given that the majority of the monitoring in the Lower Lachlan river system is confined to monitoring basin indicators (listed in Section 5.2.4) within a single zone, the data collected will be used to answer evaluation questions for zones within the Selected Area.

Zones for fish, other vertebrates and stream metabolism

The Lachlan river system Selected Area can be partitioned into five spatially, geomorphologically and hydrologically distinct river channel zones at a broad landscape scale (Figure 4 and Table 8). These zones are relevant to fish, stream metabolism and other vertebrates. Sampling strategies are based around these zones.

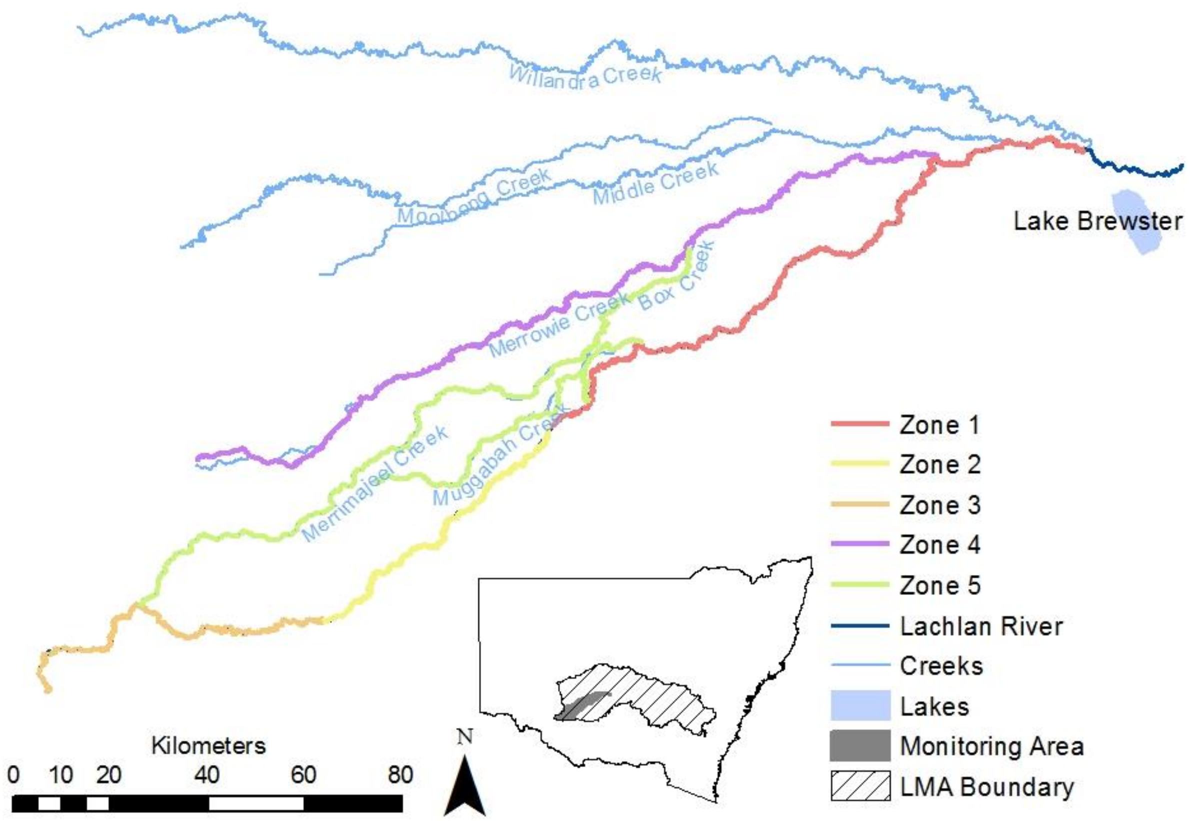

Figure 4 Map showing the extent of the Lachlan river system Selected Area and associated sampling zones

Table 8. Zones for the Lachlan river system Selected Area relevant to fish, other vertebrates, microcrustaceans and stream metabolism

ZONE	LOCATION	CHARACTER
Zone 1	Lachlan River channel between Brewster Weir and Booligal	This zone contains relatively high abundances of the required target species of fish (with potentially limited numbers of freshwater catfish). Situated in the upper reaches of the selected area, this zone also is likely to receive Commonwealth environmental water during every year of the LTIM Project.
Zone 2	Lachlan River channel between Booligal and Corrong	Located downstream of Booligal Weir and similar to Zone 1 in geomorphology. This zone differs hydrologically because of water diversion and extraction above Booligal Weir.
Zone 3	Lachlan River channel between Corrong and its terminus in the Great Cumbung Swamp	This zone starts at the point at which the mid-Lachlan wetland system re-enters (drains into) the main Lachlan channel, providing an increase in riverine productivity, stimulating food webs. The fish assemblages are currently dominated by alien species.
Zone 4	Merrowie Creek	A distributary creek that receives intermittent regulated stock and domestic flows as well as targeted environmental flows at Tarwong Lake and Cuba Dam. No data exist on the fish assemblage present within Merrowie Creek.

ZONE	LOCATION	CHARACTER
Zone 5	Torringanny, Box, Merrimajeel and Muggabah Creek system	The largely ephemeral, effluent streams of the Merrimajeel and Muggabah system north of the Lachlan main channel and Merrowie creek. This complex system is fundamentally different to main channel zones acting more like linear wetlands that are likely to only retain water for limited periods during and following environmental flow deliveries.

Zones for vegetation

The vegetation community in the Lachlan river system Selected Area is dominated by woodland communities, with river red gum and black box/river red gum communities prevalent in areas inundated by Commonwealth environmental water. Lignum and river cooba are found in mixed stands with black box and aquatic reeds; grasses and sedges are represented in some wetland sites. In relation to environmental watering, DECCW (2010) recognises two types of water dependent vegetation communities:

a. Amphibious or semi-permanent wetland communities that depend on frequent flooding (once per year) to maintain their structural integrity and community condition e.g. common reed (*Phragmites australis*), water couch grassland (*Paspalum distichum*), cumbungi (*Typha domingensis*) and mixed marsh.
b. Flood dependent communities - those that depend on flooding for the dominant overstorey species to complete their lifecycle e.g. river red gum (*Eucalyptus camaldulensis*) forest and woodland, river cooba (*Acacia stenophylla*) shrubland, lignum (*Duma florulenta*) shrubland, coolibah (*E. coolabah*) and blackbox (*E. largiflorens*) woodland.

There is no way to draw a line along or across the study area that neatly splits the study area for vegetation. Previous monitoring (e.g., Driver et al. 2004) has adopted a simplified version of Green's 1997 (Green 1997) wetland classification separating wetlands into swamps (relatively large, flat open systems) *versus* billabongs for sampling. The lack of clear delineation of vegetation types across the Selected Area means that the selection of zones is not supported. Instead, the vegetation response will be measured across the Selected Area and the evaluation stratified by Australian National Aquatic Ecosystem (ANAE) type (Brooks et al. 2013) and by the classification of Green 1997.

5.3.2 Evaluation: Ecosystem type

Ecosystem type is used in the Basin Evaluation and is an input to the analysis of the response of all indicators to Commonwealth environmental water. The approach to the use of ecosystem type data is outlined in Table 9.

Table 9. Lachlan river system Selected Area evaluation approach using ecosystem type data.

INDICATOR	ECOSYSTEM TYPE
MONITORING QUESTIONS	BASIN EVALUATION: • What did commonwealth water contribute to sustainable ecosystem diversity? • Were ecosystems to which commonwealth environmental water was allocated sustained? • Was commonwealth environmental water delivered to a representative suite of ecosystem types? AREA EVALUATION: N/A
Cause and effect diagram	Landscape ecosystem diversity
Monitoring strategy	It is generally assumed that freshwater ecosystems of similar ecosystem type and geographical location will respond in a similar, predictable fashion to flow components. This is frequently the basis for translating management actions to areas for which response data are not available. By using a broad scale classification of river and wetland type it is possible to stratify the analysis of ecosystem responses to determine if sites of the same ecosystem type within a selected area respond in a similar fashion to watering. The interim Australian National Aquatic Ecosystem (ANAE) classification framework is the proposed method for defining and delineating aquatic systems through the Murray Darling Basin. Thus for each site that is monitored an ANAE classification is required and field validation of ANAE type is required to have confidence in the ANAE Classification.
Methods	Standard Operating Procedure: Lachlan river system Selected Area ecosystem type. Monitoring involves both desktop and field verification of all sites monitored.
Zones	Not relevant – site based assessment
Data obtained	ANAE unique identifier (SYSID) for each sampling site. Dominant vegetation type for each ANAE SYSID Confirmed ANAE type
Evaluation	Questions will be answered as part of the Basin Evaluation. No specific Area evaluation questions exist. Where possible, the ANAE type will be used to stratify analyses to determine if sites of the same ecosystem type respond consistently to watering. This is particularly useful where there are a low number of wetland sites likely to be watered multiple times within the Lachlan river system Selected Area.

5.3.3 Evaluation: Vegetation

The recruitment, diversity and condition of riparian and wetland vegetation communities, including long-lived floodplain and riparian trees, is strongly influenced by the frequency and extent of inundation (Brock & Casanova 1997; Kingsford 2000). Flooding interacts with plant life-history processes such as dispersal, germination, recruitment, survival, growth, and reproduction. Although some native wetland species can thrive in permanently wetted habitats, flooding of previously dry habitats is a major stimulus to production of water plants and their associated biota (e.g. Briggs & Maher 1985). It is expected that the provision of environmental water will:

- Improve floodplain and riparian tree condition.
- Improve floodplain and riparian vegetation health.
- Promote recruitment of floodplain and riparian trees.
- Contribute to vegetation species and community diversity.

Evaluating the response of vegetation diversity and condition will build on an existing body of work undertaken by NOW (and precursor agencies) as a part of the Integrated Monitoring of Environmental Flows (IMEF) program (Chessman & et al 2003 Driver, Barbour & Michener 2011; Driver et al. 2010; Driver et al. 2003). The approach to the evaluation of vegetation diversity and condition data is outlined in Table 10.

Table 10. Lachlan river system Selected Area evaluation approach for vegetation diversity and condition

INDICATOR: VEGETATION DIVERSITY AND CONDITION	
MONITORING QUESTIONS	AREA EVALUTION: LONG-TERM (FIVE-YEAR) QUESTION: • What did Commonwealth environmental water contribute to populations of long-lived organisms? • What did Commonwealth water contribute to vegetation species diversity? • What did Commonwealth environmental water contribute to vegetation community diversity? SHORT-TERM (ONE-YEAR) AND LONG-TERM (FIVE YEAR) QUESTIONS: • What did Commonwealth environmental water contribute to the condition of floodplain and riparian trees?
Cause and effect diagram	Area Scale: Landscape vegetation diversity; vegetation condition and reproduction
Monitoring strategy	Changes in the condition, extent and life history of key plant species and communities in the Lachlan river system Selected Area (e.g. black box, cooba, river red gum and reed beds) will be measured in relation to the provision of Commonwealth environmental water, taking into account the effects of landscape context, historical flows and land use. Condition metrics will be obtained from measures of cover for each structural layer, the number of dead trees (both standing and fallen), the recruitment density, canopy condition and the proportion of native/non-native species. Species and community diversity will be obtained from measures of species richness and cover for each vegetation community type / functional group. Vegetation data will be collected from fixed locations before and after the watering season and as such is scheduled to occur March/April, and three months after first fill. The sampling design captures different vegetation communities at different elevations and locations within the wetland and / or river from submerged communities in the river or wetland bed through to emergent or littoral vegetation at the edges of aquatic ecosystems.
Zones/Sites	The method does not use Zones, but uses fixed sites within and among years. One of the key reasons for this is the need for detailed hydrology at each site, and the resources required to develop flow-inundation relationships at new sites every year or even every few years would be too high. The other key consideration is the availability of existing flow-biota relationships, hydrology and bathymetry at many of the proposed sites. Additionally, the use of fixed sites allows the control of some of the confounding issues affecting vegetation condition and diversity.
Methods	Standard Operating Procedure: Lachlan river system Selected Area vegetation diversity and condition
Data obtained	Cover for each structural layer Number of dead trees (both standing and fallen) Species presence (including native/non-native) Species richness for each vegetation community type/function group Recruitment density Canopy condition

Evaluation/ Analysis	For each survey occasion, Spearman rank correlations will be calculated between the historical dry period frequency and the number of plant species on the banks and in the water to determine the contribution of Commonwealth environmental water to species diversity. Similar analyses will be conducted for abundance (cover) of species and function groups. The recruitment and condition of key riparian species (river red gum, black box, coolabah and river cooba) will be analysed with respect to the duration of watering using univariate and graphical methods to determine the contribution of Commonwealth environmental water to populations of long-lived organisms. For floodplain and riparian vegetation communities (dominated by flood dependent trees in the overstorey) temporal changes in tree canopy condition statistics with Commonwealth environmental watering will be analysed using graphical and univariate analysis methods. Changes in tree condition will be analysed in the context of antecedent wetting, climate (particularly temperature) and seasonal effects. Similar analyses will be conducted using metrics of vegetation community condition which incorporate elements of structure and cover. Multivariate analyses (using measures of dispersion from MDS plots) will be used to detect changes across multiple elements of the vegetation community in relation to the duration of watering. Multiple regression will be used to determine effects on plant condition and diversity in the context of antecedent wetting, climate (particularly temperature), seasonal effects, adjacent landuse and disturbance. The use of fixed sites which are monitored each year will provide data with a range of antecedent watering conditions (including sites that are not watered) thus enabling more sophisticated analyses (using Boosted Regression Trees) to be used to determine the effects of watering within the context of antecedent conditions to be determined. Data from IMEF monitoring that occurred in both drought conditions (2002-2009) and wet conditions (1998-2000, 2010/2011) will provide key baselines from which to assess the benefit of environmental watering. In addition, data collected as part of river red gum health monitoring in Murrumbidgil Swamp in 2012/13 and vegetation diversity and condition data from Lake Waljeers, Lake Ita and the Great Cumbung Swamp in 2012/13 can also be used to contribute to baseline data. Evaluation will also be informed by the ANAE class and the categories of Green 1997.

5.3.4 Evaluation: Fish

Riverine fish

Flow plays an important role in the life-cycle of native fishes from larval through to adult life stages. Water may inundate habitat needed for reproduction, triggering a spawning response, create a boost in primary production that improves recruitment success, improve habitat condition through maintaining natural geomorphic processes or natural refugia during drought periods, or stimulate in-stream migration. Temporal changes in the abundance and diversity of native fishes in the Lachlan river system Selected Area will be monitored within a single zone over the five year period as part of the monitoring of basin indicators. These data will be used to evaluate the outcomes of Commonwealth environmental water for riverine fish in a single zone of the Selected Area and the approach to this evaluation is outlined in Table 11.

Table 11. Lachlan river system Selected Area evaluation approach for riverine fish.

INDICATOR: RIVERINE FISH	
MONITORING QUESTIONS	AREA EVALUTION: LONG-TERM (FIVE-YEAR) QUESTION: • What did Commonwealth environmental water contribute to native fish populations? • What did Commonwealth environmental water contribute to native fish species diversity? • What did Commonwealth environmental water contribute to native fish community resilience? • What did Commonwealth environmental water contribute to native fish survival? SHORT-TERM (ONE-YEAR) QUESTIONS: • What did Commonwealth environmental water contribute to biotic dispersal? • What did Commonwealth environmental water contribute to native fish community resilience?
Cause and effect diagram	Revised landscape fish diversity; revised fish condition; revised fish reproduction (Appendix 1)
Zones	Zone 1: Lachlan River channel between Brewster Weir and Booligal.
Monitoring strategy	Long term changes in abundance, diversity, resilience or individual body condition will be measured using field data collected annually (March) in Zone 1 as part of the Basin Evaluation. Abundance will be measured as CPUE (catch per unit effort), diversity as the number of species caught, resilience as a combination of SRA indices (nativeness, expectedness and recruitment) and population structure and individual body condition will be measured as length and mass from individual fish collected. Should cease to flow conditions occur within the Lachlan river system Selected Area and coincide with the field season, native fish populations within individual drought refugia will be monitored for survival and condition.
Methods	Standard Operating Procedure: Lachlan river system Selected Area riverine fish
Data obtained	Relative abundance; Species diversity; Length and mass of target species Length and age of target species (population structure for target species)

Evaluation/ Analysis	Evaluation will use data collected in Zone 1 for Basin Evaluation to report on the outcomes of watering within Zone 1 of the Selected Area. Long term changes in CPUE of individual species and native species richness will be analysed using parametric univariate ANOVA using year as the factor. In the same way, changes in fish assemblages will be analysed using non-parametric PERMANOVA (Primer 6). The effect size of changes in CPUE of individual species in relation to flow components (categorical variable) or hydrological parameters (continuous variables) will be analysed. Long term changes in individual body condition and CPUE or proportion of new recruits and sexually mature individuals within populations will be analysed using parametric univariate ANOVA using year as the factor. Long-term changes in length-frequency distributions of individual species will be undertaken using Kolmogorov-Smirnov tests for those species where > 50 individuals are collected in both years one and year five. The SRA derived indicators (expectedness, nativeness, recruitment and fish condition) will be compared across time to determine if the overall catch composition improved with the delivery of Commonwealth environmental water. Parametric univariate ANOVA using year as the factor will be used to conduct these analyses. The proportion of monitoring sites occupied by olive perchlet will be plotted against year to display whether this species is expanding its distribution within the Lachlan river system Selected Area in response to Commonwealth environmental water. Effect size data derived from annual sampling in Zone 1 will be correlated with hydrological features (flood pulse duration and magnitude, dry spell duration and total flow volume) quantified within each season (summer-autumn-winter-spring) using meta-analysis methods. The effect size of changes in CPUE of new recruits in relation to flow components (categorical variable) or hydrological parameters (continuous variables) will be analysed. The back-calculated spawning date of daily aged small juvenile fish collected during post-flow sampling will be plotted along with river height (or flow volume) to identify if spawning coincided with a specific feature of the hydrograph. If a pattern emerges, options for formal analysis will be investigated. If cease to flow conditions occur as a result of drought, the species composition of fish assemblages found within refugia will be compared with the assemblage structure found within that zone prior to cease to flow conditions and if possible to the assemblage found in the zone once base flow conditions return. Changes in CPUE, size frequency distributions and relative body condition of species isolated within drought refugia through time will also be analysed to determine the effect of Commonwealth environmental water on the provision of effective refugia for native fish. Evaluation will draw on data collected annually at seven sites within the Lower Lachlan river channel commencing in 2007 (Gilligan, Jess & McLean 2010) as well as other published fish data from the region (e.g. Davies et al. 2010; Growns 2001, 2008; Harris & Gehrke 1997; Price 2009; Wallace & Bindokas 2011) and unpublished data (e.g. data from nine sites in the river channel, floodplain and marsh lakes within the Great Cumbung Swamp during an inundation event in 2010/11, held by NSW DPI Fisheries) to expand the time series used in the data analysis.

Larval fish

Aspects of the flow regime are central to the recruitment of many native fish species (e.g. Junk, Bayley & Sparks 1989; King, Humphries & Lake 2003; Balcombe et al. 2006; Humphries, King & Koehn 1999). Temporal changes in the larval abundance and diversity of native fishes in the Lachlan river system Selected Area will be monitored within a single zone over the five year period as part of the monitoring of basin indicators. These data will be used to evaluate the outcomes of Commonwealth environmental water for larval fish in the single zone of the Selected Area and the approach to this evaluation is outlined in Table 12.

Table 12. Lachlan river system Selected Area evaluation approach for larval fish.

INDICATOR: LARVAL FISH	
MONITORING QUESTIONS	AREA EVALUTION: LONG-TERM (FIVE-YEAR) QUESTION: • What did Commonwealth environmental water contribute to native fish populations? • What did Commonwealth environmental water contribute to native fish diversity? SHORT-TERM (ONE-YEAR) QUESTIONS: • What did Commonwealth environmental water contribute to native fish reproduction? • What did Commonwealth environmental water contribute to native larval fish growth? • What did Commonwealth environmental water contribute to native fish survival?
Cause and effect diagram	Area Scale:: Fish reproduction; fish larval growth and survival
Zones	Zone 1: Lachlan River channel between Brewster Weir and Booligal.
Monitoring strategy	Larval fish will be monitored at 3 riverine sites in one zone for five sampling events per year (in a watering event based approach). Changes in abundance will be measured as CPUE (catch per unit effort) and diversity as the number of species caught. The age structure of the fish population will be inferred using length / age relationships previous established for each species.
Methods	Standard Operating Procedure: Lachlan river system Selected Area larval fish
Data obtained	Relative abundance of larval native fish; Population structure (age versus length)
Evaluation/ Analysis	The contribution of Commonwealth environmental water to native fish reproduction will be assessed using the abundance of larval native fish from each of the sites sampled. These data will be analysed using parametric univariate ANOVA using year as the factor. In the same way, changes in larval fish assemblages will be analysed using non-parametric PERMANOVA (Primer 6). Changes in CPUE of larval fish for each species in relation to flow components (categorical variable) or hydrological parameters (continuous variables) will be analysed. Interpretation of results will be set in the context of covariates relevant to larval fish in the Lachlan river system Selected Area. The contribution of Commonwealth environmental water to larval fish growth (hence recruitment) will be determined by analysing age versus length ratios using parametric univariate ANOVA with year as the factor. Interpretation of results will be set in the context of covariates relevant to growth and survival of larval fish such as water quality. Changes in in relation to flow components (categorical variable) or hydrological parameters (continuous variables) will also be analysed. Analysis of larval abundance and species diversity over the 5 years will be used to gauge the contribution of Commonwealth environmental water to native fish populations and diversity in the Lachlan river system Selected Area.

5.3.5 Evaluation: Waterbirds (Optional Indicator)

Waterbird breeding

Booligal wetlands have consistently been among the more important wetlands for bird breeding in the Murray-Darling Basin, based on annual surveys of all major bird breeding sites (Kingsford et al. 2013). They support a range of different waterbird species which establish with environmental flows. There are also consistently high breeding events on the Booligal wetlands during large flow events (Kingsford et al. 2013; Magrath 1992; Maher 1990). The breeding of colonial waterbirds is triggered by flows and flood events need to be maintained for more than 50 days to ensure successful breeding. Should a natural bird breeding event be triggered within Booligal wetlands, flows will be managed to ensure that the greatest opportunity for breeding success. It is therefore expected that environmental watering will improve the success of natural bird breeding events in Booligal wetlands. The approach to the evaluation is given in Table 13.

Table 13. Lachlan river system Selected Area evaluation approach for waterbird breeding

INDICATOR: WATERBIRD BREEDING	
MONITORING QUESTIONS	BASIN AND AREA SCALE EVALUTION: LONG TERM (5YR) QUESTIONS What did Commonwealth environmental water contribute to waterbird populations? SHORT TEM (1YR) QUESTIONS What did Commonwealth environmental water contribute to waterbird breeding? What did Commonwealth environmental water contribute to waterbird chick fledging? What did Commonwealth environmental water contribute to waterbird survival?
Cause and effect diagram	Waterbird recruitment and fledging; waterbird reproduction
Zones	Site specific for breeding events and not limited to zones
Sites	Booligal wetlands. Historically, the Booligal wetlands have been the site of frequent breeding events involving a diverse group of species and are the only likely target of environmental watering to support waterbird breeding.
Monitoring strategy	Waterbird breeding will be monitored at fortnightly intervals following observations of colonial nesting. Monitoring will be triggered by a request from the Commonwealth Environmental Water Office.
Methods	Standard Operating Procedure Lachlan river system Selected Area waterbird breeding
Data obtained	Nests per vegetation type Number of nests in each nesting stage Number of nests successfully fledged Mean number of chicks fledged Number of adults of each species
Evaluation/ Analysis	Within each breeding colony estimates of total species abundance, the phenology of breeding and the mean clutch size for each species will be calculated using the primary field data. Where reasonable, results will be extrapolated to obtain estimates for the entire colony. Reproductive success will be determined using the hatching rates for each species in each colony and a categorisation of data into three groups: egg, chick and nest. Success will be determined for periods between surveys. For example, if at the end of each time period between surveys the nest contained

eggs or chicks it was scored 1, if neither then 0. Data will be further analysed based upon date of first survey of that site. All survey sites will be initially sampled at egg stage. Date of first survey will be used as a surrogate for laying period in data analyses. Analyses will be grouped based upon date of first survey of that site.

Each measure of nest success will be included as response variables in subsequent modelling. A successful nest will be defined as a nest that produced at least one chick at the end of the observation period. To test for timing, water depth, food availability and predator density effects on breeding success logistic regression will be used to examine the relationship between the date of nest establishment and offspring success. We will investigate flow thresholds for breeding and breeding success using historical data and data collected through the LTIM Project.

Generalised additive models (GAM) will be developed to understand the relationships between variables for breeding of ibis and spoonbills. Several models will be developed including the relationship between clutch sizes, lay date (relative to the delivery of water) and nest site size, hydrological variables including water depth and water quality variables including pH, conductivity, DO, turbidity and temperature.

Previously published data (e.g. Driver et al. 2004; Kingsford et al. 2013; Magrath 1992; Maher 1990) and nest record data from BirdLife Australia will provide historical data that can be used to augment the analysis and contribute to the development of models.

5.3.6 Evaluation: Stream metabolism

Environmental flows may be expected to influence water quality and stream metabolism in a number of ways.

1) Inundation of terrestrial habitat may increase concentrations of nitrogen, phosphorus and dissolved organic carbon (DOC) which may in turn support increased gross primary production (nitrogen, phosphorus) and ecosystem respiration (DOC).
2) Extensive and prolonged inundation of terrestrial habitat may greatly increase DOC and therefore ecosystem respiration, resulting in depleted surface water oxygen levels (a 'blackwater event').
3) Increased channel depth may act to shade benthic biofilms and macrophytes, reducing gross primary production.
4) Increased water volumes may dilute phytoplankton cells (resulting in lower gross primary production) but then provide increased habitat and nutrients (see 1) that may then allow a 'rebound' effect resulting in higher gross primary production.

These effects act to alter the amount of energy flowing into aquatic food webs and thus to higher consumers such as invertebrates and fish. The approach to evaluating the response of stream metabolism to Commonwealth environmental water is outlined in Table 14.

Table 14. Lachlan river system Selected Area evaluation approach for stream metabolism and water quality.

INDICATOR: STREAM METABOLISM AND WATER QUALITY	
MONITORING QUESTIONS	AREA EVALUTION: LONG TERM (5YR) AND SHORT TERM (1 YR) QUESTIONS: • What did Commonwealth environmental water contribute to patterns and rates of primary productivity? • What did Commonwealth environmental water contribute to patterns and rates of decomposition?
Cause and effect diagram	Primary production Decomposition Nutrient cycling
Zones / Sites	Zone 1: Lachlan River channel between Brewster Weir and Booligal. We have selected Zone 1 as the zone for the evaluation of stream metabolism responses (where sampling methods will follow standard protocols). The four target reaches for stream metabolism are: Lanes Bridge, Whealbah Bridge, Willanthery and Cowl Cowl.
Monitoring strategy	Continuous measurement of detailed oxygen and temperature concentrations within four areas within Zone 1. With the mobility of fish and the extent over which the metabolism measures integrate, the four reaches will provide coverage over the extent of the 10 fish sites. These data, when combined with measures of the channel slope, amount of turbulence and flows, can be used to measure the total amount of photosynthetic activity by aquatic plants, algae and phytoplankton (amount of oxygen added to the channel during daylight) and the amount of respiration by animals and microbes (the amount of oxygen consumed during darkness). This provides a measure of energy flow through the aquatic food web.
Methods	Standard Operating Procedure Lachlan river system Selected Area stream metabolism and water quality

Data obtained	Gross Primary Production (GPP) Ecosystem Respiration (ER)
Evaluation/ Analysis	This method adopts the approach of determining gross primary production (GPP), ecosystem respiration (ER) and re-aeration rate (K_{O2}) from the diel dissolved oxygen curves. These parameters will be calculated from the raw data using curve fitting software (Grace et al., unpublished) as provided to the LTIM Project via the Govdex website. The model uses data for dissolved oxygen in mg O_2/L, temperature, PAR and barometric pressure (in atmospheres) at 10 minute intervals, together with information on salinity which will be derived from the monthly EC values. The model provides estimates of GPP and ER in mg O_2 /L/Day with uncertainties for each and goodness of fit parameters. Patterns in ER are indicative of decomposition, while GPP indicates primary production. Correlations between GPP, ER and likely key predictors will be assessed. In particular the effects of 1) water quality parameters and 2) stream height/provision of environmental flows on ER and GPP will be assessed. These relationships are highly non-linear and typified by thresholds in other systems. The majority of analyses are likely to be descriptive based on responses to changes in flow, and illustrated using scatterplots. If the data are available, non-linear multiple regression may be applied to identify key drivers of GPP and ER. Analyses will be stratified seasonally and by antecedent flow conditions to determine contingent responses. Historical water quality data sets held by partner organisations (particularly data collected by Lachlan CMA and NSW Office of Water) will be used to contextualise the evaluation of data collected as part of the LTIM Project.

5.3.7 Evaluation: Other vertebrates

Frogs (Optional Indicator)

The diversity and abundance of frog populations within wetlands is strongly influenced by the duration of watering and the time between watering events (Amos, Wassens & Luck 2013; Baber et al. 2004; Pechmann et al. 1989). It is expected that the provision of environmental water will

- Trigger a breeding response of frogs within wetlands,
- Maintain the diversity and abundance of frog populations,

The approach to evaluating the response of frogs to Commonwealth environmental water is outlined in Table 15.

Table 15. Lachlan river system Selected Area evaluation approach for frogs.

INDICATOR: FROGS	
MONITORING QUESTIONS	AREA EVALUTION: LONG TERM QUESTIONS • What did Commonwealth environmental water contribute to frog populations? • What did Commonwealth environmental water contribute to frog species diversity? SHORT TERM QUESTIONS • What did Commonwealth environmental water contribute to frog reproduction and recruitment? • What did Commonwealth environmental water contribute to frog survival?
Cause and effect diagram	Other vertebrate growth and survival Other vertebrate reproduction
Zones	Zone 1 Lachlan River channel between Brewster Weir and Booligal. Zone 2 Lachlan River channel between Booligal and Corrong. Zone 3 Lachlan River channel between Corrong and its terminus in the Great Cumbung Swamp Zone 4 Merrowie Creek Zone 5 Torringanny, Box, Merrimajeel and Muggabah Creek system.
Monitoring strategy	Annual and event based monitoring Monitoring of frogs will take place three times per year between August and February. This falls across three seasons (winter, spring and summer) allowing for seasonal variation in species to be captured and coinciding with the likely timing of watering. The diversity and abundance of both adults and metamorphs will be recorded. Sampling will be conducted within an average of fifteen wetland sites per year The actual number of sites surveyed in any one year will vary depending upon hydrological conditions, i.e. in dry years, fewer than 15 sites may be surveyed, and in wet years more than 15 sites may be surveyed.
Methods	Standard Operating Procedure Lachlan river system Selected Area frogs
Data obtained	Species abundance; Species diversity
Evaluation/ Analysis	Habitat occupancy modelling will be used to evaluate the contribution of Commonwealth environmental water to frog populations, species diversity, and survival. The basis for habitat occupancy modelling is presence/absence data for frog species repeatedly collected at a number of wetland locations with varying habitat characteristics. Data describing variables that define habitat characteristics are also collected, with primary data including hydrological variables that describe the wetting drying regime and connectivity of the habitat wetland. Statistical binomial models produced using maximum likelihood

	estimation that incorporate occupancy and detection variables following the techniques of MacKenzie et al. 2002 are appropriate for the analysis of frog species that can have low detection probabilities. The outputs of habitat occupancy modelling will determine the components of the Commonwealth environmental water that contributed, both directly and indirectly through related vegetation characteristics, to frog populations, species diversity, and survival (through the use of refugia in dry periods). This modelling approach using tadpole data as a primary input will also determine the contribution of Commonwealth environmental water to providing conditions favourable to frog recruitment. Evaluation will draw on past survey work from in the region (Amos, Wassens & Luck 2013; Wassens & Maher 2011) that will expand the data used to develop the habitat occupancy modelling. Previously published data from across the Murray-Darling Basin (e.g.: Wassens 2008, 2010; Wassens 2011; Wassens & Amos 2011; Wassens, Arnaiz & Watts 2007; Wassens et al. 2010; Wassens & Maher 2011; Wassens et al. 2011) will be used to compare and verify models developed specifically for the Lachlan river system Selected Area.

Other vertebrates: Freshwater decapods (freshwater crayfish and shrimp) and turtles

Temporal changes in the abundance of decapods in the rivers of the Lachlan river system Selected Area will be examined serendipitously over the five year period to evaluate the outcomes of Commonwealth environmental water. Temporal changes in the abundance of turtles may similarly be examined if resources permit. The approach to this evaluation is outlined in Table 16.

Table 16. Lachlan river system Selected Area evaluation approach for other vertebrates

INDICATOR: OTHER VERTEBRATES (DECAPODS AND TURTLES)	
MONITORING QUESTIONS	AREA EVALUTION: LONG TERM QUESTIONS • What did Commonwealth environmental water contribute to other vertebrate populations? • What did Commonwealth environmental water contribute to other vertebrate species diversity? SHORT TERM QUESTIONS • What did Commonwealth environmental water contribute to other vertebrate reproduction and recruitment? • What did Commonwealth environmental water contribute to other vertebrate survival?
Cause and effect diagram	Other vertebrate growth and survival Other vertebrate reproduction
Zones	Zone 1 Lachlan River channel between Brewster Weir and Booligal.
Monitoring strategy	Monitoring of decapods will take place annually in conjunction with fish surveys in rivers. Monitoring of turtles may also occur in conjunction with fish surveys in rivers if sufficient time and resources permit. Long term changes in abundance will be measured using field data collected annually (March) in Zone 1. Abundance will be measured as CPUE (catch per unit effort). Diversity, and individual body condition will be recorded if sufficient time permits in the field processing of fish samples. Diversity will be measured as the number of species caught, and population structure and individual body condition will be measured as length and mass from individuals collected.
Methods	Standard Operating Procedure Lachlan river system Selected Area other vertebrates decapods and turtles)

Data obtained	Species abundance Species diversity (possible) Individual body condition (possible).
Evaluation/ Analysis	The Commonwealth environmental water contribution to other vertebrate abundance and diversity will be established by analysing long term changes in CPUE of individual species numbers and, if the data permits, native species richness. The analysis will be conducted using parametric univariate ANOVA using year as the factor. In the same way, changes in other vertebrate assemblages on an annual and five year basis will be analysed using non-parametric PERMANOVA (Primer 6).

6 Selected Area schedule of monitoring

6.1 Overview of monitoring

The five year monitoring schedule has been based around the expected watering options described in Section 3.2.1 and Section 3.2.2. The focus of the monitoring on Basin Indicators means that the monitoring effort is consistent across the five years with the exception of monitoring Waterbird Breeding and Frogs which are options that can be implemented on the basis of a request from the CEWO. The annual watering priorities and the implementation plans (refer to section 3.5) will be used to give an indication of the likelihood of implementing the optional monitoring for the coming watering year.

6.2 Sampling regime and monitoring schedule

The proposed sampling regime includes three types of temporal monitoring:

1. Continuous monitoring: provides ongoing data collection, e.g. primary production and respiration.
2. Regular monitoring: provides regular sampling of a suite of variables which provide information on unpredictable natural flow events, which are important points of comparison for environmental flow events.
3. Event-based monitoring: provides an efficient use of limited resources to measure detailed responses to planned environmental flows.

The monitoring frequency depends on the indicator being investigated. The focus on regular monitoring of Basin Indicators, confines the majority of the sampling schedule to a fixed set of dates within each year. A summary of the indicators and timing of monitoring is presented in

Table 17. This will be refined each year in response to climate conditions, annual watering priorities and implementation plans and a work schedule will be established in July and January of each year and reviewed quarterly.

Table 17 Overview of the monitoring frequency for each of the indicators monitored for the Lachlan river system Selected Area

INDICATOR	MONITORING FREQUENCY	SITES	EXPECTED SCHEDULE
Ecosystem type	Once only	All sites	Establishment of ANAE type at the start of the LTIM Project. Expected August-December 2014
Vegetation diversity and condition	ANNUAL & EVENT BASED	12 fixed sites	Before and after watering (expected to be April/May and 3 months after first fill)
Riverine fish	ANNUAL	Basin Evaluation: 10 fixed sites within Zone 1	Annual sampling between March and May
Larval fish	ANNUAL	3 fixed riverine sites in Zone 1	Annual sampling 5 times during breeding season (September to February)
Waterbird breeding (Option)	EVENT-BASED (on request from the CEWO)	One fixed site – Booligal wetland	Fortnightly surveys of bird breeding triggered by breeding events in Booligal wetland. Assumes 3 breeding events in 5 years.
Stream metabolism	CONTINUOUS REGULAR	Four fixed sites matched to riverine fish sampling sites in Zone 1	Continuous monitoring of dissolved oxygen and, temperature. 6 weekly sampling of nutrients and water quality attributes.
Frogs (Option)	EVENT-BASED (on request from the CEWO)	15 sites comprising 2 to 8 wetland sites and 2 to 7 riverine sites depending on watering targets	3 sampling events between August and February (one sample in each of winter, spring and summer).
Decapods and turtles	ANNUAL	10 fixed riverine sites (matched to riverine fish) in zone 1	Annual sampling between March and May.
Hydrological monitoring	CONTINUOUS	Gauging sites	
	EVENT-BASED (in conjunction with Waterbird Breeding or Frog monitoring)	Cameras at 6 roving wetland sites	Cameras installed prior to targeted watering each year and downloaded after the watering event has passed

7 Communication and engagement

There are two elements to communication and engagement for the M&E Plan for the Lachlan river system Selected Area. The first is internal project communication which relates to the communication activities associated with the core operation of the M&E Plan and includes the project team, the CEWO and key water delivery stakeholders. The second is external communication and engagement which involves stakeholder groups outside of the core operation of the M&E Plan and includes landholders, affected communities and the general public. This communication and engagement plan outlines the approach to these two elements in Sections 7.1 and Section 7.2 respectively.

7.1 Internal project communications

The aims of the internal project communications activities are to work with core stakeholders to:

1. Facilitate smooth and efficient implementation of the M&E Plan.
2. Facilitate engagement and build relationships among core stakeholders.
3. Disseminate learning and results from project activities.
4. Contribute to on-going adaptive management associated with environmental watering.

The core stakeholders are those who are directly involved in the delivery of the M&E Plan (known as the project team, Table 18) and the delivery of environmental water within the Lachlan river system Selected Area (known as operational stakeholders, Table 19). A range of activities and actions have been identified that meet the aims of the internal project communications and these are outlined below.

Table 18. Project team

TEAM MEMBER	RESPONSIBILITY
UNIVERSITY OF CANBERRA	
Dr Fiona Dyer	Project leader, hydrology and vegetation monitoring
Mr Ben Broadhurst	Project delivery and larval fish
Mr Rhian Clear	Larval fish monitoring and project support
Associate Professor Mark Lintermans	Fish monitoring advice
Professor Ross Thompson	Primary production and water quality
UNIVERSITY OF NEW SOUTH WALES	
Dr Kate Brandis	Waterbirds
CHARLES STURT UNIVERSITY	
Dr Andrew Hall	Frogs, spatial and data analysis
NSW DEPARTMENT OF PRIMARY INDUSTRIES - FISHERIES	
Dr Jason Thiem	Riverine fish, turtles and decapods
Mr Martin Asmus	Riverine fish, turtles and decapods

TEAM MEMBER	RESPONSIBILITY
NSW OFFICE OF WATER	
Dr Patrick Driver	Vegetation
LOCAL LAND SERVICES	
Mr Fin Martin	Communication and engagement
Dr Jo Lenehan	Communication and engagement; vegetation monitoring
NSW OFFICE OF ENVIRONMENT AND HERITAGE	
Dr Sharon Bowen	Vegetation monitoring strategic advice
Dr Neil Saintilan	Strategic advice
COMMONWEALTH ENVIRONMENTAL WATER OFFICE	
LTIM Project Lachlan contact	Coordination between the CEWO and the project team

Table 19. Operational stakeholders

STAKEHOLDER
COMMONWEALTH ENVIRONMENTAL WATER OFFICE
Lachlan Contact LTIM Project
Lachlan Contact: Environmental Water Use
NSW OEH
Senior Environmental Water Management, Regional Operations Group with responsibility for the Lachlan River Watering
LACHLAN RIVERINE WORKING GROUP
Chair of Lachlan Riverine Working Group
Members of the Lachlan Riverine Working Group
CENTRAL TABLELANDS LOCAL LAND SERVICES
Team Leader
Senior Land Services Officer, High Conservation Value Aquatic Ecosystems

7.1.1 Lines of communication

The project team structure and expected lines of communication are illustrated in Figure 5. As the project leader, Fiona Dyer (IAE, University of Canberra) is the main point of contact for all project communications. Fiona is supported by Ben Broadhurst who is secondary point of contact for the project. Fiona will provide the conduit between the project team and CEWO staff, will coordinate formal communication activities between the core stakeholders and will be copied in to the majority of communication within the team.

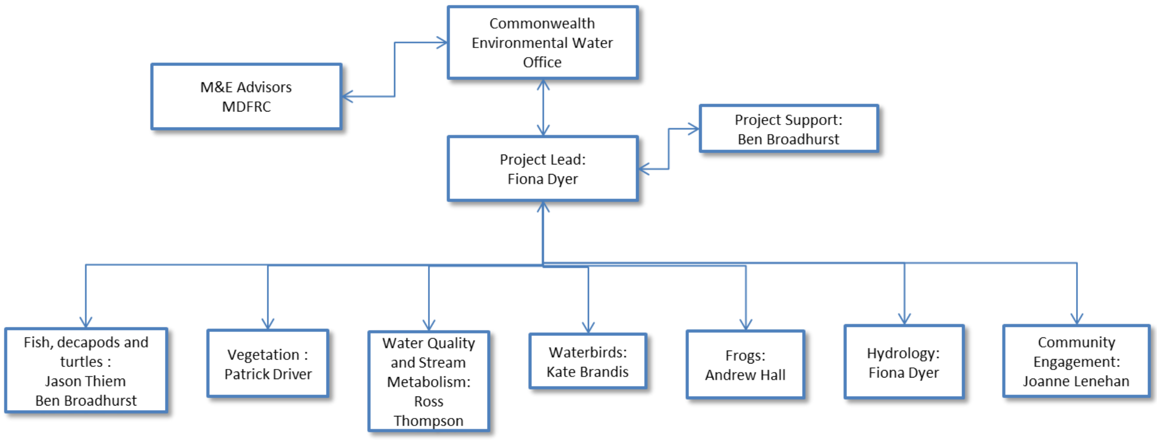

Figure 5. Project team structure and expected lines of communication.

7.1.1 Communication activities

Project team

Internal communication within the project team comprises a mix of informal contact (conversations, e-mails) and formal activities (teleconferences, face to face meetings and workshops and published documentation). Informal communication within the project team will be key to building relationships within the team that will facilitate the smooth and efficient implementation of the M&E Plan.

For a project of this scale and longevity, the majority of communication activities need to be conducted with some degree of formality to ensure that key decisions are communicated widely, messages are not confused and there is efficient use of time. A series of internal project activities are scheduled throughout the life of the project to ensure that monitoring is conducted in a coordinated and efficient fashion, and that project team members are able to learn from each other's field experiences, data collection and evaluation. These activities are outlined in Table 20.

Operational stakeholders

Communication with the operational stakeholders will predominantly be through the Lachlan LTIM Reference Group (Table 21). This group was established to "provide a forum for the exchange of information and intelligence that supports the implementation of the LTIM Project, through effective coordination of environmental watering, and monitoring and evaluation" (refer to the Terms of Reference in Appendix 2). This group provides the primary mechanism for the dissemination of information between key operational stakeholders and the project team and thus contributes to the ongoing adaptive management associated with environmental watering the Lachlan river system Selected Area. The Lachlan LTIM Reference Group will meet quarterly via phone.

Table 20. Communication activities for the Lachlan river system Selected Area LTIM Project.

ACTIVITY	OBJECTIVE	WHO	LOCATION/ METHOD	RESPONSIBILITY	TIMING	TIME COMMITMENT
PROJECT TEAM						
Monthly project status/progress catch ups	Regular contact between project leader and the CEWO contact. Project updates to • ensure project is tracking as expected • deal with any issues arising from the monitoring • communicate early observations from monitoring	CEWO contact and project leader	Teleconference	Timing will be coordinated by the project leader	Monthly	12 x 1/2 hour per year (63 in total)
Regular project team meetings	Regular contact between Theme leaders to • establish and revise workplans • ensure project is tracking as expected • deal with any issues arising from the monitoring • communicate early observations from monitoring	Theme leaders	Teleconference chaired by the project leader.	Timing will be coordinated by the project leader.	Quarterly prior to the delivery of the quarterly reports to the CEWO or as required	4 hr per year
Quarterly reporting to CEWO	Quarterly written project status/progress reports provided to the CEWO.	Theme leaders	Written project status report	Project leader to coordinate	Last business day of September, December, March and June each year	A total of 21 progress reports over the project duration, with the first in September 2014 and the last in September 2019.

ACTIVITY	OBJECTIVE	WHO	LOCATION/ METHOD	RESPONSIBILITY	TIMING	TIME COMMITMENT
Annual Outcomes Report	An annual outcomes report will be provided to the CEWO.	Theme leaders	Written outcomes report	Coordinated by the project leader	Draft – Aug 30 Final – Oct 31 First report – 2015 Final report - 2019	
Initial field campaign	Establish team Establish field sites and conduct initial ANAE verification Method training and method validation where required	Project team	Selected Area	The trip will be coordinated by the project leader	Expected August 2014	3 field days and 2 travel days
Mid-term review	To review the status of the project after three years of data collection	Theme leaders plus other relevant project team members	Canberra	Timing will be coordinated by the project leader	Following the 16/17 field season possibly lined to the annual team meeting	1 day
OPERATIONAL STAKEHOLDERS						
Quarterly Lachlan LTIM Reference Group meetings	Exchange of information and intelligence that supports the implementation of the LTIM Project.	LTIM Reference Group	Teleconference chaired by the project leader	Timing will be coordinated by the project leader.	Quarterly	4 x 1.5 hr per year
OTHER						
Biannual leaders teleconference	To provide regular contact between Project leaders across Selected Areas To deal with any issues arising from the monitoring and communicate early observations from monitoring	Project leader	Teleconference	Timing will be coordinated by the CEWO	November and March	2 x 3 hours per year

ACTIVITY	OBJECTIVE	WHO	LOCATION/ METHOD	RESPONSIBILITY	TIMING	TIME COMMITMENT
Annual forum	To • provide regular contact between Project team members across Selected Areas • deal with any issues arising from the monitoring and communicate early observations from monitoring • Share methods and learning across the teams • Discuss evaluation across Selected Areas	Four attendees from the project team	Sydney	Timing will be coordinated by the CEWO	July	2 days per year

Table 21. Membership of the Lachlan LTIM Reference Group as of April 2014

NAME	AGENCY/POSITION	ROLE
Fiona Dyer (project leader)	Institute for Applied Ecology, University of Canberra - Lachlan LTIM Project (lead organisation)	Chair
Ben Broadhurst	Institute for Applied Ecology, University of Canberra - Lachlan LTIM Project (lead organisation)	Support
Monitoring and Evaluation Representative	CEWO	Member
Water Delivery Representative	CEWO	Member
M&E Advisers Representative	M&E Advisors	Member
Lachlan Environmental Water delivery officer	NSW OEH Environmental Water Delivery	Member
Organisation representative	NSW Office of Water	Member
Organisation representative	Central Tablelands LLS and Chair LRWG	Member
Organisation representative	NSW Fisheries, conservation branch	Member

7.2 External stakeholder engagement

7.2.1 Introduction

This section of Communications and Engagement Plan (C&E Plan) focuses on stakeholder groups external to the core operation of the LTIM Project. Supporting materials are included within Appendix 2. The level of engagement considered appropriate for external stakeholders ranged from ‘inform’ (simple information provision), to ‘consult’ (obtain feedback on alternatives and/or decisions).

Four main external stakeholder groups were identified:

- Group 1: landholders and land managers (hereafter participating landholders).
- Group 2: external water resources groups (e.g. area environmental watering group or Lachlan Riverine Working Group (LRWG), Lachlan Customer Service Committee (Lachlan CSC)).
- Group 3: participating communities.
- Group 4: non-targeted general public.

The highest level of interest and influence (‘collaborate and empower’) was not considered appropriate for Group 1–4 external stakeholders as it would lead to an associated expectation which the LTIM Project and M&E Provider communications team is not designed or authorised to deliver.

The M&E Provider communications team (communications team hereafter, led by Central Tablelands Local Land Services (Central Tablelands LLS) and assisted by the OEH Senior Environmental Water Manager) will centralise and undertake or facilitate communication and engagement activities according to the protocols within this C&E Plan. The communications team will work at the direction of the project manager and closely with core stakeholders who are closely linked to the LTIM Project inception, governance and operational requirements. Core stakeholders include the CEWO, the Lachlan LTIM Reference Group, water delivery partners and those who have experience in monitoring ecosystems' responses to environmental watering in the Lachlan river system Selected Area (previously identified during consultation by the M&E Advisers with stakeholders during the scoping phase of the LTIM Project, Cottingham et al. 2013).

7.2.2 List of stakeholders

Stakeholder groups 1–4 were identified and prioritised according to (i) 'impact zone' mapping with priority given to individuals and groups directly and (potentially adversely affected) by the LTIM Project, (ii) 'interest-based' analysis and mapping for those not directly impacted by the LTIM Project but whose interests determine them as stakeholders (with potential risks to project from media or political process) and (iii) opportunity afforded such stakeholders to contribute to the longer term adaptive management of environmental water in the Lachlan Catchment.

Group 1: participating landholders

Priority one for ongoing access to monitoring sites consistent with Standard Methods Final Report (Hale et al. 2014), and for provision of local knowledge and potentially ancillary contextual information into answering evaluation questions.

The Land Access Protocol (LAP) or access arrangement includes details of when, where and how any member of the M&E Provider team will access land and how operations or monitoring activities will be conducted while on affected landholder property. No M&E Plan activities will be undertaken without having first negotiated a written LAP, which will be conducted face-to-face on a "one-on-one" basis by the communications team and M&E provider leader between 17 April and 30 June 2014. The LAP will be as comprehensive as required, and may also include privacy issues, no access locations and/ or periods, where on the land activities will be undertaken and how those areas will be accessed, nature of the activities undertaken, conditions and/or restrictions that must be observed (e.g. closing gates, dry weather only roads), dispute resolution, and how the arrangement may be changed in the future. The LAP is discussed in further detail in Appendix 2.

Permission and individual LAPs will be negotiated with:

- Private landholders/leaseholders.
- NSW National Parks and Wildlife Service (NPWS) who manage several potential monitoring sites and may assist with accommodation.

Permits may also apply, such as scientific licence under section 132C of the *National Parks and Wildlife Act* for research within the NPWS system.

Another land manager to be consulted but may require less intensive protocols include:

- NSW Trade & Investment Crown Lands Division who manage the beds of non-tidal waters (including rivers, streams and lakes) which comprise crown land.

Other entities with interests in, and access to, monitoring sites (i.e. NSW Office of Water (NoW) Integrated Monitoring of Environmental Flows (IMEF) and hydrometrics monitoring, other university researchers, OEH) will be contacted out of courtesy though existing communication networks (e.g. LRWG and Central Tablelands LLS) at the start of respective projects. In most cases, key personnel within these entities are members of the Lachlan M&E Provider team.

The Senior Local Land Services Aboriginal liaison officer for Central Tablelands LLS, who prior to 1 January 2014 worked at the Lachlan Catchment scale, will also be consulted regarding Aboriginal peoples, and community communications protocols and processes included and adhered to where deemed appropriate. A list of other partner agencies, such as OEH and NoW, who are or have undertaken consultation with Aboriginal peoples in the Lachlan Catchment will be advised of monitoring sites and activities.

A complete list of participating private landholders will be provided to relevant members of the M&E Provider team once monitoring sites and LAPs are finalised.

Group 2: external stakeholder groups

Priority one for maintaining support for environmental water delivery by demonstrating first-hand that Commonwealth environmental water is being managed well and efficiency, with effective monitoring feeding back into broader processes. Focusing on irrigation and environmental water advisory groups to engage and regularly update regarding events, monitoring efforts, outcomes and key learnings.

Primary stakeholders without direct involvement or links to the LTIM Project in water planning, management and delivery in the Lachlan include:

- Lachlan Riverine Working Group (www.lrwg.com.au): Central Tablelands Local Land Services as Executive Officer
- Lachlan Customer Service Committee: State Water Corporation as Executive Officer
- Lachlan Valley Water (http://www.lvw.com.au/site/index.cfm)

Western and Riverina Local Land Services (catchment managers) will also be informed of the LTIM Project at the start (once M&E Plan finalised), and informed of affected community communication activities if they occur.

Secondary stakeholders with an interest in water delivery in the Lachlan, and the implications of environmental water delivery and outcomes include:

- Local government: (i) Carrathool Shire Council (Hillston): Lake Brewster; (ii) Hay Shire Council (Booligal, Hay, Maude); Booligal Wetlands and majority of Lachlan Swamps; (ii) Balranald Shire Council (Oxley, Balranald): Great Cumbung Swamp and southern, lower tip of Lachlan Swamps.
- Water trust districts: Water Trust Districts administer works for domestic, stock water and irrigation, and are empowered to levy and collect rates covering the cost of works repayable to the Crown by instalments and to cover the cost of operation and maintenance of the works. Torriganny, Muggabah and Merrimajeel Creeks Trust District (~ 68 894 ha of land which benefits from the rates) and Merrowie Creek Trust District (~118, 427 ha as above).

- Universities and research institutes in general: Charles Sturt University, University of New South Wales, Australian National University

Group 3: participating communities

Priority two to (i) highlight the use of Commonwealth environmental water and the beneficial outcomes that such actions achieve and (ii) enlist community 'champions' that will self-promote the wider role of environmental water and the involvement of our stakeholders in managing it.

Based on preliminary monitoring site locations, three local 'service or social hubs' were identified for holding public communication activities (e.g. community meetings or speaking engagements):

- Hillston.
- Booligal.
- Hay.

Group 4: non-targeted general public

Priority two for the Selected Area. Communication activities will mostly include mass media products (e.g. social media, major newspapers) permissible via prior consultation with CEWO and communication of Basin Evaluation outcomes. May also include stakeholder group newsletters and publication of information through the LRWG affiliated website and Lachlan Environmental Water Management Plan (LEWMP; www.lrwg.com.au) for Selected Area outcomes.

Group 5: Core stakeholders

Group 5 stakeholders were described in 7.2.1. However, the following points illustrate where and how in governance terms, Group 5 stakeholders, in particular the CEWO, function as the overarching stakeholder pathway, guiding C&E activities:

- CEWO, whereby the CEWO area leader is the first point of contact at all times for M&E Provider team.
- Lachlan LTIM Reference group, operating under Terms of Reference approved by the CEWO. Responsible for supporting strategic direction of the LTIM Project and exchanging information and intelligence to support the LTIM Project and adaptive management.
- Lachlan delivery partners or 'groups with responsibility and/or monitoring and evaluation of environmental water', for example: (i) State Water Corporation (SWC) as principal river operations–delivery partner; (ii) CEWO Environmental Water Use section and OEH Regional Operations Group for environmental water delivery planning, management and reporting; (iii) OEH Water, Wetlands and Coasts Science Branch (Science Division), NSW Office of Water and NSW DPI Fisheries for monitoring data, in particular, existing datasets and programs; and (iv) other research institutions for research and monitoring, in particular, Charles Sturt University.

7.2.3 Overview of key relationships

Figure 6 illustrates the flow of information between Lachlan river system Selected Area stakeholders identified in this C&E Plan (either direct (____) or indirect (- - - -)).The C&E Plan draws on M&E Provider team's existing relationships with environmental water managers (in particular delivery partners), land and catchment managers and local environmental water management groups, as evident by the number of inter-connections in Figure 6. Direct relationship between two stakeholder groups is where one or more representatives are members of both groups with potential first-hand access to information and discussions. Indirect relationship between two stakeholder groups is where representatives support, advise or communicate with the other stakeholder group on particular points of relevance periodically, but from outside the process or group.

As mentioned in 7.2.1, the Group 5 stakeholders potentially require all levels of engagement, with final decision-making and partnership responsibilities. The CEWO, Lachlan LTIM Reference Group and the Lachlan M&E Provider team network via direct relationships. The Lachlan M&E Provider team also network directly with Central Tablelands LLS (Land and Catchment Managers), and affected landholders via the LAP and monitoring activities (Figure 6). The network of direct relationships continues to inter-connect as the Executive Officer of the LWRG is not only a member of the Lachlan M&E Provider Team but the C&E Plan Theme leader and one of two staff responsible for implementing the C&E Plan as well as a member of the Lachlan LTIM Reference Group. The communications team has direct representation on five of the nine groups in Figure 6.

Formal and informal interactions with external stakeholders, and the provision of communications material and engagement activities will be overseen by CEWO and Lachlan LTIM Reference Group via the following mechanisms:

- Past actions and C&E activities and discuss implementation of proposed actions and C&E activities will form an agenda item for the monthly project status meetings between the Project Manager and the CEWO. The C&E Theme Leader may be invited to these phone hook-ups if relevant.
- 'Update on community engagement' is also a standing item on the agenda for the Lachlan LTIM Reference Group's quarterly meeting, and all members will be informed via email or telephone if consultation and/or notification of upcoming C&E activities are required out-of-session.
- So as to enable the Lachlan LTIM Reference Group to guide what information is to be provided to, and what feedback is required from, stakeholder groups, Lachlan LTIM Reference Group quarterly meetings will be scheduled to occur, where possible, prior to similar such meetings of external stakeholder groups (e.g. Lachlan Riverine Working Group (LRWG) quarterly meetings). The LRWG Executive Officer will provide a brief summary of LRWG reaction to LTIM Project update.

Communication protocols with operation delivery partners, such as SWC, OEH and CEWO, are addressed in the Internal Communications section.

The LRWG is the CEWO specified primary 'external' engagement pathway or 'area environmental watering group'. In particular, the LRWG will provide an important existing structure for Group 5 stakeholders and Lachlan M&E Provider team to effectively engage with stakeholders as illustrated in Figure 6 with:

- The greatest number of direct relationships via dual representation of LRWG representatives on core ( ) and secondary ( ) Group 2 stakeholder groups.
- All LRWG landholder representatives are listed potential monitoring sites and hence affected landholders.
- High overlap between Lachlan LTIM Project personnel ( ) and the LRWG, while NSW agencies responsible for aspects of the Basin Plan which have potential to influence water delivery (e.g. NoW: WSP remake June 2015 and WRP 2019) and/or environmental flows and actions (OEH: regional long term watering plans with regard to Basin wide watering strategy) consult the LRWG (Figure 6).

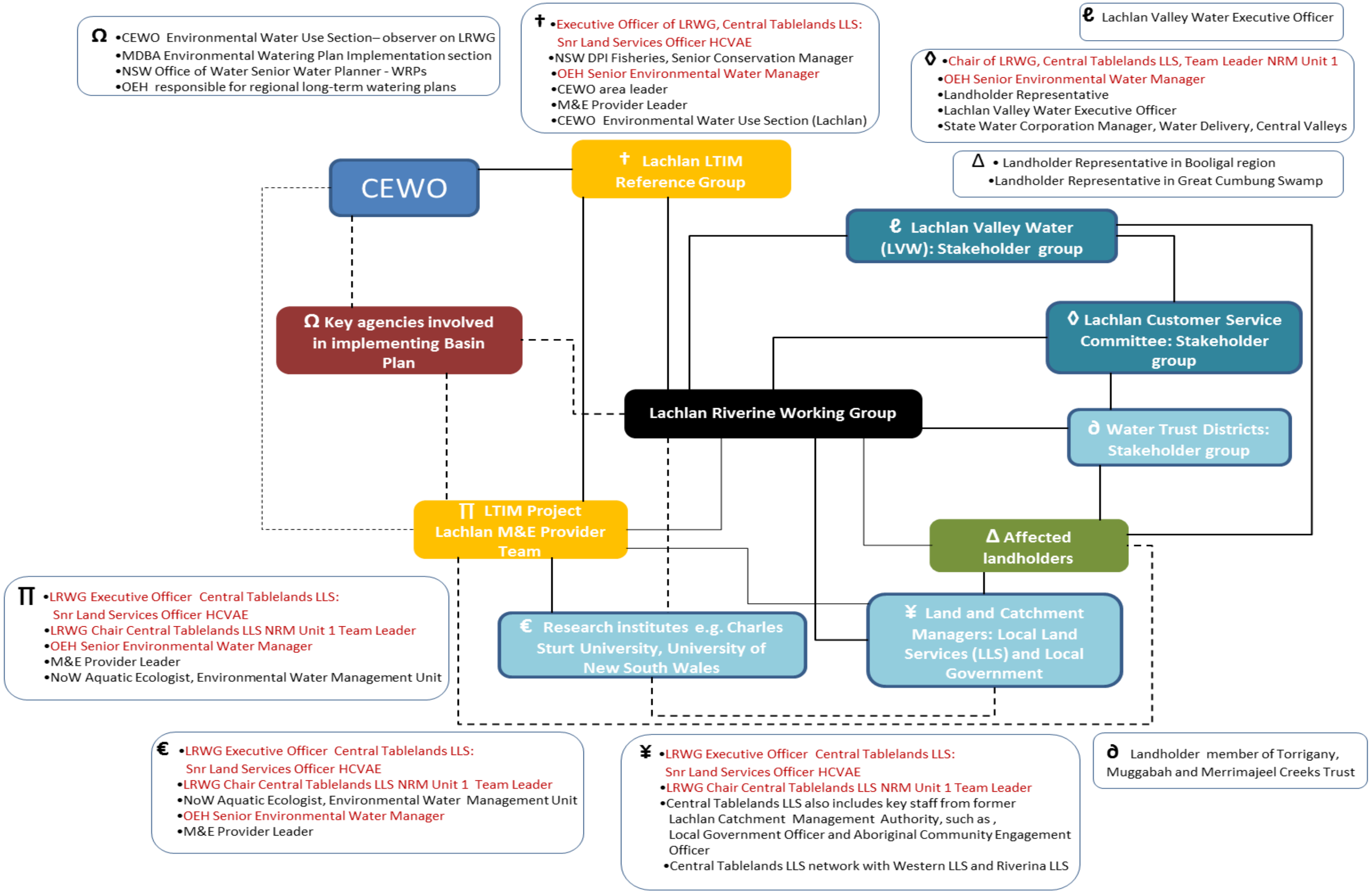

Figure 6 Relationships between water resource management stakeholders identified in this C&E Plan in the Lachlan Catchment, where essentially all relationships involve a two-way dialogue and input. The position titles of those stakeholder representatives involved in C&E Plan and associated activities are included in perimeter boxes with corresponding symbols (e.g. † for Selected Area Working Group). Position titles in red text are integral to the development and implementation of this C&E Plan, in conjunction with CEWO, the Lachlan LTIM Reference Group and M&E Provider leader.

7.2.4 Foundational analysis for planning communication and engagement activities

Engagement strategies and activities were tailored to fit the needs of the project. Thus, prior to drafting the schedule of proposed C&E activities (see Table 5 in Appendix 2) the following supporting analyses were conducted, with additional information in Appendix 2 – Communication and Engagement.

Purpose and desired outcomes

A broad desktop needs and stakeholder analysis was conducted and summarised in Table 3 of Appendix 2. This section identifies why engagement is important for the success of the project (e.g. meet the five high-level objectives of the LTIM Project and answer evaluation questions), and the desired outputs or products and outcomes to be achieved by undertaking stakeholder engagement (e.g. seeking local knowledge, obtaining buy-in from stakeholders, case studies, reports).

Level of engagement and risk management

After identifying the purpose, desired outcomes and list of key stakeholders, it was important to consider the stakeholders' expectations and their levels of interest and influence in relation to the LTIM Project high-level objectives. This C&E Plan also recognises the interest or influence of a stakeholder may change as the LTIM Project progresses. Therefore, the communications team will continually reassess and identify new stakeholders and level of stakeholder engagement at different stages of the LTIM Project. Table 4 in Appendix 2 outlines stakeholder expectations based on impact, interest and opportunity. Risks are associated with the stakeholder engagement processes, such as different understanding of engagement objectives and expectations about the outcomes of engagement process, stakeholders feeling excluded from the process or having insufficient time and opportunity to contribute fully or raise concerns. Risks and suitable mitigation strategies to prevent risks occurring and/or contingency plans to reduce their likelihood and/or impact are identified in Appendix 2.

7.2.5 Methods of engagement and proposed schedule of communication and engagement activities

A full and detailed schedule of C&E activities is provided in Table 5 of Appendix 2. The appropriate methods of stakeholder engagement and the relevant tools and techniques to facilitate the engagement process will potentially vary and be dynamic over the LTIM Project. However, information contained in the foundational analysis were used to propose methods based on their appropriateness, benefits, limitations, cost-effectiveness and links to existing stakeholder engagement pathways – and hence Table 5 of Appendix 2 should be read in conjunction with Tables 3 and 4 of Appendix 2. That is, C&E activities were designed to meet stakeholder expectations and mitigate risks, as well as contribute to LTIM Project reasons for engagement, outputs, outcomes and high-level objectives.

Protocol for obtaining CEWO approval

The CEWO area leader will be notified and consulted of all C&E activities via email as standard protocol and out of courtesy. Any written material circulated to stakeholder groups or made public will also be provided to the M&E Provider Leader and Lachlan LTIM Reference Group. All such material will contain a caveat in the header 'Not for public distribution without prior approval'. No media communications will take place without the express permission from the Direction, Monitoring and Evaluation Section with the CEWO which will be facilitated via the CEWO area leader.

Where possible, a list and summary of up and coming proposed C&E activities will be circulated as part of the monthly progress reports (depending on activity levels), and a quarterly summary provided in the quarterly report to the CEWO. Table 22 is a summary of what activities either require CEWO pre-approval or will involve prior consultation/notification with CEWO area leader.

Table 22 Summary of activities or communications which required consultation with CEWO area leader or approval by the CEWO

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	METHOD(s)	RESPONSIBILITY	TIMING
(1)	Initial landholder meetings to develop Land Access Protocol	Affected landholders	•Process to develop written LAP (includes individual face-to-face meetings with each landholder) •Draft LAP template	M&E Provider Leader and Central Tablelands LLS Snr Land Services Officer (HCVAE)	ASAP after 17 April 2014 and by 30 June 2014
(2)	Final Land Access Protocol	Affected landholders	CEWO to 'sign-off' on each negotiated LAP	CEWO area leader; M&E Provider Leader and Central Tablelands LLS	• Between 17 April and 30 June 2014 so field monitoring staff to be 'trained' in relevant LAP
(3)	Oversight of landholder protocols and relationships	Affected landholders	• Post/email copy of Area evaluation report • Brief summary report specific to property or areas of interest (i.e. fish, birds) after each monitoring period or event • CEWO to 'sign-off' on all materials prior to distribution.	M&E Provider Leader, Central Tablelands LLS Snr Land Services Officer (HCVAE) and CEWO area leader; each of the theme leaders and/or research field team	Event-based, annually to coincide with Annual Area evaluation report: around November each year or after each discrete monitoring period
(4)	Grievance	Affected landholders	• Any proposed dispute resolution action (e.g. letter of response, face-to-face mediation and any correspondence received by affected landholder)	CEWO area leader, M&E Provider Leader, and Central Tablelands LLS Snr Land Services Officer (HCVAE)	If required
(6)	Opportunistic presentations as existing community events	Affected communities	• Provision of Key Messages and approved communication material (e.g. Media Releases, item in newsletters) at Local Land Services stalls at local community events (e.g. Henty Field Days)	Not scheduled activities at this stage, to be put to the CEWO area leader for approval from Director , Monitoring and Evaluation	• If LLS or partners have stalls at appropriate venues (e.g. Henty Field Days, local shows e.g. Booligal and Hillston shows) or other Local Land Services awareness raising events e.g. Carp a Thons, community

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	METHOD(s)	RESPONSIBILITY	TIMING
			• Potential presentation at partnerships forums or Local Land Services events, for example, Science Forum	Section within CEWO, if such opportunities arise or are requested; M&E Provider Leader, and Central Tablelands LLS Snr Land Services Officer (HCVAE)	forums. If request for presentations occur from either affected communities via affected landholders or exposure to official media (newspaper articles, press releases etc)
(7)	Media and internal communication products (i.e. Fact Sheet)	All stakeholders especially non-targeted general public and affected communities and landholders	• Media releases • Newspaper editorials (local and regional/state) •Local ABC radio •Newsletters (including E-newsletters),such as LLS newsletters and Lachlan Environmental Water Management Plan newsletters • LTIM Project dedicated project page on LEWMP website (www.lrwg.com.au), which would be updated via LRWG Executive Officer after obtaining permission from Direction, Monitoring and Evaluation Section within CEWO •Social media • Utilise Western/Riverina Local Land Services (LLS) networks and planned project activities e.g. distribute newsletters, website, fact sheets, field days, forums	NOT TO OCCURE WITHOUT EXPRESS PERMISSION OF Director, Monitoring and Evaluation Section within CEWO facilitated via CEWO area leader, M&E Provider Leader, and Central Tablelands LLS Snr Land Services Officer (HCVAE)	Event and outcome based, opportunistically as they arise with existing networks, such as: • 4 times a year for quarterly LRWG internal newsletter via Lachlan CSC and LVW, LRWG landholder email distribution lists and connections with Water Trust Districts. • Regularly or as 'good news stories' or outcomes of watering events become apparent – posted on Lachlan LTIM Project page on LEWMP website.
(8)	LRWG initial consultation	LRWG	LRWG Quarterly meeting: The LTIM Project agreed as standing Agenda Item at each LRWG meeting and a summary update of LTIM Project will be provided to LRWG by LRWG Executive Officer after prior review by Selected Area Working Group, in particular, CEWO area leader	CEWO area leader, Lachlan LTIM Reference Group; Central Tablelands LLS Snr Land Services Officer (HCVAE) as LRWG Executive Officer	Wednesday 26 February 2014 with outcomes reported back to M&E Provider Leader and CEWO area leader, and used to inform the final M&E Plan due 17 April 2014. LTIM Project discussed at LRWG 9 April 2014 meeting.

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	METHOD(s)	RESPONSIBILITY	TIMING
(9)	Ongoing communication with LRWG	LRWG	• Any briefing papers or draft products (reports) provided to LRWG via Executive Officer	• Central Tablelands LLS Snr Land Services Officer (HCVAE) and Lachlan LTIM Reference Group	As required, however, where possible updates (i.e. quarterly progress reports and draft Annual Area evaluation reports) should coincide with LRWG quarterly meetings • M&E Provider Leader may attend planning session for Lachlan Valley Annual Watering Plan (~ Feb/March each year)
(10)	Existing stakeholder group pathway	Lachlan Customer Service Committee (CSC)	• Material for LRWG newsletter and CSC briefing papers; potential to present at CSC meeting by request or invitation • CEWO to 'sign-off' on all materials prior to distribution.	As above	As required via above protocols
(11)	Existing stakeholder group pathway	Lachlan Valley Water (LVW) and Water Trust Districts	• Material for LRWG newsletter and briefing papers as requested • CEWO to 'sign-off' on all materials prior to distribution.	As above	As above
(12)	Existing stakeholder group pathway	Local government	• Inform via Briefing Papers - Local Land Services Local Government Officers and associated reference/advisory groups • CEWO to 'sign-off' on all materials prior to distribution.	Any briefing papers prepared by Central Tablelands LLS Snr Land Services Officer (HCVAE) will be approved by Lachlan LTIM Reference Group/CEWO	When required (pre or post watering events)
(13)	Collaborate with other research/ monitoring or water resource projects	Research institutes	• Inform and establish collaborative/information sharing relationships via existing LTIM Project team networks • CEWO to 'sign-off' on all materials prior to distribution.	• M&E Provider Leader to liaise with relevant Lachlan LTIM Project staff to obtain a list of relevant projects, contact details, and access to available information	Prior to 30 June 2014 and ongoing

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	METHOD(s)	RESPONSIBILITY	TIMING
(15)	Case studies	Affected landholders	Via specific interviews with select affected landholders, and utilising all project information available from M&E Provider Team (i.e. LAPs, annual C&E Plan evaluation, Stakeholder log, emails and feedback surveys, review of LAPs etc)	M&E Provider Leader and Central Tablelands Snr Lands Services Officer (HCVAE) to liaise with relevant Lachlan LTIM Project staff	As requested or expedited by affected landholder; Year 4 or 5 of LTIM Project. Not scheduled activities at this stage, to be put to the CEWO area leader for approval from Director , Monitoring and Evaluation Section within CEWO, if such opportunities arise or are requested to mitigate risk of communities and landholders feeling they were not sufficiently involved in interpretation of 'how their local system works and the relative contribution of CEWO environmental water'.

7.2.6 General protocols for consistent messaging

The M&E Provider communication team will consult with CEWO, M&E Advisers and M&E Provider leader between 28 February and 17 April, as the M&E Plan is reviewed and finalised, to develop key messages for all stakeholders. Those key messages are likely to be based upon the five high-level objectives, frequently asked questions as supplied by the CEWO Media and Communications section, and the analysis of stakeholder engagement purpose/objectives and level of engagement in defined in Appendix 2.

Formal settings

The following processes are proposed for conveying consistent messaging about the LTIM Project in formal settings:

- Centralisation: majority of formal presentations and meeting briefings, etc. will be undertaken through the communications team.
- Consultation with CEWO: all written or visual communication material (i.e. PowerPoint presentation, Fact Sheets, Briefing Papers, Case Studies etc., to be pre-approved by CEWO area leader.
- Consistency:
    - (i) the key messages component of final M&E Plan will be internally available to all Lachlan LTIM Project team members as part of final M&E Plan, and provided at the Land Access Protocol staff training/induction (Activity 2 in Table 5 of Appendix 2).
    - (ii) key messages converted into communication material which is emailed to all LTIM Project staff to be used as basis of each formal engagement (e.g. fact sheet, FAQ and responses, case studies etc,.)
- Templates will be used where possible (i.e. Standard Terms and approved Style Guide).

- Referral: if no consistency key message relates to the topic or situation contact CEWO area leader and M&E Provider leader.

Informal settings

The following processes are proposed for conveying consistent messaging about the LTIM Project in more informal settings:

- Preparation: prior to potential exposure to informal situation where may be questions by public, LTIM Project staff to familiarise themselves with key consistent messages.
- Referral: impromptu questions or comments to be referred or followed-up more formally with reference to CEWO area leader and M&E Provider leader.

7.2.7 Complaint and grievance process

The LAP and oversight role of the communications team as outlined in Table 4 in Appendix 2 has safeguards built in to prevent the degeneration of stakeholder relationships to the point where a formal grievance procedure is enacted. That is, the communications team will facilitate the internal resolution of any complaints with the assistance of Central Tablelands LLS senior staff and M&E Provider leader by the following steps:

- Listen and record the details of the complaint ensuring to obtain dates, locations, and names of relevant Lachlan M&E Provider staff or representatives. This may be a phone call but allowance has been made for face-to-face mediation.
- Inform CEWO area leader and incorporate advice.
- Come to an agreed understanding of what action will resolve the complaint.
- Inform all affected or involved persons/parties of agreed resolution and time frame to implement and review/follow-up.
- Record time/date complaint resolved and forward to CEWO via area leader.
- Follow-up at agreed time and method.

Complaints which cannot be resolved by informal mediation within the M&E Provider team (with notification to CEWO area leader) will be referred via CEWO area leader to CEWO Grievance Management staff or procedures.

7.2.8 Evaluate the engagement process

Evaluation of C&E Plan can be compartmentalised into three stages or processes:

- Stage 1 M&E Plan or Proposal Development one-off during (28 February–30 June 2014);
- Stage 2: M&E Plan Implementation (annual process); and
- Stage 3: ongoing and opportunistic.

It is not possible to schedule Stage 3 type adaptive management of C&E Plan but it is assumed that by acknowledging potential opportunities, improvement will be implemented:

- LAP has potential to constantly evolve as current unknowns become realised through unique and individual environmental water delivery actions, and associated actions to implement schedule of monitoring activities;
- Informal feedback from stakeholders and M&E Provider Team via engagement pathways and activities (i.e. audience feedback, pub conversations etc);
- Formal feedback via social media, website, email etc

Stage 1 and 2 evaluations with involve a formal review process which may be based on Table 23 below. It is also envisaged that Stages 1–3 of the evaluation process and informal discussion among Group 5 stakeholders, M&E Provider Team and the Communications theme leader will assess and update of the C&E Plan.

Specific items, such as the LAP for each monitoring trip and site, LAP action sheet, stakeholder log, and any complaint/grievance material will be available for audit of the M&E Plan on an annual basis. While 'reassess and identify new stakeholders and level of stakeholder engagement' will be ongoing and opportunistic (Stage 3), it will also be part of the Stage 2 annual process.

Table 23 Example stakeholder engagement evaluation plan to be completed after M&E Plan is finalised.

	What do we want to know? **Evaluation questions for each stage listed of the engagement process. The number of questions will depend on the size/complexity of the engagement process.**	What evaluation methods will we use? **Methods you will use to evaluate each stage of the evaluation Phase listed**	How will the evaluation be conducted? **Describes how each engagement method will be carried out, by whom and by when.**
Planning Process	Provide examples or case study of where C&E Plan was implemented, and include a critical evaluation including missed opportunities for engagement	e.g. observations and reflections, structured interviews, informal feedback (emails, conversations etc)	Documented feedback through C&E mechanisms and M&E Provider team/Group 5 stakeholders: Central Tablelands LLS, Snr Lands Services Officer HCVAE
	Reassess and identify new stakeholders and level of stakeholder engagement	e.g. desktop review, outcomes of stakeholder communications	Feedback as provided by M&E Provider Team and all stakeholder Categories 1–5
Engagement Activities	What engagement activities worked well and why?	Observations and reflections, feedback sheets and LAPs, LAP Action List, Stakeholder Log, any grievance or disputes, personal communications with stakeholders	
	What need or opportunities arose for additional engagement activities?		
LTIM Project objectives, benefits, outputs and outcomes	How have relationships with stakeholders changed or improved?		
	To what extent are the five high-level objectives being met, if so, give examples or case study		

8 Project management

8.1 Project governance

The project is being delivered by a team comprising staff from three Universities and four state agencies (see Table 18 for more detail). In addition, there are numerous stakeholders from within the state and commonwealth agencies. To ensure that the project meets its obligations, governance structures have been developed to ensure clear definition of accountability and decision pathways Figure 7.

8.1.1 Accountability: Roles and responsibilities

Project lead: The project is lead from the University of Canberra by Dr Fiona Dyer. Fiona has responsibility for the overall delivery of the project. She will coordinate the project team, chair the Lachlan LTIM Reference Group, manage the budget, provide the main point of contact with the CEWO representatives and ensure that the milestones are met. Fiona will be supported at the University of Canberra by Ben Broadhurst and a part time research assistant.

Project team: Monitoring and evaluation activities will be delivered by a project team which has been divided into themes. Each theme is led by a senior scientist (Figure 7 and Table 18).

Theme leaders: Theme leaders have responsibility to ensure that the field activities, data delivery and reporting for each theme are delivered on time, to budget and to an acceptable level of quality. They will manage the day to day operational activities associated with collecting data. They are also responsible for ensuring that health, safety and environmental risks are managed appropriately. Theme leaders will work with the project lead to provide an integrated evaluation of the environmental outcomes of Commonwealth environmental water.

Lachlan LTIM Reference Group: A reference group has been established to provide a forum for the exchange of information and intelligence that supports the implementation of the LTIM Project, through effective coordination of environmental watering, and monitoring and evaluation, see the Terms of Reference in Appendix 2). The reference group comprises representatives from the key stakeholder organisations and recognises the value that can be added to the monitoring project through their advice. The reference group has no decision making power and is advisory only (Figure 7).

Quality management: Theme based data management, data analysis and reporting will be conducted by the project team. Central management of data sets will be the responsibility of the data custodian and the quality of the deliverables will be assured through peer review and audit. The auditor (IAE Business Manager) and reviewer (Dr Jane Roberts) will report directly to the project lead and theme leaders who will be responsible for ensuring that any issues are addressed.

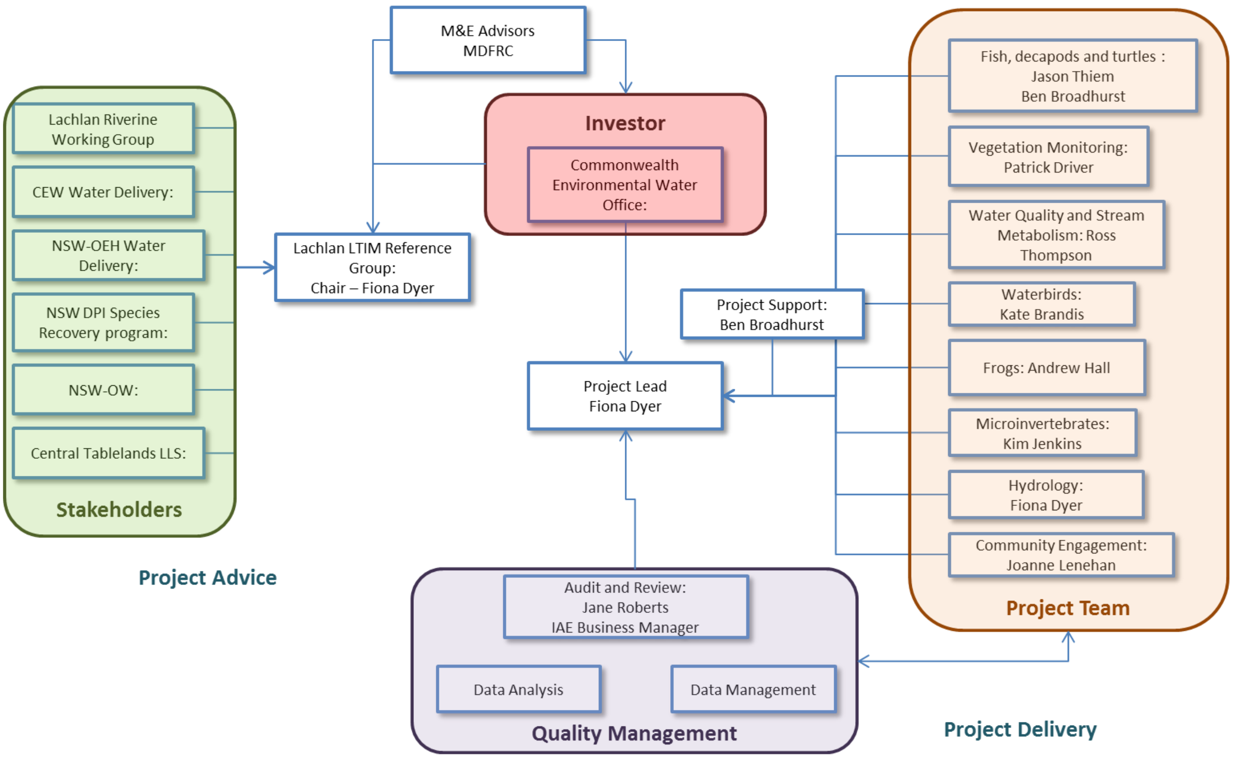

Figure 7. Project governance structure: Lachlan LTIM Project

8.2 Risk assessment

A risk assessment for the project has been conducted to minimise risk to:

- People: the health and safety of individuals (and teams) undertaking monitoring activities.
- Environment: risks to the environment and aquatic ecosystems as a result of monitoring activities.
- Stakeholders: agencies involved in the LTIM Project (e.g. CEWO, OEH, etc.), land holders, research institutions, etc.
- Monitoring activities: disruption to monitoring schedule or results.
- Project objectives: encompass a broad category of risks, including risks that monitoring activities will not be able to be implemented, risks that evaluation activities will not be able to identify the contribution of Commonwealth environmental water, and risks to the ability of M&E Providers to deliver high quality, timely Area Evaluations.

A standard methodology to assess risk has been used. This methodology considers the likelihood of the hazard occurring (refer to Table 24 for more detail), and the consequence of the hazard (refer to Table 25 for additional detail) to determine risk. Control measures are put in place to reduce the likelihood and/or consequence to produce a residual risk rating. These control measures are referred to as a hierarchy of controls, e.g.:

- Elimination: remove the hazard, e.g. get rid of a dangerous machine.
- Substitution: replace the hazard with a safer alternative, e.g. replace the machine with a safer one.
- Isolate: isolate the hazard from people, e.g. keep machine in a closed room and operate remotely.

- Engineering: control the hazard e.g. attach guards to the machine to protect users.
- Administration: change the way people work, e.g. train workers to operate machine safely.
- Personal protective equipment (PPE): wear PPE, e.g. gloves, goggles etc.

A summary risk register to people, environment, stakeholders, monitoring activities, and project objectives, are provided in

Table 27, Table 28, Table 29,

Table 30, and Table 31 respectively. In addition each activity proposed for the LTIM Project has an associated Safe Method Work Statement (SMWS) which is presented in detail in the Workplace Health and Safety Plan. Each institution involved in the project has also provided Health and Safety Protocols for their designated field work. See Appendix 3 for additional information.

Table 24: Categorisation of likelihood

LIKELIHOOD	DESCRIPTION
Almost certain	Is expected to occur in most circumstances
Likely	Will probably occur
Possibly	Might occur at some time in the future
Unlikely	Not expected to occur
Rare	May occur under exceptional circumstances

Table 25: Categorisation of Consequence

CONSEQUENCE	NEGLIGIBLE	MINOR	MODERATE	MAJOR	CRITICAL
PEOPLE	Incident requiring first aid treatment.	Minor incident requiring treatment by a medical practitioner.	Moderate incident requiring short term hospitalisation.	Serious incident requiring extensive hospitalisation.	A fatality, permanent disability, or multiple people affected by a serious incident.
ENVIRONMENT	Negligible environmental damage.	Short term, localised, reversible damage to the environment.	Short term, widespread damage to the environment reversible to intensive effort.	Long-term damage to the environment and/or risk of continuing environmental damage.	Long-term, widespread, irreversible damage.
STAKEHOLDERS	Short-term, isolated complaints from stakeholders.	Sustained but isolated complaints from stakeholder. Relationship with stakeholder temporarily affected.	Sustained complaints from stakeholders. Relationship with stakeholder damaged.	Short-term but significant complaints from stakeholders. Relationship with stakeholder significantly damaged.	Sustained and significant complaints from stakeholder. Relationship with critical stakeholder irreversibly damaged.
MONITORING ACTIVITIES	Monitoring activities undertaken according to M&E Plan, with data from all planned samples available.	Minor disruption to the monitoring program with a small number of planned samples (<10%) not collected or data not available	More than 10% of planned samples not collected / available, however sufficient data available for planned analyses	Data from more than 50% of planned samples not collected / available. Limited monitoring outcomes reported	No useable data collected, analyses not possible, no monitoring outcomes reported
PROJECT OBJECTIVES	Short delay in achievement of project objectives	Delay in achievement of project objectives	Element or project objective not met	Project objectives not met	Project objectives harmed (negative impact)

Table 26: Risk Matrix

	NEGLIGIBLE	MINOR	MODERATE	MAJOR	CRITICAL
ALMOST CERTAIN	Low	Medium	High	Severe	Severe
LIKELY	Low	Medium	Medium	High	Severe
POSSIBLE	Low	Low	Medium	High	Severe
UNLIKELY	Low	Low	Low	Medium	High
RARE	Low	Low	Low	Medium	High

Table 27: Risk register to people

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELIHOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
General	Snake bite	Possible	Moderate	Medium	Wear long pants or gaiters. Avoid a snake if it is in your path – do not try and move/scare it. Ensure first aid kit includes compression bandages.	Unlikely	Moderate	Low
General	Slips, trips, falls	Possible	Moderate	Medium	Wear appropriate footwear. Take care when walking on uneven surfaces. Take the safest route to a location.	Unlikely	Moderate	Low
General	Temperature extremes	Possible	Moderate	Medium	Wear appropriate PPE. Take rests and drink water in hot conditions. Observe others for signs of stress.	Unlikely	Moderate	Low
General	Car accidents while driving to remote location	Possible	Major	High	If driving on unsealed roads undertake 4WD training. Take regular breaks to ensure drivers stay alert. Be aware of wildlife.	Unlikely	Major	Medium
General	Falling branches	Possible	Moderate	Medium	Look up. Be aware of location of dead branches. Do not work under canopy in strong winds.	Unlikely	Moderate	Low
General	Bee / insect bite	Possible	Moderate	Medium	Take care and be observant. Avoid ant's nests and bee/wasp nests. Do not place hands under rocks, logs or into dense vegetation. First Aid kit on site. Insect repellent worn and on site. Wear PPE. If allergic bites/stings carry medication and alert others to your condition.	Unlikely	Moderate	Low
General	Injury causing open wounds	Possible	Moderate	Medium	Staff trained in first aid. Adequate and appropriate first aid equipment on site. All workers to be familiar with the location and contents of first aid kits. Inspect first aid kits regularly, and replace missing material.	Unlikely	Moderate	Low

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK LIKELIHOOD	CONSEQUENCE	RISK	CONTROL MEASURES	RESIDUAL RISK LIKELIHOOD	CONSEQUENCE	RISK
General	Becoming lost / stranded	Possible	Minor	Low	Where practicable, fieldworkers should avoid working alone, especially if working in remote locations. Each employee working in remote areas should be able to navigate competently. Where appropriate, topographic maps, compass and/or GPS should be carried. Ensure all workers are supplied with appropriate communication and emergency signalling devices (e.g. radio, satphone or EPIRB) & are familiar with their use. Carry sufficient food, water and fuel. Maintain a communication plan. Check local road/weather conditions before trip. On extended or remote tasks, Travel itinerary must provide description of fieldworkers movements and contact details (e.g. Radio selcall or satphone no.)	Unlikely	Minor	Low
General	Infection with Ross River virus or Murray River encephalitis	Possible	Major	High	Avoid sampling at dawn and dusk. If sampling during this period can't be avoided, then appropriate PPE should be worn, e.g. long sleeves/pants, and insect repellent should be used.	Unlikely	Major	Moderate
Camping	Burns and scalds	Possible	Minor	Low	At least one member of each field team must have appropriate first aid training. Be aware of burn hazards when bush camping / cooking.	Unlikely	Minor	Low
Aquatic surveys	Drowning	Possible	Critical	Severe	Take care when walking along river banks and wear a life jacket near fast flowing water. When working in water take care not to exceed height of waders or waist. Do not work in areas of fast flowing water. Wear a life jacket when using boats.	Unlikely	Critical	High
Aquatic surveys	Unstable river banks	Possible	Moderate	Medium	Work in a safe stable area.	Unlikely	Moderate	Low

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK LIKELIHOOD	CONSEQUENCE	RISK	CONTROL MEASURES	RESIDUAL RISK LIKELIHOOD	CONSEQUENCE	RISK
Aquatic surveys	Boat crash	Possible	Major	High	Boat operators must be familiar with the requirements of safe boating (see MSB Safe Boating Handbook) and adhere to licensing requirements. Obey navigation rules and drive to the conditions. Carry safety equipment specified by The Boating (Safety Equipment) Regulation NSW and the MSB Safe Boating Handbook. Before setting out, ensure that another person has been informed of where and how long the trip will be, particularly if operating in remote or hazardous areas, and boat and safety equipment has been checked for seaworthiness. Check there are no fuel leaks. Check local weather forecast and conditions have been taken into consideration and adequate maps, charts or navigational aids are consulted if in unfamiliar waters.	Unlikely	Major	Medium
Equipment	Use / moving heavy equipment e.g. lifting a boat on / off trailer	Possible	Minor	Low	Maintain good posture and body movements. Use correct lifting procedures.	Unlikely	Minor	Low

Table 28: Risk register to environment

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK LIKELIHOOD	CONSEQUENCE	RISK	CONTROL MEASURES	RESIDUAL RISK LIKELIHOOD	CONSEQUENCE	RISK
Captured and handling of biota during monitoring activities	Injury or mortality to biota	Possible	Major	High	Appropriate capture and handling procedures (following protocols approved by ethics committees and outlined in sampling permits)	Unlikely	Moderate	Low
Accessing monitoring sites	Destabilisation of banks, trampling / driving over vegetation causing damage.	Possible	Minor	Low	When driving stay on formed tracks where possible. When on foot treading carefully around vegetation where possible.	Unlikely	Minor	Low

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK LIKELIHOOD	CONSEQUENCE	RISK	CONTROL MEASURES	RESIDUAL RISK LIKELIHOOD	CONSEQUENCE	RISK
Accessing monitoring sites	Damage to un-sealed roads during/following rain.	Possible	Moderate	Medium	Obeying road council enforced and landholder advised road closure. Checking access with landholder prior to entering unsealed road on private land. Staying on formed roads during moderate / heavy rainfall (>5 mm)	Unlikely	Moderate	Low
Accessing monitoring sites	Hitting wildlife with vehicle	Possible	Major	High	Drive to conditions outlined in relevant SWMS documents (Appendix 3). Avoid driving at dawn or dusk. Take care when driving during periods of low light.	Unlikely	Major	Medium
Accessing monitoring sites	Vehicles bringing in weeds / exotic seeds	Possible	Moderate	Medium	Before leaving home base check vehicle to dirt/weeds/seeds and wash down if necessary.	Unlikely	Moderate	Low
Re-fuelling of boats	Spillage of fuel into the environment causing localised pollution hazard	Possible	Minor	Low	Follow of SWMS for re-fuelling (Appendix 3). Re-fuelling to be conducted well away from waterways (>100 m).	Unlikely	Minor	Low
Waterbird monitoring	Observer disturbance causes abandonment of nests	Possible	Minor	Low	Follow appropriate survey procedures (following protocols approved by ethics committees and outlined in sampling permits)	Unlikely	Minor	Low

Table 29: Risk register to stakeholders

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK LIKELIHOOD	CONSEQUENCE	RISK	CONTROL MEASURES	RESIDUAL RISK LIKELIHOOD	CONSEQUENCE	RISK
Stakeholder engagement	Stakeholders not informed / engaged in the project	Possible	Major	High	Actively engage with stakeholders as per the stakeholder engagement plan detailed in Section 7.2.	Unlikely	Major	Medium
Site access	Restricted access by landholders	Possible	Major	High	Actively engage with stakeholders as per the stakeholder engagement plan detailed in Section 7.2. Establish appropriate “back-up” sites, and shift to these if necessary.	Unlikely	Moderate	Low

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK LIKELIHOOD	CONSEQUENCE	RISK	CONTROL MEASURES	RESIDUAL RISK LIKELIHOOD	CONSEQUENCE	RISK
Land management	Land management practises (including fire) affecting vegetation transects	Possible	Moderate	Medium	Agreement with landholders that the study sites are managed in a way that will not compromise the study design. The project team will activate response based monitoring in the event of fire to assess impact on indicators. See also stakeholder management plan in Section 7.2. Establish appropriate "back-up" sites, and shift to these if necessary.	Unlikely	Minor	Low

Table 30: Risk register to monitoring

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK			CONTROL MEASURES	RESIDUAL RISK		
		LIKELIHOOD	CONSEQUENCE	RISK		LIKELIHOOD	CONSEQUENCE	RISK
Flooding	Interference with study design.	Possible	Moderate	Medium	The project team will activate response based monitoring of flood events to assess impact on indicators.	Unlikely	Moderate	Low
Ecological responses	Unexpected changes.	Possible	Minor	Low	The project team has constructed conceptual diagrams of controlling processes associated with indicators to minimise this.	Possible	Minor	Low
Indicators	Not detecting change.	Possible	Moderate	Medium	The project team has constructed conceptual diagrams of controlling processes associated with indicators to minimise this.	Possible	Minor	Low
Environmental events	Events such as blackwater or drought affecting results.	Possible	Moderate	Medium	The project team will activate response based monitoring of such events to quantify impact on monitoring program indicators.	Possible	Minor	Low
Invasive species	Invasive animals CRC carp control program influencing results.	Possible	Minor	Low	Based on the study design for riverine, wetland and larval fish indicators, the reduction in carp is unlikely to significantly influence results.	Unlikely	Minor	Low

ACTIVITY	POTENTIAL HAZARD	INHERENT RISK LIKELIHOOD	CONSEQUENCE	RISK	CONTROL MEASURES	RESIDUAL RISK LIKELIHOOD	CONSEQUENCE	RISK
Monitoring area	The large scale of the study area impacts on monitoring program being undertaken successfully	Possible	Moderate	Medium	The project team seeks to utilise local knowledge in the form of CMA partners in the Lachlan River catchment. The project team is well equipped to adequately plan for the large scale of the study area. Planning activities have included a site visit to provide the project team with on-ground perspective of the entirety of the study area.	Unlikely	Minor	Low

Table 31: Risk register to project objectives

Activity	Potential hazard	Inherent risk LIKELIHOOD	CONSEQUENCE	RISK	Control measures	Residual risk LIKELIHOOD	CONSEQUENCE	RISK
Environmental watering	Inadequate water availability	Possible	Major	High	There is no way to minimise this risk. The project team will assume that adequate water will be available for release scenarios.	Possible	Major	High
Watering delivery	Delivery scenarios are not met	Possible	Moderate	Medium	Clear communication between the project team and water providers will provide the project team with flow release forecast scenarios. This clear communication will also aid in project planning to utilise available water delivery.	Unlikely	Minor	Low
Budget	Unexpected events requiring additional or changed monitoring regime	Possible	Moderate	Medium	The budget associated with each component of the LTIM Project includes costing for response based monitoring.	Unlikely	Moderate	Low
Budget	Reduction of in-kind support	Unlikely	Moderate	Low	The large number of institutions that comprise the project team ensures that it is somewhat robust to small and moderate reductions of in-kind support.	Unlikely	Minor	Low

Activity	Potential hazard	Inherent risk LIKELIHOOD	CONSEQUENCE	RISK	Control measures	Residual risk LIKELIHOOD	CONSEQUENCE	RISK
Budget	Reduction in budget results in reduction in sampling intensity or the removal of some indicators from the evaluation process.	Possible	Moderate	Medium	The project team will revisit the conceptual models and assess which of the monitoring activities could potentially be altered to reduce costs. The potential use of value-adding components such as post-graduate projects may assist in absorbing budget reductions.	Possible	Minor	Medium
Project management	High workloads of project team members impacting on availability for monitoring and evaluation.	Possible	Moderate	Medium	The project team are experienced in managing workloads associated with large scale project. See section 7.1.1.	Unlikely	Minor	Low
Project management	Changes in project leadership impacts on monitoring, evaluation and project delivery.	Unlikely	Major	Medium	There are a number of experienced members of the project team that could absorb any change to the leadership structure.	Unlikely	Moderate	Low
Project management	Changes to institutions or staff impacts on monitoring, evaluation and project delivery.	Unlikely	Minor	Low	Structural and staff changes are not uncommon and the project team will have experience in how to manage this. The size and expertise of the project team renders it robust to such changes.	Unlikely	Minor	Low
Project management	Timeline pressures impacts on monitoring, evaluation and project delivery.	Possible	Moderate	Medium	The project team are experienced in managing workloads associated with this scale of project. See Section 7.1.1 for capabilities.	Unlikely	Minor	Low
Data access	Access to previous datasets is restricted, thus impacting on evaluation and project delivery.	Possible	Minor	Low	The project team comprises many institutions that already have datasets from the Lachlan. The professional networks of the project team place it in a sound position to formalise agreements with other dataset holders	Unlikely	Minor	Low
Data management	Data management and sharing procedures deteriorate across the project team impacting on evaluation and project delivery	Possible	Major	High	A centralised coordination based at a single institution will decrease risks associated with data management across institutions.	Unlikely	Major	Medium

8.2.1 Roles and responsibilities for risk management

In addition, the project team recognises that the LTIM Project has occupational health and safety risks associated with carrying out on-ground monitoring activities. Draft SWMS have been developed for each of the field activities that address risks specifically related to fieldwork of their program and these are included in Appendix 3. The theme leaders will ensure that all staff will comply with the SWMS developed of this work. It must be noted that the project team contains experienced researchers who have operated under the SWMS risk management framework for the activities to be undertaken in previously research activities.

8.3 Quality plan

This quality assurance plan documents quality control and quality assurance procedures for activities at the Selected Area.

8.3.1 Equipment

Much of the equipment used to collect data for both Basin and Selected Area Evaluation requires ongoing maintenance and calibration. An outline of equipment to be used and details of maintenance and calibration required for each piece of equipment is provided in Table 32.

Table 32. Equipment to be used in the Lachlan LTIM Project including maintenance and calibration schedule

EQUIPMENT	USE	MAINTENANCE / CALIBRATION	FREQUENCY	WHO	LOG KEPT	INDICATOR
General Oceanics Mechanical Flow-meter	Monitor volume of water sampled by drift and tow nets	Calibration as per manual	Monthly during sampling (Sept – Feb)	University of Canberra	Yes	Fish (larval)
500 micron Drift nets	Capture larval fish in drift and by tow in required	Check for holes, patch if required	Prior to each sampling event	University of Canberra	Yes	Fish (larval)
Modified quatrefoil light-traps	Capture larval fish	Check for holes / cracks / gaps, patch is required	Prior to each sampling event	University of Canberra	Yes	Fish (larval)
Boat and backpack electrofishing equipment	Capture of fish	Serviced and assessed for safety and to ensure that gear is working efficiently	Prior to each sampling event	External specialist contractor	Yes	Fish (river)
Fine mesh fyke net	Capture small-bodied fish	Check for holes, patch if required	Prior to each sampling event	NSW DPI Fisheries	Yes	Fish (river)
Coarse mesh fyke net	Capture medium-large bodied fish	Check for holes, patch if required	Prior to each sampling event	NSW DPI Fisheries	Yes	Fish (river)
Turbidity meter	Spot turbidity readings for larval fish monitoring	Calibrated using standardised solutions	Prior to each sampling event	University of Canberra	Yes	Fish (larval)

EQUIPMENT	USE	MAINTENANCE / CALIBRATION	FREQUENCY	WHO	LOG KEPT	INDICATOR
PAR sensor and logger	Stream metabolism	Calibration in the field following methods outlined in standard operating procedure	6-weekly	University of Canberra	Yes	Stream metabolism
Dissolved oxygen sensor & logger	Measuring dissolved oxygen in the water	Calibration in the field following methods outlined in standard operating procedure	6-weekly	University of Canberra	Yes	Stream metabolism
Water Quality loggers	Monitor temperature, pH, electrical conductivity, turbidity & dissolved oxygen.	Internally calibrated using known standardised solutions	Seasonally	University of Canberra	Yes	Water quality, Stream Metabolism

8.3.2 Data collection (field and laboratory) – samples and measures

Relevant permits and ethics authorisation will be obtained prior to the commencement of data collection estimated to be June 2014 (see Table 33).

Table 33. Permit and ethics requirements for the Lachlan LTIM Project

INDICATOR	ETHICS AUTHORISATION REQUIRED? BY WHO?	PERMIT REQUIRED FOR SAMPLING? FROM WHO?	WHO IS RESPONSIBLE TO OBTAINING RELEVANT AUTHORISATIONS?
Fish (Larval)	Yes, University of Canberra Animal Ethics Committee	Yes, NSW DPI Fisheries Sampling permit	Ben Broadhurst – University of Canberra
Fish (River)	Yes, NSW DPI Ethics	Yes, NSW DPI Fisheries Sampling permit	Jason Thiem & Martin Asmus – NSW DPI Fisheries
Birds (Breeding and Diversity)	Yes, UNSW Animal Care and Ethics Committee (ACEC).	Yes, NPWS permit	Kate Brandis – University of New South Wales
Tortoises/Turtles	Yes, NSW DPI Ethics	Yes, NSW DPI Fisheries Sampling permit	Jason Thiem & Martin Asmus – NSW DPI Fisheries
Frogs and Tadpoles	Yes, Animal Care & Ethics Committee (ACEC)	Yes, NPWS permit	Andrew Hall – Charles Sturt University

Specific data quality controls listed are in Table 34. Training is required for some techniques and details of staff who have undertaken training will be recorded in the training log (refer to section 8.3.5). Data will be recorded onto datasheets (waterproof paper) in the field and scanned in at the first available opportunity. A back-up of the scanned datasheets will be held at the lead institution (University of Canberra). Samples collected in the field will be preserved and processed in accordance with methods outlined below. Samples will be held for the duration of the LTIM Project at theme leaders' institutions.

Table 34. Specific data collection quality control considerations for each indicator

INDICATOR	QUALITY CONTROLS IN PLACE FOR DATA COLLECTION
Vegetation diversity and condition	• All tree condition assessments where possible, will be undertaken by the same experienced observers (i.e. observers who have undertaken training in tree stand condition and/or plant species identification) to maintain consistency over time. • All observers must undergo training prior to undertaking monitoring surveys, including calibration against experienced observers (i.e. observers who have undertaken training in tree stand condition and/or plant species identification and who have had previous experience undertaking tree stand condition and/or vegetation diversity assessment) to ensure standardisation of measurements. • Visual assessments of tree condition will often differ between observers. To minimise the variance associated with different observers, a minimum of two staff are assigned to tree assessments. Where there are significant differences in original observer scores, observers will discuss their rationale and where appropriate adjust scores to mutually agreed values.
Fish (River & Larvae), Decapods and Tortoises	• NSW DPI electrofishing operators are certified under the NSW DPI Electrofishing Training schedule (Wooden, Bruce & Bindokas 2013) and operate under the requirements of the Australian Code of Electrofishing Practice. • Providers must have relevant boat licenses. • Electrofishing equipment is serviced by the manufacturer (Smith-Root Pty Ltd) on an annual basis. • Fisheries and ethics permits are to be kept with providers while sampling. • All capture gear (fyke nets, drift nets and light traps) will be checked for holes as part of every field trip. Any net with a hole will be repaired or replaced. • Range checks in place to ensure that outlier or aberrant data is queried. • A select sample of voucher specimens of those species groups typically difficult to identify in the field (see Muschal et al. 2010, MDBA (2013) Appendix 1) will be preserved for ID verification in the laboratory. • A sub-sample of 10% of otoliths will be read twice to validate the readings. • Larval fish will be preserved in 90% ethanol. Identification of larval fish to species will be undertaken by the same experienced processors (processors with previous experience with identification of larval fish) where possible. 10% of samples will be double processed (processed again by a different observer) to ensure quality control.
Waterbird breeding and Waterbird diversity	• All Waterbird assessments within a Selected Area, where possible, will be undertaken by the same experienced observers (i.e. observers who have undertaken field and aerial surveys of waterbirds previously) to maintain consistency over time. All observers must undergo training prior to undertaking monitoring surveys, which will include calibration against experienced observers to ensure standardisation of measurements. • Identification of difficult to see species will often differ between observers. To minimise the variance associated with different observers, a minimum of two staff are assigned to Waterbird assessments, particularly when aerial methods are used. Where there are significant differences in original observer scores, observers will discuss their rationale and where appropriate adjust scores to mutually agreed values. For aerial surveys this will be done immediately after flights to get agreement on species identifications.
Stream metabolism & Water quality	• All water quality samples will be taken in duplicate, collected, stored and analysed according to APHA (2014) protocols by a NATA accredited laboratory. • All laboratory analyses will be carried out to NATA standards including analysis of blanks. Samples will be held for a maximum time as indicated in the appropriate protocols in the SOP document. • All loggers will be calibrated 6-weekly as indicated in the protocols outlined in the SOP document

INDICATOR	QUALITY CONTROLS IN PLACE FOR DATA COLLECTION
Hydrology (Channel & Wetland)	• Quality assurance and quality control protocols implemented by the hydrographic agencies responsible for the gauging stations will be relied up for flow data from existing gauging stations • Water level loggers records absolute pressure, which is later converted to water level readings using software which takes into account atmospheric pressure. To compensate for barometric pressure changes, a barometric reference will be used. The barometric reference used for the stream metabolism measurements will be used. • Water level sensors may drift during deployment. To check for sensor drift, a reference level is taken at the beginning and end of the deployment. • Protect the logger. The logger can be damaged by shock and must always be handled with care. The logger may lose its calibrated accuracy or be damaged if it is dropped. Proper packaging will be used to protect the logger during transporting or shipping. • Inspect the logger for biofouling. Biological growth on the face of the pressure sensor will throw off the pressure sensor's accuracy. Organisms that grow inside the sensor nose cone and on the sensor itself can interfere with the sensor's operation and eventually make the sensor unusable. The logger will be checked for biological growth when downloading data. • For wetlands, spot measurements of water depth during field visits and notes on the extent of inundation will be used to verify the NSW OEH mapping of inundation extent and wetland connection.
Frog and tadpoles	• On all field occasions involving frog surveys, a research assistant trained in frog identification will be present. • Species that are not identifiable on site will be photographed and identified using the following field guides Anstis, M. 2002; Anstis, Marion 2013. • Consultation between trained research assistant and frog experts at Charles Sturt University will be used to identify species from photographs.
Waterbird breeding and Waterbird diversity	• All Waterbird assessments within a Selected Area, where possible, should be undertaken by the same experienced observers to maintain consistency over time. All observers must undergo training prior to undertaking monitoring surveys, including calibration against experienced observers to ensure standardisation of measurements. • Identification of difficult to see species will often differ between observers. To minimise the variance associated with different observers, a minimum of two staff are assigned to Waterbird assessments, particularly when aerial methods are used. Where there are significant differences in original observer scores, observers will discuss their rationale and where appropriate adjust scores to mutually agreed values. For aerial surveys this should be done immediately after flights to get agreement on species identifications.

8.3.3 Data storage and management

Data management for the LTIM Project is guided by the following principles:

- **Good governance:** Leadership and coordination is essential to ensure the effective delivery of the LTIM Project.
- **Custodianship:** Data custodians are trustees that do not 'own' data but responsibly manage and maintain it for use by a wider community of users. Data is maintained in one location as the authoritative source for the dataset.
- **Shared responsibility:** Those collecting the data are responsible for the quality of the data. The CEWO is responsible for the integrity of the dataset. Data users are responsible for wise and appropriate use of the data.
- **High quality data:** Comprehensive but achievable quality assurance and quality control (QA/QC) procedures ensure the collection of high quality data that is fit for purpose.
- **Standards and interoperability:** Consistent adherence to data standards facilitates linkages with related or complementary data and preserves the utility and comparability of data through time.
- **Metadata:** Accurate metadata accompanying each dataset provides contextual information on where, who, how and why the data were collected and documents known assumptions or limitations to guide interpretation.

Theme leaders will be responsible for collating raw and processed data relevant to both Basin and Selected Area Evaluation. A back-up of raw data (that is not to be altered) will be held by the lead organisation (University of Canberra). Backup of raw data will occur within 1 month of collection of data (i.e. downloading of loggers or data from processed of samples). Data sharing between theme leaders and between Selected Areas may occur, and will be based upon written agreements between the parties. Investigations into the use of Australian Living Atlas are being made for longer-term storage of raw data. Derived data supplied to the CEWO for basin scale evaluation will adhere to LTIM data standards Version 0.2. M&E Providers will submit their data that supports shared evaluation needs within 1 month of collection, and according to the protocols established by CEWO.

8.3.4 Document management

Overall document management and final document custodianship will lie with the lead organisation (University of Canberra). Theme leaders will be responsible for providing all updated documents to University of Canberra for back-up. Reviewing of documents (to ensure quality and fit for audience targets being met) will take place internally within each theme leader's institution, then of the overall document by the theme leaders. The annual reports will be reviewed by an external reviewer who is yet to be named. The process for selecting an external reviewer will be to select someone with extensive experience in environmental assessments, especially those relating to environmental flows. External reviewer will not be a part of any institution that forms part of the Lachlan LTIM Project team. Currently that person is Dr. Jane Roberts.

Table 35. Document management procedures for the Lachlan LTIM Project. For details on the provision of the documents refer to Table 20

DOCUMENT TYPE	PREPARED BY	DETAILS OF REVIEW	REVIEWED BY
Progress/Status reports	Project lead -Fiona Dyer with input from theme leaders	None	
Quarterly reports	Project lead -Fiona Dyer with input from theme leaders	Internal review	**Theme leaders**
Annual reports	Project team, led by Fiona Dyer	Initially internal review will be undertaken by theme leaders prior to document being submitted for external review 1 month prior to submission to CEWO. The external review will then be due back to the project team 2 weeks after submission to reviewer to allow time for review to be addressed.	**Theme leaders (Internal review) & external review (see above to criteria in selecting external reviewer/s)**

8.3.5 Training

A number of the methods to be used in Basin-scale evaluation have training requirements (e.g. field assessments of tree stand condition), so document evidence or include logs of training.

Table 36. Training requirements for field assessments

Method	Training	Staff who will have completed training	Training due
Boat & backpack electrofishing	Electrofishing principles and techniques – provided by US Fish and Game Department	Martin Asmus, (and NSW DPI technical officers), Ben Broadhurst, Rhian Clear.	End of February 2015
Boat operation	Boat licence	Martin Asmus, Ben Broadhurst and Rhian Clear.	31st August 2014

8.3.6 Auditing

CEWO will be establishing whole-of-project audit procedures. Self-auditing will be conducted (led by University of Canberra - Fiona Dyer and Ben Broadhurst and implemented by theme leaders) annually to ensure that;

- Quality plan specifications are being met. Specifically:
  - Standard operating methods are being adhered to.
  - Data management is following prescribed methods.
  - Document control procedures are in place.
  - Training is updated and completed where necessary.
  - Gear maintenance has been conducted and logged (where appropriate).

Self-audits will be undertaken in June each year. Following the audit a review of the quality plan will be undertaken and an update created. Amendments to the quality plan will be recorded in a document log (below). Preparation of amendments will be undertaken by the project team and approved by the project leader and the CEWO.

Table 37. Log of amendments of the Lachlan LTIM Project quality Plan

Register of amendments					
Date of approved amendment	Page	Version No.	Description of amendments	Prepared by	Approved by

8.4 Health, safety and environment plan

8.4.1 Overview

The Work Health Safety (WHS) Plan prepared for the Lachlan river system Selected Area LTIM Project team complies with the Commonwealth Work Health Safety Act 2011, Work Health and Safety Regulations 2011 and Work Health and Safety Codes of Practice 2011 and relevant State and Territory legislation. Refer to Appendix 3 for additional information.

The overarching objective of the WHS plan is to ensure that project risks are eliminated or mitigated through the identification of hazards, assessment of risk and the application of effective control measures.

The key components of this WHS Plan cover:

- Project scope and outline.
- Document control.
- Objectives and targets.
- Hazard identification, risk assessment and control.
- Personal protective equipment.
- Roles and responsibilities.
- Training and competencies.
- Consultation.
- Hazardous substances / dangerous goods management.
- Electrical equipment management.
- Hazard and incident reporting and investigation.
- Supporting reference documents (SWMS, policies etc.)

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Commonwealth Environmental Water Office Long Term Intervention Monitoring Project Lachlan River System

Appendix 1 Standard Operating Procedures

February 2015

UNIVERSITY OF CANBERRA

Contents:

1 Ecosystem Type

1.1 Evaluation questions

This is a protocol to validate the interim Australian National Aquatic Ecosystems (ANAE) classification at monitoring sites. The interim ANAE ecosystem typology and classification are relevant to the following Basin evaluation questions:

Short-term (one-year) and long-term (five year) questions:

- What did Commonwealth environmental water contribute to sustainable ecosystem diversity?
- Were ecosystems to which Commonwealth environmental water was allocated sustained?
- Was Commonwealth environmental water delivered to a representative suite of ecosystem types?

The process for evaluating these questions is illustrated in Figure 1, with components covered by this protocol highlighted in blue.

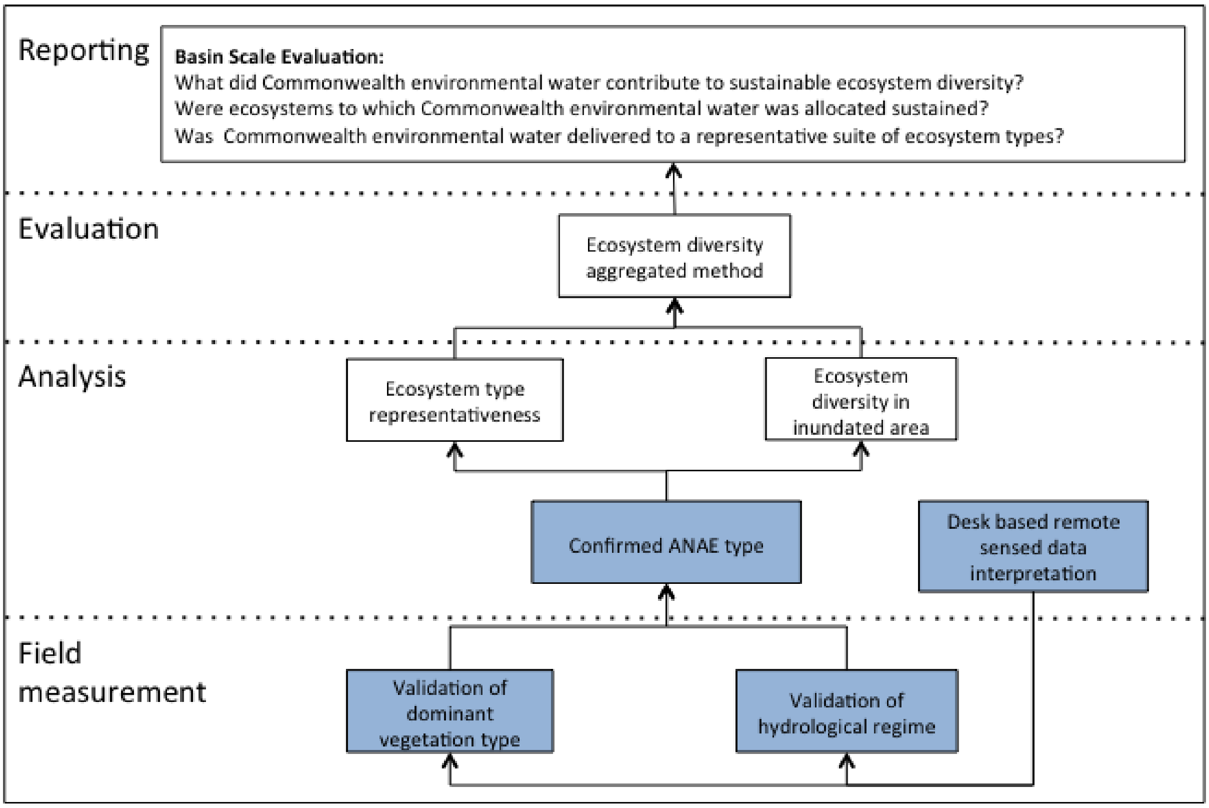

Figure 1: Schematic of key elements of the LTIM Project Standard Protocol: Ecosystem type.

1.2 Relevant ecosystem types

Rivers and wetlands. Note that the definition of wetland used in the Logic and Rationale for the LTIM project incorporates palustrine and lacustrine systems as defined in the interim Australian National Aquatic Ecosystem (ANAE) classification. Also note, that while the protocol is to be applied to wetlands on floodplains, it is not currently recommended for broader areas of the floodplain surface.

1.3 Relevant flow types

All flow types are relevant to ecosystems.

1.4 Overview and context

This method is the field validation if the ANAE classification that is required for the Basin Scale evaluation of ecosystem diversity for the LTIM project. Brooks et al. (2013) applied the interim ANAE framework to aquatic ecosystems across the Murray Darling Basin using the best available mapping and attribute data. Wetland polygons, riverine polygons, and river centre lines were attributed with the majority coverage of each attribute without dividing them further. The scale and coverage of available mapping and attribute data varied considerably across the MDB has not yet been validated by the contributing jurisdictions. There is a need to validate the mapping outputs from Brooks et al. (2013) as they relate to specific sampling sites, and the Selected Areas. The current mapping may be useful within the LTIM project but should not be relied upon until validated. This validation must be carried out at all Selected Areas for each ecosystem type that falls within an assessment unit for all other on-ground monitoring programs:

- LTIM Standard Protocol: Fish (River)
- LTIM Standard Protocol: Fish (Wetland)
- LTIM Standard Protocol: Fish (Larvae)
- LTIM Standard Protocol: Hydrology (River)
- LTIM Standard Protocol: Hydrology (Wetland)
- LTIM Standard Protocol: Macroinvertebrates
- LTIM Standard Protocol: Stream metabolism
- LTIM Standard Protocol: Tree stand condition
- LTIM Standard Protocol: Vegetation diversity
- LTIM Standard Protocol: Waterbirds breeding
- LTIM Standard Protocol: Waterbirds diversity
- LTIM Standard Protocol: Water quality

1.5 Complementary monitoring and data

Mapping output from Brooks et al. (2013) or any regional sources with updated feature mapping for the Selected Area, any fine scale resolution vegetation mapping and/or remote sensed data, current aerial photography, satellite imagery (e.g. SPOT6 – panchromatic resolution 1.5 m, multispectral resolution 8 m) and NVIS41_MDB vegetation mapping (NVIS v4.1 updated with CMA mapping by Brooks et al. 2013). These should be used in the first instance to aid in identifying aquatic ecosystem types prior to the field validation.

1.6 Interim ANAE classification

1.6.1 Terminology

For the purposes on the LTIM project aquatic ecosystems have been described in the Logic and Rational document as rivers, floodplains and wetlands. This is a simplification of four ecosystem classes into three common terms. For the validation protocol the terminology defined by the interim ANAE classification (Aquatic Ecosystem Task Group 2012) is to be applied. The ecosystem classes relevant to the LTIM project are as follows:

- **Floodplain systems** are those aquatic systems that are either seasonally or intermittently flooded flat areas that are outside the riverine channels or palustrine/lacustrine systems but that display characteristics of hydric soils or vegetation that are characteristically adapted to the seasonal or intermittent presence of water. ***Excluded from this protocol.***

- **Lacustrine systems** (lakes) are open-water dominated systems, characterised by deep, standing or slow-moving water with little or no emergent vegetation (<30% cover). (Included as wetlands in Logic and Rational document).
- **Palustrine systems** are primarily shallow, vegetated, non-channel environments, including billabongs, bogs, swamps, springs, soaks etc. (Included as wetlands in Logic and Rational document).
- **Riverine systems** are those that are contained within a channel and its associated streamside vegetation. This definition refers to both single channel and multi-channel systems e.g. braided channel networks. The beds of channels are not typically dominated by emergent vegetation, may be naturally or artificially created, periodically or continuously contain moving water, and may form a connecting link between two bodies of standing water (Aquatic Ecosystem Task Group 2012). (Includes riparian systems).

The typology used to assign ecosystem types is presented as a dichotomous key in section 0 and as an extract from Brooks et al. (2013) in section 0.

An example of the mapping output from Brooks et al (2103) for some saline Victorian systems is shown in Figure 2. This highlights some of the potential validation issues that may be encountered. In some cases the data provided for the MDB mapping project included situations were multiple polygons were sub-units of larger polygons. In most cases this is likely to represent a different habitat/vegetation type within a single wetland. In this case, as illustrated below, it is advised to use the larger ecosystem and unique identifier as the assessment ecosystem. Attribute mapping that overlays these polygons (e.g. vegetation, hydrological regime, salinity) may also contain inaccuracies. Confidence measures included in the Brooks et al (2103) mapping product should be used to guide interpretation. Note that it is expected that updated mapping will be made available in coming years as attribute data improves, however the ecosystem typology is considered robust and is less likely to change significantly.

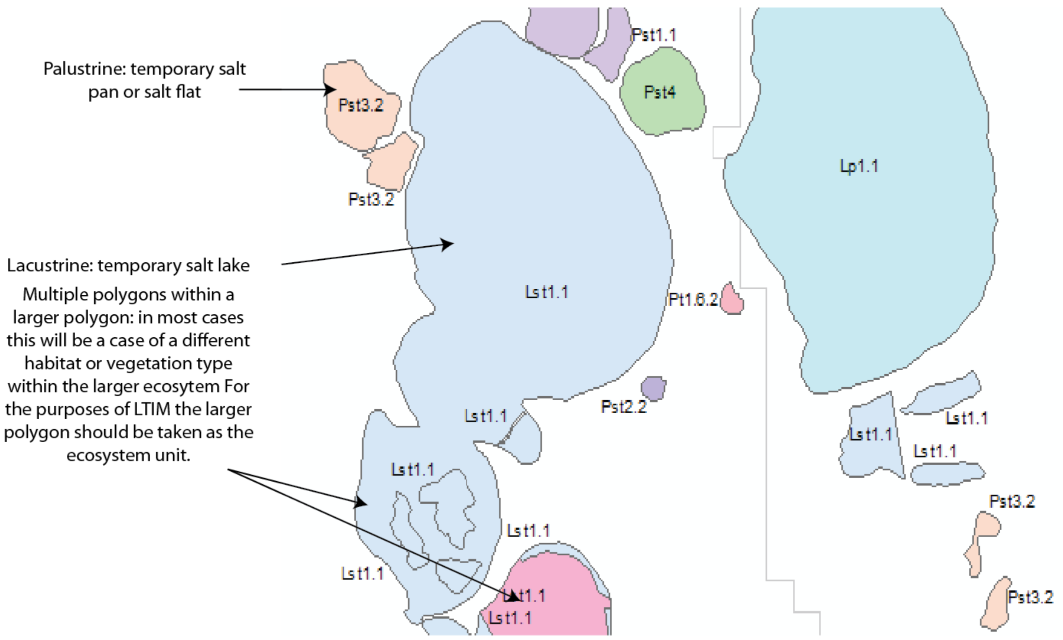

Figure 2: Example of mapping output from Brooks et al. (2013) with areas requiring validation.

A unique number (SYSID) for each polygon (wetland, lake, floodplain) or line (river, creek, stream) identifies each mapped unit (Brooks et al. 2013). On ground validation of the interim ANAE classification is required to confirm the aquatic ecosystem types for use in the LTIM program.

1.6.2 Validation Sites

Validation sites include all sites for other monitoring protocols (i.e. waterbird breeding sites, tree stand condition sites, fish sites, etc.). Where a site has not been mapped the typology developed by Brooks et al. (2013) should be used to assign an ecosystem type *de novo* (Protocol step 3 below).

1.6.3 Equipment

- Maps of Selected Area including assessment site information.
- Aerial imagery should be as current as possible and of sufficient resolution to identify vegetation.
- Satellite imagery – e.g. SPOT6.
- GPS.
- Datasheets and/or field computer.
- Appropriate safety gear.
- Copy of this protocol.
- Appropriate plant identification field guides.

1.6.4 Protocol

1. Prior to field visit, source and review all relevant information relevant to the potential area of influence of Commonwealth environmental water.

This will include, but not necessarily be limited to, mapping output from Brooks et al. (2013) for the selected area, current aerial imagery (e.g. Google Earth), satellite imagery and fine scale mapping (aquatic ecosystem type and or vegetation mapping) from state agency partners.

2. Identify the ecosystems to be assessed and record/locate their unique identifier code.
    - If mapped by Brooks et al. (2013) use the SYSID as the unique identifier for each mapped ecosystem.
    - If the ecosystem is not mapped then record coordinates (GDA94) of the centre of the ecosystem and either locate compatible GIS mapping or delineate the boundary of the ecosystem using remote sensed data. Contact your Selected Area M&E Advisor to obtain a unique identifier for the ecosystem.
3. Using the dichotomous key presented in Supplement B assign an ecosystem type and code to each assessment ecosystem, noting any knowledge gaps that relevant unambiguous classification
    - If the aquatic ecosystem is mapped then check if the interim ANAE type allocated to the polygon/line feature representing the ecosystem (see Supplement B) is correct. (Note that is it possible to have lacustrine and palustrine systems located on floodplains and some, or potentially many, of these may not have been captured in the interim ANAE mapping).
    - Record the correct interim ANAE type as per the typology in Supplement B.
4. Determine locations for ground-truthing, mark on map and note GPS co-ordinates. The ground truthing should be designed to:
    - Confirm / identify dominant vegetation type (note the typology is based on dominant vegetation type only, so not all habitat/ vegetation types require ground-truthing).

- Fill any knowledge gaps identified in step 2.
- Be easily and safely accessible.

5. Use the information collected in the field to update (if necessary) the ecosystem type as identified in step 4.

1.7 Quality Assurance/Quality Control

The dominant vegetation type at each site will be recorded during the initial field campaign. Prior to field assessments, staff will be trained in the methods and a field site used to verify the ability of staff to determine the dominant vegetation. All sites will be verified by a team of two staff and where the classification differs from that of Brooks et al., (2013) standardised photographs of the site will be provided as evidence of the classification.

1.8 Data Description

The spatial unit for which data is reported for this validation is an ANAE feature identified by the ANAE SYSID.

Each row of data provided for this validation will identify the ANAE SYSID, the original classification, and the revised classification. The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

All data provided for this indicator will conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

1.9 Health and safety

For details on health and safety please refer to the Workplace Health and Safety Plan for the Lower Lachlan river system Selected Area (WHS 202.1) in appendix 3.

1.10 References

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Supplement A: Example Ecosystem Type Validation field sheet

ECOSYSTEM TYPE VALIDATION FIELD SHEET: Page ---------------- of ------------------			Selected Area:	
Date:			Name of recorder:	
Mapped ecosystems				
SYSID	ANAE Type (code and name)	Valid Y/N	Correct ANAE type (code and name)	Relevant assessment protocol
e.g. 123456	Lst1.1: Temporary saline lakes	N	Lst1.2: Temporary saline lakes with aquatic beds	Waterbird breeding

ECOSYSTEM TYPE VALIDATION FIELD SHEET: Page ---------------- of ------------------		Selected Area:	
Date:		Name of recorder:	
New ecosystems (not mapped by Brooks et al. 2013)			
Unique identifier	Location GDA94	ANAE Type (code and name)	Relevant assessment protocol

Supplement B: Key to MDB interim ANAE Typology

The following terminology explains some of the descriptors used in the typology, and some of the assumptions made in order to simplify the naming convention (modified from Brooks et al. 2013):

Energy (high, low) – pertains to the relative energy of riverine flows resulting from the slope or steepness of the terrain.

Fen and bogs – peatlands (bogs and fen) are created under a range of hydrological and physical conditions. Fens are formed where mineral rich groundwater flows sustain vegetation such as grasses, sedges, reeds, shrubs and trees (Batzer and Sharitz 2006). The alkaline nature of fens and the fact that their primary water source is groundwater, with some surface and rainfall inputs, distinguishes them from bogs, which are dominated by surface water inputs. Bogs are further characterised as supporting Sphagnum moss.

Freshwater – unless specified, aquatic ecosystems are assumed to be freshwater (salinity <3000 mg/L).

Intermittent – used to describe the water regime of periodically inundated types in which inundation is known to be less frequent than annual or seasonal inundation, but more frequent than episodic and ephemeral inundation. Flooding may persist from months to years (Boulton and Brock 1999). Only used in the type name when the inundation requirements of the dominant vegetation associated with the system are able to inform the frequency of inundation, or when waterholes have been identified as being present in a stream.

Lake – an inland body of water, predominantly still or lentic in nature. Cowardin et al. (1979) defines them as being situated in a topographic depression or a dammed river channel, and having less than 30 per cent emergent vegetation. Size may vary but most will exceed eight hectares; those with similar habitats but less than eight hectares can also be included, however, if active wave-formed or bedrock shoreline features makes up all or part of the boundary, or their depth is greater than 2 meters. Ocean-derived salinity is always less than 0.5 parts per thousand, thus separating them from lagoons.

Marsh – a wetland dominated by non-woody emergent vegetation such as sedges, reeds and rushes. Marshes can be shallow or deep with a combination of emergent and submergent vegetation types. They may also have areas of open water in deeper systems, up to 70 per cent of wetland area. Marshes are typically between 0.5 to 2 meters depth, but depth can be highly variable.

Meadow – a wetland dominated by grasses (excluding Phragmites which is typically found in deeper marsh environments) and forbs. Meadows typically have shallow depths in the order of 10 to 50 centimeters. They are rarely permanent, often being filled on a seasonal basis.

Permanent – used to describe the water regime of commonly wet systems (wet >70 per cent of the time). This assumes that for commonly wet lakes, for example, that they have water all year round except during extreme droughts, when they can dry out. Permanent is used as a commonly accepted term (e.g. Ramsar and Queensland typologies).

Saline – ecosystems with a salinity >3000 mg/L.

Streams – 'streams' is taken to include rivers, streams and creeks for the purposes of simplifying the naming convention. Rivers are large natural in-channel bodies of moving water (lotic) which have the capacity to structure the surrounding landscape (i.e. alluvial processes). This includes large anabranching systems (e.g. Edward-Wakool Rivers are major anabranches of the River Murray). Streams and creeks, both of which are typically smaller in-channel bodies of moving water, can be either a tributary or distributary of a river.

Swamp – a wetland dominated by woody vegetation, either shrubs and or trees.

Temporary – used to describe the water regime of periodically inundated types when the frequency of inundation is not known, but is less than commonly wet (wet <70% of the time).

Key to MDB interim ANAE types

This typology can be used to validate ecosystem types at which assessments are made for both mapped and unmapped features. It can also be used to identify ecosystems that have not been mapped. For greater detail see section 0.

1a	Ecosystem being validated/classified is a line feature, has flowing water and a defined channel.................................***Riverine systems*** got to 2
1b	Ecosystem being validated/classified is a polygon feature, typically lacks flowing water and a defined channel..go to 5
2a	Water regime permanent (surface water >70% of time) ....go to 3
2b	Water regime temporary (surface water present <70% of time)..go to 4
3	Landform for ANAE was derived in GIS by intersecting features with the 3sec CSIRO Valley Bottom Flatness and does not require field validation…
Rp1.1: Permanent high energy upland streams	
Rp1.2: Permanent transitional zone streams	
Rp1.3: Permanent low energy upland streams	

Rp1.4: Permanent lowland streams

4 Landform for ANAE was derived in GIS by intersecting features with the 3sec CSIRO Valley Bottom Flatness and does not require field validation…

Rt1.1: Temporary high energy upland streams

Rt1.2: Temporary transitional zone streams

Rt1.3: Temporary low energy upland streams

Rt1.4: Temporary lowland streams

5a. Ecosystem with less than 30% emergent vegetation, large enough to support wave action ……………………………….***Lacustrine systems*** go to 6

5b. Ecosystem with more than 30% emergent vegetation, or no vegetation. If no vegetation typically shallow and doesn't develop wave action (i.e. deflation basins, salt flats, clay pans etc.). ………..........go to 17

6a Water type: fresh ……go to 7

6b Water type: saline…….go to 10

7a Permanent (surface water >70% of time)……go to 8

7b Temporary (surface water <70% of time)……go to 9

8a Permanent floodplain lakes, with or without submergent aquatic macrophyte……………………………………………………………………………………….

……….**Lp2.1: Permanent floodplain lakes**

……….**Lp2.2: Permanent floodplain lakes with aquatic beds**

8b Permanent non-floodplain lakes, with or without submergent aquatic macrophytes………………………………………………………………………………

……….**Lp1.1: Permanent lakes**

……….**Lp1.2: Permanent lakes with aquatic beds**

9a Floodplain lakes, with or without submergent aquatic macrophytes…………………………………………………………………………………………………….

……….**Lt2.1: Temporary floodplain lakes**

……….**Lt2.2: Temporary floodplain lakes with aquatic beds**

9b Non- floodplain lakes, with or without submergent aquatic macrophytes ……………………………………………………………………………………………

……**Lt1.1: Temporary lakes**

……**Lt1.2: Temporary lakes with aquatic beds**

10a Permanent saline lakes (surface water >70% of time)………go to 11

10b Temporary saline lakes (surface water <70% of time)………go to 12

11a Floodplain saline lakes, with or without submergent aquatic macrophytes……………………………………………………………………………………………

……**Lsp2.1: Permanent saline floodplain lakes**

……**Lsp2.2: Permanent saline floodplain lakes with aquatic beds**

11b Non-floodplain saline lakes, with or without submergent aquatic macrophytes……………………………………………………………………………………………

……**Lsp1.1: Permanent saline lakes**

………………………………………………………………… **Lsp1.2: Permanent saline lakes with aquatic beds**

12a Temporary saline floodplain lakes, with or without submergent aquatic macrophytes ……………………………………………………………………………………

……**Lst2.1: Temporary saline floodplain lakes**

……**Lst2.2: Temporary saline floodplain lakes with aquatic beds**

12b Temporary saline non-floodplain lakes, with or without submergent aquatic macrophytes…………………………………………………………………………

……**Lst1.1: Temporary saline lakes**

……**Lst1.2: Temporary saline lakes with aquatic beds**

13a The ecosystem is a wetland depression ……………………………………………………………………………………………………***Palustrine systems*** go to 14

14a Water type: fresh……go to 15

14b Water type: saline……go to 20

14c Unspecified, no data…………………………………………………………………………… **Pu1: Unspecified wetland**

15a Permanent springs…………………………………………………………………………… **Pp5: Permanent springs**

15b Permanent (surface water >70% of time), non-springs……go to 16

15c Temporary (surface water <70% of time)………go to 23

16a Permanent floodplain wetlands……go to 19
16b Permanent non-floodplain wetlands………go to 18
17a Floodplain swamps - dominated by woody vegetation ………………………..**Pp1.1.1: Permanent floodplain paperbark swamps**
17b Floodplain marshes – dominated by non-woody vegetation…………………………………………………………………………………………
(e.g. Typha, Phragmites, Baumea, Juncus: tall spp typically>1m)………………..…**Pp2.1.1: Permanent floodplain tall emergent marshes**
(species typically <1m)…………………………………………………………………….…..**Pp2.2.1: Permanent floodplain sedge/grass/forb marshes**
………………………………………………………………………………………………..……..**Pp2.3.1: Permanent floodplain grass marshes**
……………………………………………………………………………………………….……..**Pp2.4.1: Permanent floodplain forb marshes**
17c Floodplain wetland, unspecified vegetation...…**Pp4.1: Permanent floodplain wetland**

18a Non-floodplain swamps- dominated by woody vegetation …………………**Pp1.1.2: Permanent paperbark swamps**
18b Non-floodplain marshes, bogs and fens – dominated by non-woody vegetation……………………………………………………………………
(e.g. Typha, Phragmites, Baumea, Juncus: tall spp typically>1m).……………………**Pp2.1.2: Permanent tall emergent marshes**
(species typically <1m)…………………………………………………………………….…..**Pp2.2.2: Permanent sedge/grass/forb marshes**
………………………………………………………………………………………………….....**Pp2.3.2: Permanent grass marshes**
…………………………………………………………………………………………………....**Pp2.4.2: Permanent forb marshes**
(fen marshes dominant water source is groundwater)...................................... **Pp3: Peat bogs and fen marshes**
18c Non-floodplain wetland, unspecified vegetation…..……………………………**Pp4.2: Permanent wetland**
19a Temporary floodplain swamps and marshes, identified by dominant vegetation type…………………………………………………………………
………………………………………………………………………………………………………**Pt1.1.1: Intermittent River red gum floodplain swamp**
………………………………………………………………………………………………………**Pt1.2.1: Intermittent Black box floodplain swamp**
………………………………………………………………………………………………………**Pt1.3.1: Intermittent Coolibah floodplain swamp**
………………………………………………………………………………………………………**Pt1.4.1: Intermittent River Cooba floodplain swamp**

………**Pt1.5.1: Temporary paperbark floodplain swamp**

(tree species unidentified)……………………………………………………………………………**Pt1.6.1: Temporary woodland floodplain swamp**

………**Pt1.7.1: Intermittent Lignum floodplain swamps**

(e.g. Typha, Phragmites, Baumea, Juncus: tall spp typically>1m)……………………**Pt2.1.1: Temporary tall emergent floodplain marsh**

(species typically <1m)…………………………………………………………………………………**Pt2.2.1: Temporary sedge/grass/forb floodplain marsh**

(water typically <50cm, often seasonally inundated)…………………………………………**Pt2.3.1: Floodplain freshwater meadow**

………**Pt3.1.1: Floodplain clay pan**

(unspecified vegetation)………………………………………………………………………………**Pt4.1: Temporary floodplain wetland**

19b Temporary non-floodplain swamps, marshes, identified by dominant vegetation type…………………………………………………………………………………………

………**Pt1.1.2: Intermittent River red gum swamp**

………**Pt1.2.2: Intermittent Black box swamp**

………**Pt1.3.2: Intermittent Coolibah swamp**

………**Pt1.4.2: Intermittent River Cooba swamp**

………**Pt1.5.2: Temporary paperbark swamp**

(tree species unidentified)……………………………………………………………………………**Pt1.6.2: Temporary woodland swamp**

………**Pt1.7.2: Intermittent Lignum swamps**

(e.g. Typha, Phragmites, Baumea, Juncus: tall spp typically>1m)…………………… **Pt2.1.2: Temporary tall emergent marsh**

(species typically <1m)…………………………………………………………………………………**Pt2.2.2: Temporary sedge/grass/forb marsh**

(water typically <50cm, often seasonally inundated)…………………………………………**Pt2.3.2: Freshwater meadow**

(lacks vegetation, shallow)…………………………………………………………………………**Pt3.1.2: Clay pan**

(unspecified vegetation)………………………………………………………………………………**Pt4.2: Temporary wetland**

20a Permanent saline palustrine systems (surface water >70% of time), identify by dominant vegetation type……………………………………………………

………**Psp1.1: Saline paperbark swamp** (e.g. samphire)………………………………………………………………………………………….**Psp2.1: Permanent salt marsh**

………**Psp3.1: Permanent seagrass marsh**

………**Psp4: Permanent saline wetland (vegetation not specified)**

20b Temporary saline palustrine systems (surface water <70% of time) identify by dominant vegetation type ………………………………………………….

………**Pst1.1: Temporary saline swamp**

(e.g. samphire)…………………………………………………………………………………………**Pst2.2: Temporary salt marsh**

………**Pst3.2: Salt pans and salt flats**

(vegetation unspecified)……………………………………………………………………………**Pst4: Temporary saline wetland**

Typology (extract from Brooks et al. 2013)

Water regime, water type and vegetation are the main attributes used throughout the typology developed by Brooks et al. (2013). It should be noted that only vegetation structure (not dominant vegetation) has been used to help distinguish types for lacustrine and riverine classes. 'Non-vegetated' is a valid category for riverine systems as it can represent areas of settlement, or cleared areas. As lacustrine systems are defined on the basis of having less than 30 per cent emergent vegetation, 'only water' is considered as a valid attribute category for the dominant vegetation attribute in the typology for lakes. For example, it would not be appropriate to describe a type on vegetation that only occurred over, say, 5 per cent of the site.

Lacustrine systems

The typology proposed for lacustrine systems (Table 30) is based on the following Level 3 ANAE attributes:

- Water type;
- Water regime (water permanency);
- Dominant vegetation (water only);
- Finer vegetation (aquatic bed).

The typology for lacustrine systems also captures if the system is located on a floodplain. A number of types can be aggregated (for example permanent lakes with or without submerged macrophytes can be aggregated up to being called just permanent lakes) and this is explained in the descriptions for each combination of attributes in Table 1. In the typology lacustrine systems are considered freshwater unless stated otherwise in the naming convention. Also lakes are assumed to have no submergent vegetation unless stated in the name convention.

Table 1: Lacustrine types using Level 3 attributes and a location descriptor (floodplain) (from Brooks et al. 2013).

Note: Dominant vegetation and fringing vegetation do not provide any greater separation of types. Codes: Lp = permanent freshwater lacustrine/lakes, Lt = temporary freshwater lacustrine/lakes, Lsp = permanent saline lacustrine/lakes, Lst = temporary saline lacustrine/lakes

WATER TYPE	WATER REGIME	DOMINANT VEGETATION	FINER SCALE VEGETATION	LOCATED ON FLOODPLAIN	TYPE			DESCRIPTION
Fresh	Commonly wet	Water	No vegetation	No	Lakes	Lp1: Permanent lakes	Lp1.1: Permanent lakes	Includes volcanic lakes, dune lakes, crater lakes, alpine lakes and other inland lakes. Typically greater than 2 metres deep with substantial areas of open water – may have fringing vegetation in littoral zone, but are defined as having less than 30 per cent emergent vegetation and no to limited submergent vegetation. Often greater than 8 ha in size, but smaller systems are also included if they are greater than 2m deep and support wave action.
			Aquatic bed				Lp1.2: Permanent lakes with aquatic beds	As for Lp1.1 but have substantial areas of submergent macrophytes (e.g. Hattah Lakes). This type of lake is likely to be shallow in areas which support macrophytes.
			No vegetation	Yes		Lp2: Permanent floodplain lakes	Lp2.1: Permanent floodplain lakes	As for Lp1.1, but lakes located on floodplains.
			Aquatic bed				Lp2.2: Permanent floodplain lakes with aquatic beds	As for Lp1.2, but lakes located on floodplains.
	Periodic inundation	Water	No vegetation	No		Lt1: Temporary lakes	Lt1.1: Temporary lakes	As for Lp1.1 but tend to be shallower and periodically dries (temporary).
			Aquatic bed				Lt1.2: Temporary lakes with aquatic beds	As for Lp1.2; but lakes are temporary.
			No vegetation	Yes		Lt2: Temporary	Lt2.1: Temporary floodplain lakes	As for Lt1.1, with main distinction being location on floodplain with

WATER TYPE	WATER REGIME	DOMINANT VEGETATION	FINER SCALE VEGETATION	LOCATED ON FLOODPLAIN	TYPE			DESCRIPTION
						floodplain lakes		dominant water source assumed to be from parent stream.
			Aquatic bed				Lt2.2: Temporary floodplain lakes with aquatic beds	As for Lt1.2, with main distinction being location on floodplain with dominant water source assumed to be from parent stream.
Saline	Commonly wet	Water	No vegetation	No	Saline lakes	Lsp1: Permanent saline lakes	Lsp1.1: Permanent saline lakes	As for Lp1.1, but saline.
			Aquatic bed				Lsp1.1: Permanent saline lakes with aquatic beds	As for Lp1.2, but saline. Examples of typical aquatic vegetation include systems with *Ruppia*.
			No vegetation	Yes		Lsp2: Permanent saline floodplain lakes	Lsp2.1: Permanent saline floodplain lakes	As for Lp2.1 but saline.
			Aquatic bed				Lsp2.2: Permanent saline floodplain lakes with aquatic beds	As for Lp2.2 but saline.
	Periodic inundation	Water	No vegetation	No		Lst1: Temporary saline lakes	Lst1.1: Temporary saline lakes	As for Lt1.1, but saline
			Aquatic bed				Lst1.2: Temporary saline lakes with aquatic beds	As for Lt1.2, but saline.
			No vegetation	Yes		Lst2: Temporary saline floodplain lakes	Lst2.1: Temporary saline floodplain lakes	As for Lt2.1, but saline.
			Aquatic bed				Lst2.2: Temporary saline floodplain lakes with aquatic beds	As for Lt2.2, but saline.

Palustrine systems

The typology proposed for palustrine systems (Table 31) is based on the following Level 3 ANAE attributes:

- Water type;
- Water regime;
- Dominant vegetation (structure);
- Finer scale vegetation (dominant species) **(Note this equates to vegetation type/habitat type in LTIM).**

The typology for palustrine systems also captures if the system is located on a floodplain. The typology for palustrine systems includes a greater number of types as the potential range of vegetation associations/attributes is greater, as these reflect the greater range or variability in water regime encountered in this ecosystem class. Springs were assigned to individual features as designated in jurisdictional data sets and were assumed to be commonly wet.

Table 2: Palustrine types using Level 3 attributes (from Brooks et al. 2013).

Codes Pp = permanent wetland types, Pt = temporary wetland types, Psp = permanent saline wetland types, Pst = temporary saline wetland types, Pu = unknown

WATER TYPE	WATER REGIME	DOMINANT VEGETATION	FINER SCALE VEGETATION	LOCATED ON FLOODPLAIN	TYPE			DESCRIPTION
Fresh	Commonly wet	Tree	Paperbark	Yes	Pp1: Permanent swamp forest	Pp1.1: Permanent paperbark swamps	Pp1.1.1: Permanent floodplain paperbark swamps	Permanent wetlands on floodplains; vegetation is emergent and dominated by paperbark.
				No			Pp1.1.2: Permanent paperbark swamps	As for Pp1.1.1, but not on floodplains.
		Sedge	Tall emergent aquatic	Yes	Pp2: Permanent marsh	Pp2.1: Permanent tall emergent marshes	Pp2.1.1: Permanent floodplain tall emergent marshes	Permanent wetlands on floodplains; vegetation is dominated by emergent aquatic species, including *Typha*, *Phragmites*, *Eleocharis*, some *Juncus* species, Includes species ≥1m in height.
				No			Pp2.1.2: Permanent tall emergent marshes	As for Pp2.1.1, but not on floodplains.
		Sedge	Aquatic sedge/grass/forb	Yes		Pp2.2: Permanent sedge/grass/forb marshes	Pp2.2.1: Permanent floodplain sedge/grass/forb marshes	Permanent wetlands on floodplains; vegetation is emergent, but can also include submergent species as well. Height of emergent species is typically ≤1m – can include species from *Carex*, *Cyperus*, *Myriophyllum*, *Triglochin*, *Eleocharis, Sporobolus, Amphibromus, Pseudoraphis spinescens etc*. Includes obligate

WATER TYPE	WATER REGIME	DOMINANT VEGETATION	FINER SCALE VEGETATION	LOCATED ON FLOODPLAIN	TYPE			DESCRIPTION
								aquatics as well as amphibious species in littoral zones.
				No			Pp2.2.2: Permanent sedge/grass/forb marshes	As for Pp2.2.1, but not on floodplains.
		Grass/forb	Freshwater grasses	Yes		Pp2.3: Permanent grass marshes	Pp2.3.1: Permanent floodplain grass marshes	Permanent wetlands on floodplains; vegetation is emergent grass species.
				No			Pp2.3.2: Permanent grass marshes	As for Pp2.3.1, but not on floodplains.
		Grass/forb	Freshwater forb	Yes		Pp2.4: Permanent forb marshes	Pp2.4.1: Permanent floodplain forb marshes	Permanent wetlands on floodplains; vegetation is emergent forb species.
				No			Pp2.4.2: Permanent forb marshes	As for Pp2.4.1, but not on floodplains.
		Sedge/Grass/ forb	Bogs and fen	No	Pp3: Peat bogs and fen marshes			Permanent wetlands with emergent sedge, grass or forb. Fen marshes are separated from bog by the presence of Sphagnum and groundwater being the dominant water source.
		All remaining	Not specified	Yes	Pp4.1: Permanent floodplain wetland			Permanent wetlands on floodplains with unspecified vegetation.
				No	Pp4.2: Permanent wetland			As per Pp4.1 but not on floodplains.
			Not specified	All	Pps5: Permanent springs			Permanent freshwater wetlands in groundwater discharge areas.
	Periodic inundation	Tree	River red gum	Yes	Pt1:Temporary swamps	Pt1.1:Intermittent River red gum	Pt1.1.1: Intermittent River	Intermittent River red gum wetland on

WATER TYPE	WATER REGIME	DOMINANT VEGETATION	FINER SCALE VEGETATION	LOCATED ON FLOODPLAIN	TYPE			DESCRIPTION
						swamp	red gum floodplain swamp	floodplains; can include both woodland and forest forms.
				No			Pt1.1.2: Intermittent River red gum swamp	As for Pt1.1.1, but not on floodplains.
		Tree	Black box	Yes		Pt1.2:Intermittent Black box swamp	Pt1.2.1: Intermittent Black box floodplain swamp	Intermittent Black box wetlands on floodplains; have predominantly woodland structure. Occurs on infrequently flooded outwash areas, as a narrow fringe around intermittent lakes, as a woodland across the floor of some deflation basins and as a string of trees following a palaeo-channel (Roberts and Marston 2011).
				No			Pt1.2.2: Intermittent Black box swamp	As for Pt1.2.1, but not on floodplains.
		Tree	Coolibah	Yes		Pt1.3:Intermittent Coolibah swamp	Pt1.3.1: Intermittent Coolibah floodplain swamp	Intermittent Coolibah wetlands on floodplains; mainly restricted to the north-west of the Basin. Often the dominant tree in infrequently inundated floodplains of northern rivers such as the Darling and Gwydir; forming extensive woodlands. This type may also occur as a riparian fringe beside river channels and around waterholes

WATER TYPE	WATER REGIME	DOMINANT VEGETATION	FINER SCALE VEGETATION	LOCATED ON FLOODPLAIN	TYPE			DESCRIPTION
								(Roberts and Marston 2011).
				No			Pt1.3.2: Intermittent Coolibah swamp	As for Pt1.3.1, but not on floodplains.
		Tree	River Cooba	Yes		Pt1.4:Intermittent River Cooba swamp	Pt1.4.1: Intermittent River Cooba floodplain swamp	Intermittent River Cooba wetlands on floodplains. River Cooba is also known as Belalie and Eumong (Roberts and Marston 2011). Common in the northern Basin.
				No			Pt1.4.2: Intermittent River Cooba swamp	As for Pt1.4.1, but not on floodplains.
		Tree	Paperbark	Yes		Pt1.5:Temporary paperbark swamp	Pt1.5.1: Temporary paperbark floodplain swamp	As for Pp1.1.1 but temporary.
				No			Pt1.5.2: Temporary paperbark swamp	As for Pp1.2.1 but temporary.
		Tree	Other aquatic trees	Yes		Pt1.6:Temporary swamp	Pt1.6.1: Temporary woodland floodplain swamp	Temporary wetlands on floodplain with a range of aquatic trees such as *Casuarina*, *Allocasuarina*, *Eucalyptus ovata*.
				No			Pt1.6.2: Temporary woodland swamp	As for Pt1.6.1, but not on floodplains.
		Shrub	Lignum	Yes		Pt1.7:Intermittent Lignum swamps	Pt1.7.1: Intermittent Lignum floodplain swamps	Temporary Lignum swamps on floodplains.
				No			Pt1.7.2: Intermittent Lignum swamps	As for Pt1.7.1, but not on floodplains.
		Sedge	Tall emergent aquatics	Yes	Pt2: Temporary marshes	Pt2.1: Temporary tall emergent	Pt2.1.1: Temporary tall emergent	Temporary floodplain wetlands dominated by

WATER TYPE	WATER REGIME	DOMINANT VEGETATION	FINER SCALE VEGETATION	LOCATED ON FLOODPLAIN	TYPE			DESCRIPTION
						marshes	floodplain marsh	*Phragmites*, *Juncus* *Typha*, *Eleocharis*, *Baumea,* etc.
				No			Pt2.1.2: Temporary tall emergent marsh	As for Pt2.1.1, but not on floodplains.
		Sedge/grass/ forb	Aquatic sedge/grass/forb	Yes		Pt2.2: Temporary sedge/grass/forb marsh	Pt2.2.1: Temporary sedge/grass/forb floodplain marsh	Temporary sedge/grass/forb marshes on floodplains. Marshes tend to be deeper than meadows, ranging anywhere from 20-30 centimetres in depth to up to two metres in depth. Can be vegetated across the whole system or include areas of open water (deeper areas). Includes systems with *Eragrostis*, *Eleocharis*, *Carex*, *Cyperus*, *Paspalum*, etc
				No			Pt2.2.2: Temporary sedge/grass/forb marsh	As for Pt2.2.1, but not on floodplains.
		Grass/forb	Freshwater grasses, Freshwater forbs	Yes		Pt2.3: Freshwater meadow	Pt2.3.1: Floodplain freshwater meadow	Temporary meadows on floodplains, which tend to be shallow typically ranging between 20 to 40 centimetres in depth. Meadows are typically vegetated across whole system, may have scattered trees, shrubs, and or sedges, but are dominated by grasses and forbs.

WATER TYPE	WATER REGIME	DOMINANT VEGETATION	FINER SCALE VEGETATION	LOCATED ON FLOODPLAIN	TYPE			DESCRIPTION
				No			Pt2.3.2: Freshwater meadow	As for Pt2.3.1, but not on floodplains.
		No vegetation/ Water	n/a	Yes	Pt3: Freshwater playas	Pt3.1:Clay pans	Pt3.1.1: Floodplain clay pan	Floodplain clay pans typically less than eight hectares and less than two metres deep. Lack wave action characteristic of lacustrine systems
				No			Pt3.1.2: Clay pan	As for Pt3.1.1, but not on floodplains.
		All remaining	Not specified	Yes	Pt4.1: Temporary floodplain wetland			Temporary wetlands on the floodplain with unspecified vegetation.
				No	Pt4.2: Temporary wetland			As for Pt4.1, but not on floodplains.
Saline	Commonly wet	Tree	Paperbark	All	Psp1: Saline swamps	Psp1.1: Saline paperbark swamp		Permanent saline paperbark swamps, including *Melaleuca halmaturorum.*
		Shrub/sedge/ grass/forb	Saltmarsh	All	Psp2: Salt marsh	Psp2.1: Permanent salt marsh		Permanent inland saltmarsh.
		Grass	Seagrass	All	Psp3: Seagrass marsh	Psp3.1: Permanent seagrass marsh		Permanent saline marshes dominated by seagrass.
		All remaining	Not specified	All	Psp4: Permanent saline wetland			Permanent saline wetlands with unspecified vegetation.
	Periodic inundation	Tree	All trees	All	Pst1: Saline swamp	Pst1.1: Temporary saline swamp		Temporary saline wetlands with tree species.
		Shrub/sedge/ grass/forb	Saltmarsh	All	Pst2: Salt marsh	Pst2.2: Temporary salt marsh		Temporary inland saltmarsh wetlands.
		No vegetation/ water	n/a	All	Pst3: Saline playas	Pst3.2: Salt pans and salt flats		Temporary saltpans and playas typically less than eight hectares and

WATER TYPE	WATER REGIME	DOMINANT VEGETATION	FINER SCALE VEGETATION	LOCATED ON FLOODPLAIN	TYPE	DESCRIPTION
						less than two metres deep. Lack wave action characteristic of lacustrine systems.
		All remaining	Not specified	All	Pst4: Temporary saline wetlands	Temporary saline wetlands with unspecified vegetation.
Unknown	Unknown	Unknown	Unknown	All	Pu1: Unspecified wetland	There is no information with which to assign a type.

Riverine systems

The typology for palustrine systems (Table 3) is based on the following Level 3 ANAE attributes:

- Water source,
- Water regime, and
- Landform.

The riverine confinement attribute was also considered for the typology but was found to be highly correlated with the landform attribute and so provided no additional ecological information.

Waterholes are assumed to have been identified in temporary or periodically inundated streams. However, approaches such as designating permanent palustrine features that intersect steams as 'waterholes' resulted in a vast (unrealistic) number of features being so assigned. The designation of a feature as a 'waterhole' therefore relies on designations from jurisdiction databases.

Including substrate as an attribute in the typology for riverine systems would be informative; however, there is insufficient information available for the MDB to include it at this stage. It may be considered in future iterations of the ANAE framework as it would add useful information on the characteristics of a riverine system (e.g. help define sandy bottom, cobble, boulder or bedrock streams).

Table 3: Riverine types using Level 3 attributes(from Brooks et al. 2013).

Codes: Rp = riverine – permanent streams, Rt = riverine – temporary streams, Rw = riverine – waterholes, Ru = unspecified streams.

WATER SOURCE	WATER REGIME	LANDFORM	TYPE		DESCRIPTION
Surface	Commonly wet	High energy upland	Rp1: Permanent streams	Rp1.1: Permanent high energy upland streams	Fast flowing streams with steep gradient (>6%), and dominated by riffles and runs. Often with coarse substrate. Base flow typically maintained except in extreme droughts.
		Transitional		Rp1.2: Permanent transitional zone streams	Intermediate slope (4-6%) with long runs and riffle zones; pools are infrequent.
		Low energy upland		Rp1.3: Permanent low energy upland streams	Low gradient (<4%), slow flowing systems, often with a narrow channel on relatively flat land. May lack extensive riffle areas.
		Lowland		Rp1.4: Permanent lowland streams	Low gradient (<4%),systems that can include both narrow and relatively shallow flowing systems with pool, riffle, run sequences, and large deeper lowland systems with slow flow and no riffle areas. Base flow is maintained in dry periods, except in extreme drought.

WATER SOURCE	WATER REGIME	LANDFORM	TYPE		DESCRIPTION
	Periodic inundation	High energy upland	Rt1: Temporary streams	Rt1.1: Temporary high energy upland streams	As for Rp1.1, but may be systems which rise and fall rapidly, wetting and drying for varying lengths of times.
		Transitional		Rt1.2: Temporary transitional zone streams	As for Rp1.2, but are only periodically wet.
		Low energy upland		Rt1.3: Temporary low energy upland streams	As for Rp1.3, but are only periodically wet.
		Lowland		Rt1.4: Temporary lowland streams	As for Rp1.4, but are only periodically wet.
All	Commonly wet	All	Rw1: Waterholes		Commonly wet remnant pools that are located on periodically wet riverine segments.
	Unknown	Unknown	Ru1: Unspecified river		There is no information with which to assign a type.

2 Vegetation diversity and condition

This monitoring protocol encapsulates the Category 2 monitoring of vegetation diversity as well as additional components that enable vegetation condition to be determined. This method is, however, a category 3 which allows modifications such as greater alignment with state-based methods.

2.1 Evaluation questions

This monitoring protocol addresses the following Area Evaluation questions in relation to vegetation condition and diversity:

- **Short-term (one-year) and long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to vegetation species diversity?
  - What did Commonwealth environmental water contribute to vegetation community diversity?

- **Long term (five year) questions:**
  - What did Commonwealth environmental water contribute to populations of long-lived organisms?
- **Short term (one-year) questions:**
  - What did Commonwealth environmental water contribute to condition of floodplain and riparian trees?
  - What did Commonwealth environmental water contribution to vegetation condition and reproduction?

The process for evaluating these questions is illustrated in Figure 1 and with components covered by this protocol highlighted in blue. The brown boxes for tree recruitment and structure will be implemented in the Lachlan river system Selected Area as they form part of historical monitoring protocols. This information can be collected with little additional field time cost and recruitment of floodplain and riparian species is known to be a key outcome of environmental watering in the region.

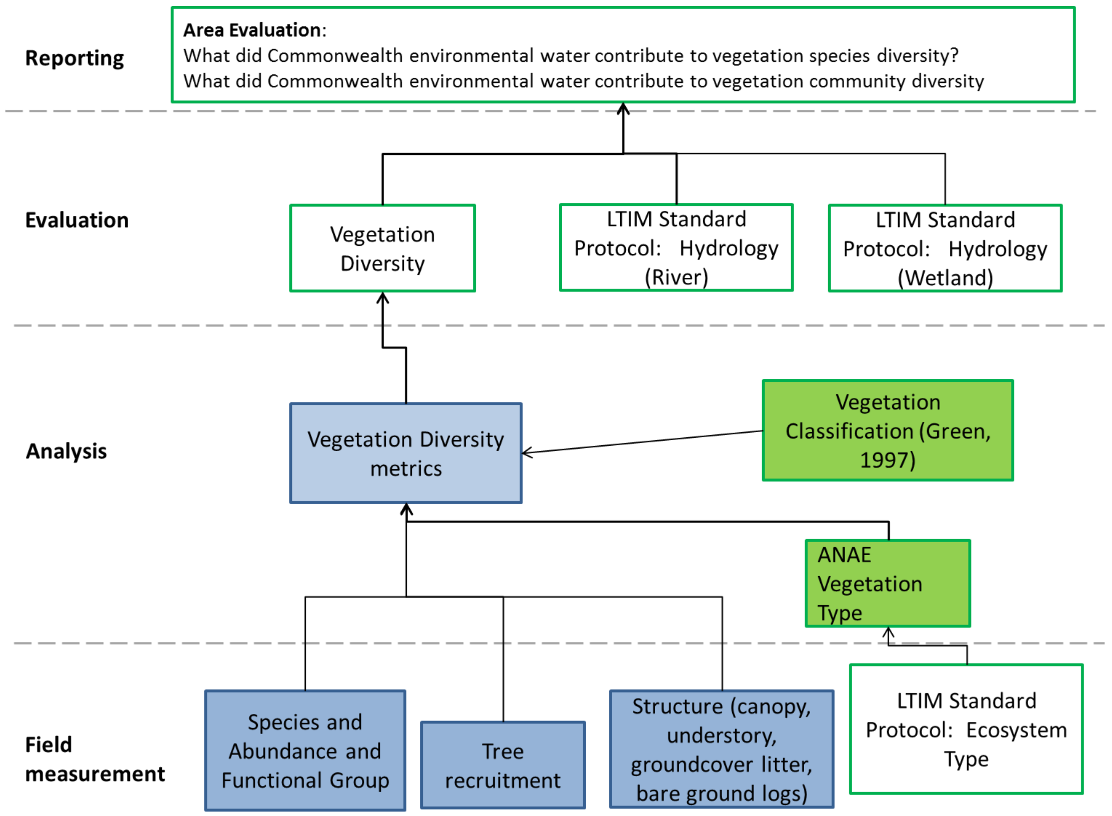

Figure 1. Schematic of key elements of the LTIM Protocol for the evaluation of Vegetation Diversity for the Lower Lachlan river system Selected Area.

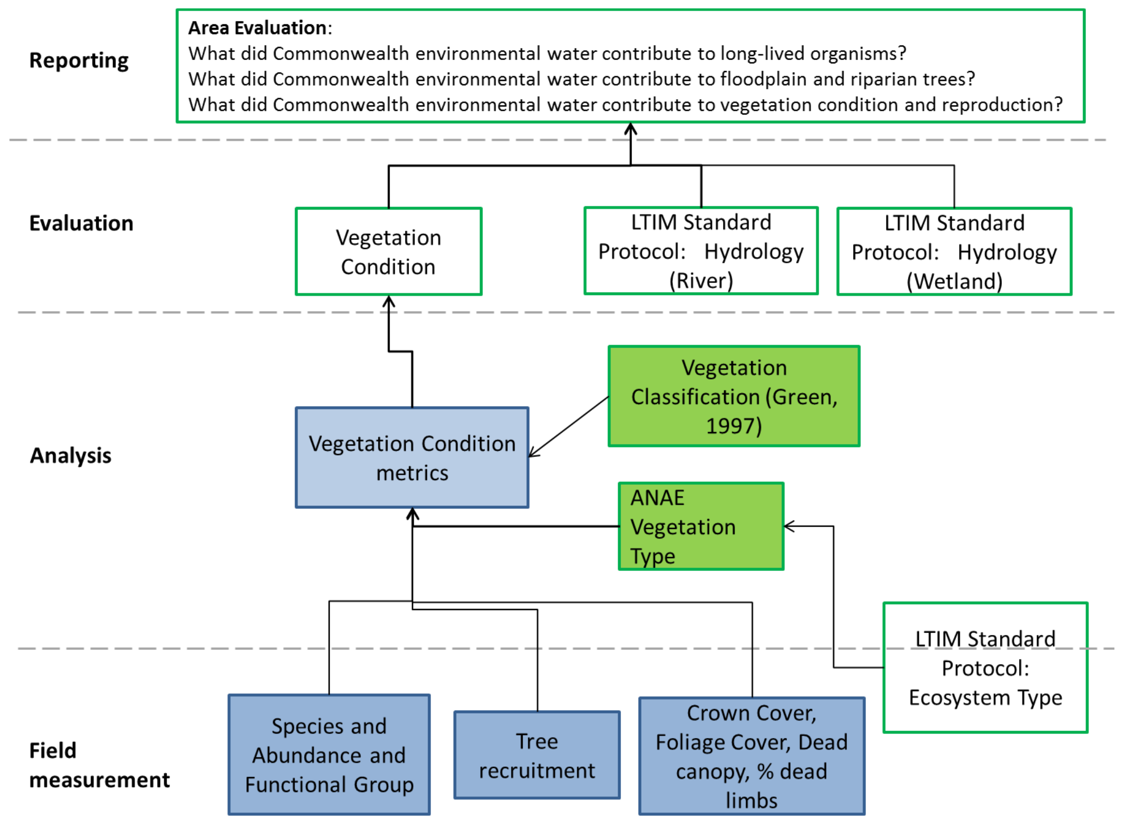

Figure 2. Schematic of key elements of the LTIM Protocol for the evaluation of Vegetation Condition for the Lower Lachlan river system Selected Area.

2.2 Relevant ecosystem types

Rivers and wetlands are the relevant ecosystem types for evaluating vegetation diversity and condition.

2.3 Relevant flow types

Fresh, bankfull, overbank (infrastructure assisted) are the relevant flow types for evaluating diversity and condition.

2.4 Overview and context

The condition, type and diversity of riparian and wetland vegetation communities are strongly influenced in by the frequency and extent of inundation (Brock and Casanova 1997; Kingsford 2000). Floodplain wetlands are major repositories of biodiversity (Kingsford 2000) and support distinct biological communities (Hillman 1986). Wetlands are a major target for ecological rehabilitation driven, at least in part, by environmental water allocations. Wetland vegetation is critical for carbon cycling and provision of food and habitat for water birds, amphibians, fish, terrestrial vertebrates and a variety of other biota (Kingsford and Thomas 1995, 2001; Kingsford and Johnson 1999; Leslie 2001).

Flooding frequency is associated with wetland biota structure and function on the floodplain (Boulton and Lloyd 1992; Jenkins and Boulton 1998). Flooding interacts with plant life-history processes such as dispersal, germination, recruitment, survival, growth, and reproduction. Although some native wetland species can thrive in permanently wetted habitats, flooding of previously dry habitats is a major stimulus to production of water plants and their associated biota such as invertebrates, both of which are important food sources for some waterbird species (Maher and Carpenter 1984; Briggs and Maher 1985).

The Lachlan river system in the study region, is low gradient and includes many paleochannels, anabranches and distributaries, such as Merrowie, Middle and Willandra creeks. There are abundant swamps, lagoons and billabongs associated with the distributaries of the lower river, culminating in the terminal Great Cumbung swamp. The predominant land uses in cleared areas of the floodplain are grazing and dryland and irrigated cropping (cereals, cotton, grapes, wheat and vegetables). However, there are significant areas of native vegetation, including three wetlands of national importance, listed in the Directory of Important Wetlands in Australia; Booligal Wetlands, the Great Cumbung Swamp and Lachlan Swamp. In addition there are other significant wetlands along Merrowie Creek, at Lake Brewster and Lake Cowal (DLWC 1997; Driver et al. 2010).

High-value wetland plant communities present include black box *Eucalyptus largiflorens*, river cooba (*Acacia stenophylla*), extensive reed beds (*Phragmites australis*) and extensive areas of riparian fringing river red gum forest (*Eucalyptus camaldulensis*) and woodland, including one of the largest stands of river red gum in NSW at the Great Cumbung Swamp. These vegetation communities support breeding events for tens of thousands of colonial nesting birds including straw-necked ibis and glossy ibis, birds listed under international migratory bird agreements including great egret, glossy ibis, sharp-tailed sandpiper, common greenshank, Latham's snipe, painted snipe and white-bellied sea-eagle and birds listed as vulnerable including the Australasian bittern, blue-billed duck and freckled duck.

The vegetation diversity and condition methods will quantify and interpret the response of key plant species and communities e.g. black box, cooba, river red gum and reed beds in terms of condition, extent and life history responses to the provision of Commonwealth environmental water, taking into account the effects of landscape context, historical flows and land use. Function will be represented by measures of wetland vegetation response, focussed on condition and extent (assessed on-ground). Diversity is assessed on ground through surveys, and validation of these surveys as diversity-assessment tools. The resulting data will build on existing capacity to predict responses of different plant communities and species to alternative environmental flow scenarios delivered to the Lachlan floodplain.

For the Lower Lachlan River system Selected Area, much of the held environmental water delivered is combined with, or subsequent to other flows (e.g. translucent flow, stock and domestic replenishment, natural events or irrigation delivery). The capacity of Commonwealth environmental water to be delivered to specific locations will be similar to other forms of environmental water. In dry years this becomes more difficult, except at locations such as Booligal Swamp where structures such as Lake Brewster and Torrigany Weir enable local, controlled delivery (modelled in Driver et al. 2005).

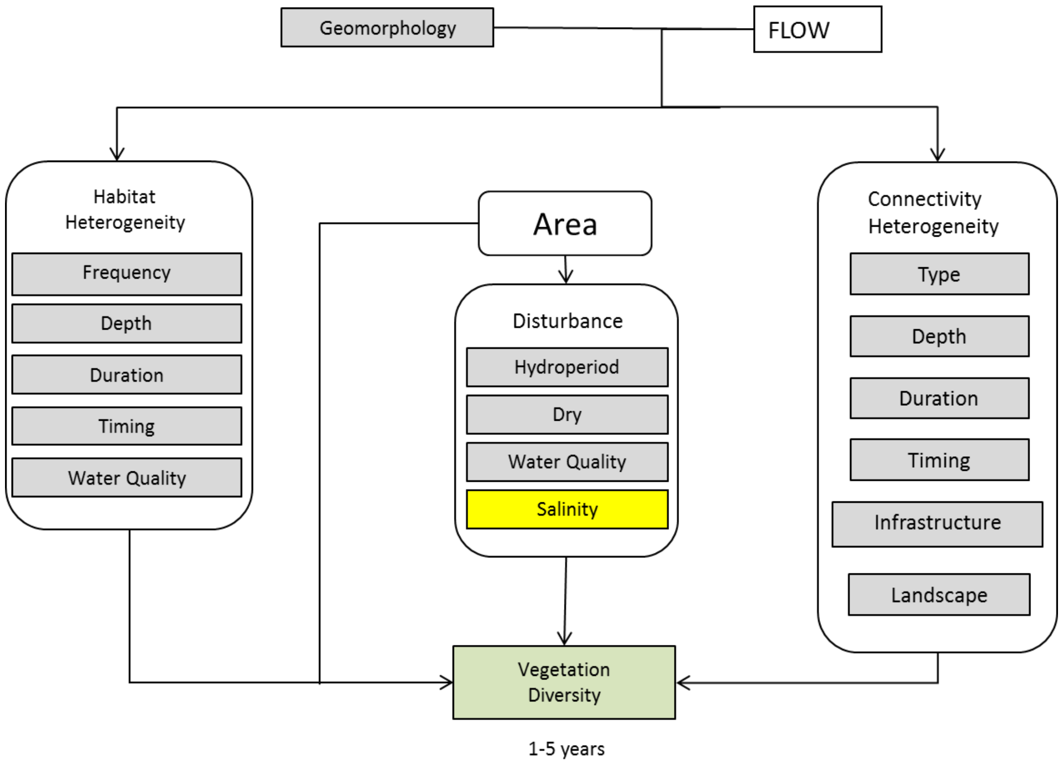

Figure 3. Cause and effect diagram for Vegetation diversity.

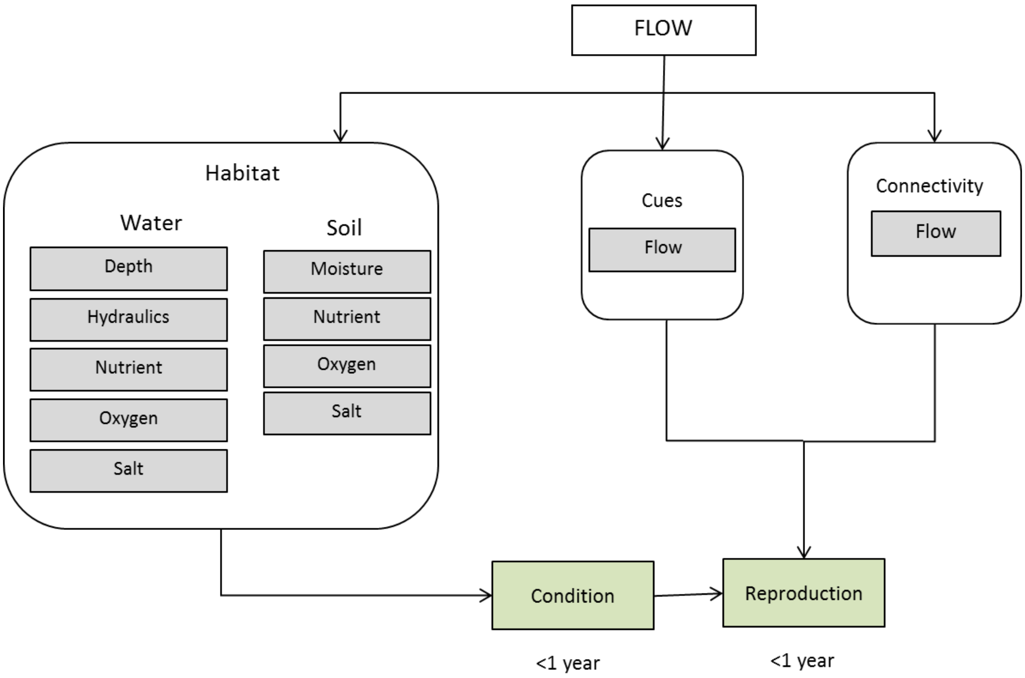

Figure 4. Cause and effect diagram for vegetation condition and recruitment

2.5 Complementary monitoring and data

The field measures required for the assessment of vegetation diversity are largely unique to the Lachlan river system Selected Area and are consistent with the Integrated Monitoring of Environmental Flows (IMEF) transect method that has already been employed in the Lachlan (Driver et al 2003) with some modifications based on Bowen (2013). Quadrat (within transect) data will be linked to geomorphic characteristics (sensu Roberts & Dyer (2007)) defined as wet, amphibious and dry. The consistency with the IMEF transect method means that historical data can be used to assist in interpreting the vegetation response to Commonwealth environmental water.

2.6 Monitoring locations

2.6.1 Overview

The LTIM Project for Basin Evaluation has adopted a hierarchical approach to sample design (see Gawne et al. 2013). Briefly, the spatial hierarchy for vegetation monitoring is as follows:

Selected Area → Zone → Site → Habitat (vegetation type, open water)

2.6.2 *Selection of zone(s)*

The vegetation community in the Lachlan river system Selected Area is dominated by woodland communities, with River red gum and Black box/River red gum communities prevalent in areas inundated by Commonwealth environmental water. Lignum and River Cooba are found in mixed stands with Black box and aquatic reeds, grasses and sedges are represented in some wetland sites. There is no way to draw a line along or across the study area that neatly splits the study area for vegetation.

The lack of clear delineation of vegetation types across the Selected Area means that the selection of zones is not supported. Instead, the vegetation response will be measured across the Selected Area and the evaluation stratified by Australian National Aquatic Ecosystem (ANAE) type (Brooks et al. 2013) and by the classification of Green (1997).

2.6.3 *Selection of sites*

The Selected Area contains several wetlands of national and regional significance as listed in the Directory of Important Wetlands (Environment Australia 2001). Many or all of these wetlands will be targets of CEWO, or NSW OEH environmental flow deliveries (Figure 5). The criteria used to select sites are:

1) Accessibility: Each site should be accessible under a range of watering conditions so that monitoring can occur each year.
2) Representative: Each site should not be an obvious ecological aberration and in combination, the sites should adequately represent the range of inundation dependent vegetation characteristic of the Selected Area. Vegetation types to be identified using the interim ANAE typology developed for the MDB (see Brooks et al. 2013) is presented in **Error! Reference source not found.**.
3) Likelihood of watering: The site must be highly likely to receive Commonwealth environmental water at least once in the next five years. Sample locations will be selected to cover the range of water dependent vegetation communities likely to be affected by Commonwealth Environmental Water within a given Selected Area.
4) Bathymetry: Preference should be given to sites with known bathymetry (or DEM) and water level recording infrastructure.

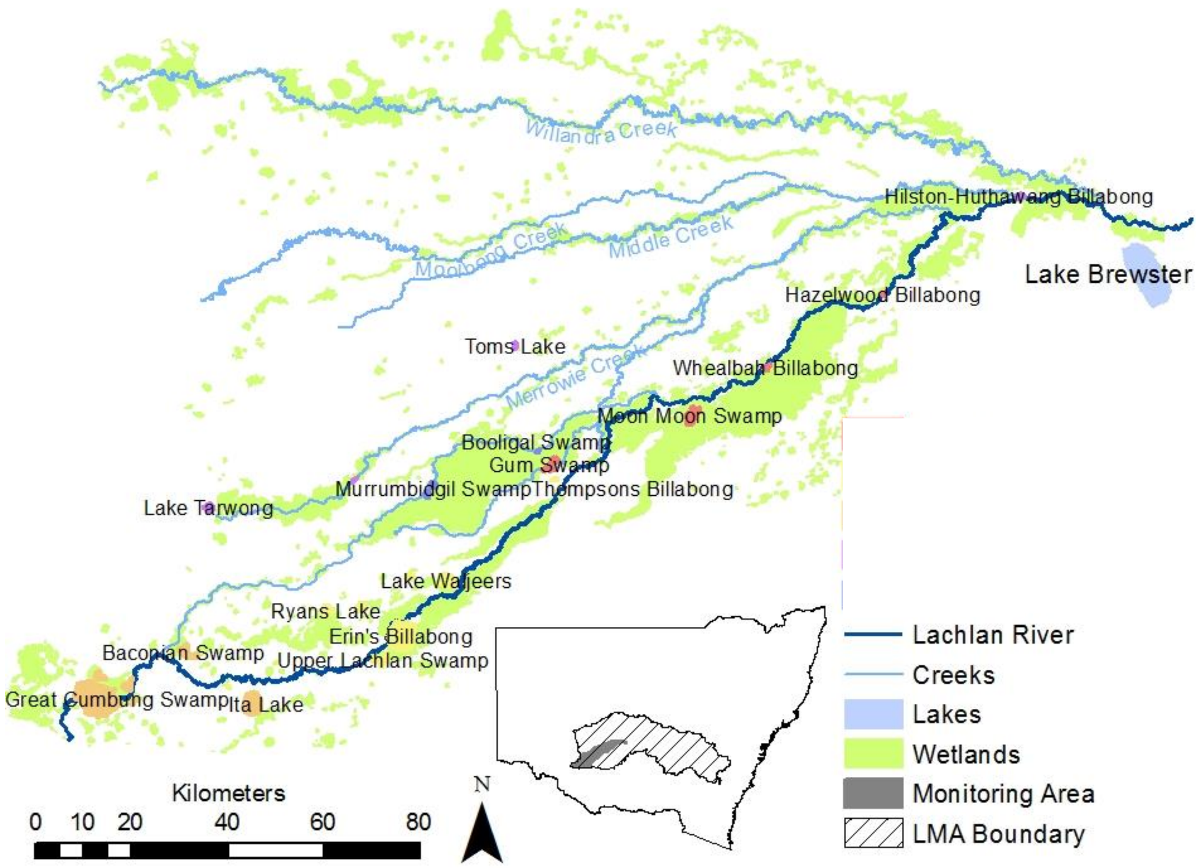

Figure 5. Potential vegetation diversity and condition monitoring sites.

Table 1. Vegetation type and applicability to the Lachlan category 3 vegetation diversity method

COMMONWEALTH CRITERIA	APPLICABILITY TO THE LACHLAN CATEGORY 3 VEGETATION DIVERSITY METHOD
River red gum forest	N/A
River red gum woodland	Yes
Black box forest	N/A
Black box woodland	Yes, but not pure stands, more mixed RRG/BBX woodland in the areas inundated by the Commonwealth environmental water.
Coolibah	Not in the Lachlan
River Cooba	Yes, but in mixed stands as with BBX (e.g. at Whealbah Lagoon).
Unidentified aquatic trees	N/A
Lignum	Yes, in mixed stands, often under RRG (e.g. Murrumbidgil Swamp).
Other shrub	N/A
Tall emergent aquatic (reeds, Phragmites, cumbungi, etc)	Yes. Represented (e.g. in Marrool, currently club rush).
Aquatic sedge/grass/forb	Yes
Freshwater grasses	Warrego Summer Grass is often common, but not dominant
Freshwater forb	No

2.6.4 *Fixed site locations among years*

Aquatic ecosystems are notoriously variable in space, so if sample size is not large and the sites selected change among years, inter-annual differences may be caused by spatial heterogeneity, not temporal effects. The method presented below relies on the use of fixed sites within and among years. One of the key reasons for this is the need for detailed hydrology at each site, and the resources required to develop flow-inundation relationships at new sites every year or even every few years would be too high. The other key consideration is the availability of existing flow-biota relationships, hydrology and bathymetry at many of the proposed sites. Additionally, the use of fixed sites allows the control of some of the confounding issues described above.

2.6.5 Site locations

Unpublished IMEF analyses indicate that 12 sites represent about 90% of catchment diversity within the Lachlan floodplain (with the study area defined within the site selection criteria described above). Twelve sites along the length of the Lower Lachlan River system Selected Area were selected as core monitoring sites for each year with optional sites that will be monitored depending on time and resources during sampling trips (Table 1). At each site data from replicate plots and transects will be collected.

Table 2. Sites selected for monitoring vegetation diversity and condition in the Lachlan river system Selected Area. Optional sites; which will be surveyed where possible. The clusters include sites from nationally significant wetland complexes (Environment Australia 2001): Booligal Wetlands, Merrowie/Box Creek, Great Cumbung Swamp (GCS) and Lachlan Swamp.

Wetland Complex	Site	Core (C) Optional (O)	Wetland Transects	Riparian Plots
Booligal Wetlands	Merrimajeel Lagoon	C	2	2
	Murrumbidgil Swamp	C	3	3
	Merrowie Creek	C	2	2
	Moon Moon swamp	C	2	2
Merrowie/Box Creek	Merrowie Creek on Cobb Hwy	O	0	2

	Lake Tarwong	C	2	4
Lachlan Swamp	Lake Bullogal	C (O)	2 (2)	2 (2)
	The Ville	C	2	2
Great Cumbung Swamp	Marrool Lake	C	2	2
	Red gum 1. Old Lachlan	C	2	2
	Red gum 2. Nr Clear Lake	C	2	2
	Lake Ita inlet channel	O		2
	Lake Ita RRG	O		2
	Lignum Lake *	O	Photo observation of IMEF RRG time series only and [optional] birds during events.	
Lachlan River Floodplain	Whealbah Billabong	C	2	2
	Hazelwood Billabong	C	2	2
	Erin's Billabong (Lachlan Swamp)*	O	Photo observation of RRG only	

2.6.6 ***Plot size /No of transects***

This part of Australia has no forest-level densities of trees (see Specht 1970) and so only woodland communities are recorded. The non-treed community sampling design captures different non treed vegetation communities that occur at different elevations and locations within the wetland and / or river from submerged communities in the river or wetland bed through to emergent or littoral vegetation at the edges of aquatic ecosystems. The treed community sampling design is a minimum of 2 replicate 0.1 ha plots located entirely within the treed community and not encroaching into the adjoining aquatic or littoral vegetation communities see (Bowen 2013).

For treed communities overstorey tree health plots are 20x50 m (0.1ha) is the plot size used in the NSW Office of Environment and Heritage (NSW OEH) method for tree health (Bowen 2013) and is derived from Siverston (2009). For understory floristic survey 20x20 m (0.04ha) is the standard OEH method for floristic vegetation survey (Sivertson 2009).

2.7 Timing of field sampling

Sampling will occur both before and following delivery of Commonwealth environmental water. The exact timing of sampling will be largely dependent on the target vegetation communities and expected lag time for response to watering. Commonwealth environmental water is typically delivered in the Lachlan catchment in June – August. As such, sampling is intended to occur March/April, and three months after first fill.

2.8 Monitoring Protocol: Non-tree community

This is largely based on the transect method (Driver et al 2003), partly modified for consistency with LTIM and OEH methods applied in the Lachlan. It is applied to the riparian zones of billabongs, just below or within the tree fringe, and starting at the top of the bank for billabongs and finishes within the deeper sections of billabongs (or other floodplain wetlands).

2.8.1 Equipment

- GPS
- 100 m Tape
- Sample bags/project books
- Permanent markers
- Pens
- Hand lens
- Site poles
- Fluorescent spray paint
- Mallet
- 1 x 1 m quadrat
- Field data sheets.
- Camera (with inbuilt GPS)
- Boat (for wide or deep streams).
- Life Jackets
- Waders/wetsuit & boots
- Wetsuit gloves
- A copy of this protocol.

2.8.2 Preparation

- Before leaving the office / laboratory the following should be checked:
    - Batteries are charged and properly inserted.
    - Previous data downloaded and memory cleared.
    - GPS camera recording correctly
    - All equipment listed above is present and in functional order.

2.8.3 Site Establishment

1) Find the site using the point location established in the Monitoring and Evaluation Plan.
2) Record the following on the field sheet:
    a) River or wetland name and ANAE ID.
    b) Date and time.
    c) GPS coordinates (latitude and longitude; GDA94).
    d) Name(s) of installation team.
3) Install the initial site marker pole at the high water mark, ensuring that it is solidly fixed.
4) Run a tape perpendicular to the bank 100m into the wetland. Install the 2nd marker pole at the end of the tap (or known distance if more practical)

2.8.4 Data Collection

1) Each person who will be entering the water is to put on protective clothing (e.g. life jacket plus waders with an external belt, or wetsuits and boots and wetsuit gloves).
2) Always start the survey at the highest elevation.

3) Attach a 100 m tape to the site marker pole at the start of the first transect and run the tape out towards the end marker pole
4) Standing at the starting site marker pole, photograph along the line of the tape, to the right and left of the tape and take a panorama photograph (or set of panoramas)
5) Place the one metre square quadrat on the ground or water surface in front of you record the direction from the tap of the quadrat
6) For each quadrat, record the following details on the field data sheet:
    a) Transect number;
    b) Quadrat number;
    c) Distance from the start of the transect;
    d) Water depth (m);
    e) Stock pug (hoof) marks per square metre;
    f) Estimated percentage cover of litter/debris;
    g) Estimated percentage cover of bare ground/mud;
    h) Name of each plant species (if known). If unknown record a Temporary code (e.g. unknown sedge # 1);
    i) Estimated percentage cover of each plant species (nearest 10 %, or below about 5 % cover, the nearest 1 % [~ %PFC]), and;
    j) the number of individual plants in a quadrat
    k) The linear length of fallen timber > 10 cm
    l) Median height of individual plant species in a quadrat
    m) The life stage of each plant species (Vegetative (V), Flowering (FL), Fruiting (FR), Seeding (S) or Dead (D);
7) If you are unsure of taxonomic status remove a specimen, including flowers and fruits if present, and place it in a plastic bag. Ensure that the destructive effects of sampling are minimised, especially with less common species. Label the bag with:
    a) Site Number.
    b) Site/Wetland Name.
    c) Collectors Name(s).
    d) Date collected.
    e) Temporary code (e.g. unknown sedge # 1).
8) Please note these ‘unknown specimens’ should be pressed and preserved as soon as possible for later identification.
9) When you return to the office, remove specimens from their bags and tape each plant to a specimen sheet. Label the sheet appropriately. Allow specimens to dry completely before pressing.
10) Place the specimen sheets into a plant press.
11) Carefully place pressed specimens into a specimen box.
12) Contact the NSW Herbarium and advise them in advance of the number of specimens that you will be sending them and the type of analysis that you require.
13) Send specimen boxes to the NSW Herbarium for identification, to species level. Naphthalene or toilet soap may be added to the specimen box to prevent specimens being eaten by insects.

2.9 Monitoring protocol: Tree Community

This method is based on the NSW OEH method for survey and monitoring of flood dependent vegetation (Bowen, 2013). It is designed to capture quantitative measures of the condition, structure and species composition of flood dependent vegetation communities. It includes measures of:

- Measures of cover.
- Tree recruitment.
- Community Structure.
- Species abundance.
- Functional group.

2.9.1 Equipment

- GPS
- 2 x 100 m Tape
- 4 x hooked sand tent pegs for marking corners of the plot
- Sample bags/project books for collecting plant samples
- Permanent markers
- Pens
- Hand lens
- Site poles
- Fluorescent spray paint
- Mallet
- Aluminium tags
- Galvanised roofing nails
- Hammer
- DBH tape
- Field data sheets
- Field ID books
- Camera (with inbuilt GPS)
- Gumboots or waders
- A copy of this protocol.

2.9.2 Preparation

- Before leaving the office / laboratory the following should be checked:
  - Batteries are charged and properly inserted.
  - Previous data downloaded and memory cleared.
  - GPS camera recording correctly
  - All equipment listed above is present and in functional order.

2.9.3 Site Establishment

1) Find the site using the point location established in the Monitoring and Evaluation Plan.
2) Record the following on the field sheet:
   a) River or wetland name and ANAE ID.
   b) Date and time.
   c) GPS coordinates (latitude and longitude; GDA94).
   d) Name(s) of installation team.
3) Install the initial site marker pole at the NE corner of the 0.1 ha plot.

4) Plot is oriented north/south (i.e. tape is run 50 m S and 20 m W, starting from the NE corner). Alternate orientation is allowable but must be recorded.
5) Install the second site marker pole at the SW corner of the plot
6) Mark the corners of the plot with sand pegs and also place markers at the 20m point on the long side of the plot to mark out a nested 0.04 ha plot
7) Tag and number each live tree of diameter at breast height (dbh) greater than 10 cm within the 0.1ha plot using aluminium tags and galvanized nails, starting with the tree closest to the NW corner of the plot. Trees within the 0.04 ha plot must be tagged first, before tagging the remaining trees in the 0.1ha plot.

2.9.4 Data Collection: Floristic Data

1) Mark out the site using the site establishment protocol (section 1.9.3)
2) For the 0.04ha plot record the following details on the field data sheet for all vascular species and each structural component of the vegetation (Tallest stratum, mid-stratum (>1m) and lower (<1 m) stratum).
   a) % plot flooded
   b) % plot wet soil
   c) % open water (including % submerged litter; % submerged bare ground; % submerged vege)
   d) % unsubmerged litter
   e) % unsubmerged bare ground
   f) Average water depth (cm)
   g) Species Cover recorded as **Foliage Cover**[12] (FC) and is the percentage of the sample plot occupied by the vertical projection of *foliage and branches* (if woody) of a species for in each stratum in which it occurs.
   h) **Crown Extent[3]** (CE) and **Canopy openness (CO)** for all tree species <u>in the tallest stratum</u> in treed communities
   i) the percentage of the sample plot occupied by **litter** (non-attached plant matter e.g. leaves and branches less than 10 cm diameter) and is recorded as the sum of submerged and non-submerged litter in flooded plots (Note: where plants are dry or dead but can still be identified to species and are attached to the base of the plant, their cover is included in the species cover not in per cent litter)
   j) the percentage of the sample plot occupied by bare earth and is recorded as the sum of submerged and non-submerged **bare ground** in flooded plots.
   k) Number of individuals of each species (actual count or estimated number from sub quadrats for superabundant species) in each stratum in which it occurs.
   l) **Strata type** (T=tallest, M=mid (>1m), L = lower (<1 m)
   m) **Upper height** (average) of each species (metres).
   n) **Lower height** (average) of each species (metres)

[1] Foliage cover (FC) is the percentage of the sample site occupied by the vertical projection of foliage and branches (if woody). This is sometimes also termed per cent foliage cover or projected canopy cover. (Ayers et al 2009).
[2] Projective Foliage Cover is the percentage of the sample site occupied by the vertical projection of foliage only (Walker and Hopkins 1998). Not to be confused with Foliage Cover.
[3] Crown cover (CC) is the percentage of the samples site within the vertical projection of the periphery of crowns. In this case, crowns are treated as opaque. (Ayers et al 2009).

   o) **Linear length of fallen timber at site** – the total length of fallen timber of diameter >10 cm is recorded.
3) If you are unsure of taxonomic status remove a specimen, including flowers and fruits if present, and place it in a plastic bag. Ensure that the destructive effects of sampling are minimised, especially with less common species. Label the bag with:
   a) Site Number.
   b) Site/Wetland Name.
   c) Collectors Name(s).
   d) Date collected.
   e) Temporary code (e.g., unknown sedge # 1).
4) Please note these 'unknown specimens' should be pressed and preserved as soon as possible for later identification.
5) When you return to the office, remove specimens from their bags and tape each plant to a specimen sheet. Label the sheet appropriately. Allow specimens to dry completely before pressing.
6) Place the specimen sheets into a plant press.
7) Carefully place pressed specimens into a specimen box.
8) Contact the NSW Herbarium and advise them in advance of the number of specimens that you will be sending them and the type of analysis that you require.
9) Send specimen boxes to the NSW Herbarium for identification, to species level. Naphthalene or toilet soap may be added to the specimen box to prevent specimens being eaten by insects.

2.9.5 Data Collection: Tree Data

1) Mark out the site using the site establishment protocol (section 1.9.3)
2) For the 0.1ha plot record the following details on the field data sheet for trees (live or dead) of >10cm dbh
   a) Species
   b) Tree height (m)
   c) Diameter at breast height (dbh) (cm)
   d) The location as being within the 0.04 ha sub-plot or within the remainder of the 0.1 ha plot
   e) **Canopy Extent - CE $_{(tree)}$.** This is the 2 dimensional lateral spread (length x width) of the branches and foliage of a live tree, or the limbs of a dead tree, measured from the edge to edge of the remaining bare limbs or branches.
   f) **Canopy openness - CO $_{(tree)}$:** estimated as the percentage of the sky that is obscured by the canopy (leaves and small branches).
   g) **Percentage Dead Canopy - DC $_{(tree)}$:** is the percentage of the tree canopy CE $_{(tree)\ that}$ is dead or severely damaged.
   h) **Epicormic growth: yes /no** Y/N
   i) **Ratio of dead to live limbs - DLL** $_{(tree)}$: the number of dead major limbs as a ratio of the total number is recorded. Major limbs are limbs arising from the main trunk or from multiple stems but not branches. For example: a tree with 4 major limbs and one dead, DLL = 1 of 4.
   j) **Breeding status -** the presence of flowers (F) and / or buds (B) and or / fruit (Fr)
   k) **Number of hollows[4] -** appropriate for hollow dependent (fauna that can be seen with the aid of binoculars

[4] Hollows are defined as in Rayner *et al.* (2013): cavity with entrance diameter >1cm and depth =/> entrance dimension.

l) **Number of nests** is recorded for each numbered tree.

3) For the 0.1ha plot the number of trees (live or dead) of each species of <10cm dbh is recorded on the field data sheets
4) **Linear length of fallen timber at site** – the total length of fallen timber of diameter >10cm both within the 0.04 ha and remainder of the 0.1 ha plot.
5) **Total number of seedlings** - stems that are <10 dbh and < 1 m tall and are not sprouting from a coppiced rootstock, are treated as seedlings and the number is recorded separately for the 0.04 ha and remainder of the 0.1 ha plot.
6) **Total number of saplings** - stems that are <10cm dbh and > 1 m tall and are not sprouting from a coppiced rootstock, are treated as saplings and the number is and the number is recorded separately for the 0.04 ha and remainder of the 0.1 ha plot.

2.10 Data analysis

Once data have been collected from each site, the following additional steps need to occur

1) Check the Calculation of Total Foliage Cover (FC)

Total FC for lower stratum (<1 m) + ∑Species Cover + % litter + %bare ground = 100%, unless lower stratum space is occupied by mid storey emergent tussock form graminoid or spreading shrub species >1m tall (e.g. Lignum, rushes or reeds). Thus ground stratum the FC lower (ground) stratum = ∑Species Cover + % litter + %bare ground = 100% - total ∑FC of these mid stratum species.

In flooded sites total FC lower (ground) stratum includes; submerged vegetation, submerged bare ground and submerged litter.

2) Assign functional groups

Plant species are to be grouped into the four following functional groups (Brock and Casanova 1997, Casanova 2011):

- Amphibious responders (AmR) – plants which change their growth form in response to flooding and drying cycles.
- Amphibious tolerators (AmT) – plants which tolerate flooding patterns without changing their growth form.
- Terrestrial damp plants (Tda) – plants which are terrestrial species but tend to grow close to the water margin on damp soils.
- Terrestrial dry plants (Tdr) - those which are terrestrial species which don't normally grow in wetlands but may be encroaching into the area due to prolonged drying.

The use of these Brock and Casanova 1997 functional groups has been commonly employed in NSW state reporting [e.g. IMEF, Mawhinney 2003, Driver *et al.* 2010, 2011 and NSW OEH, Bowen 2013), and this will carry through to this method. Variations to the above method, consistent with state methods, will include:

- Measures of diversity based on the % cover of plant species recorded in the field. At least one level of correction will be required because the transect method records on average about 60% of the diversity that would be recorded in ocular surveys (Driver *et al.* 2014);
- For analysis and survey design vegetation species and communities are also grouped within "functional groups" (described in terms of the response to flooding of their dominant or canopy species) consistent with the definition of a wetland in the NSW Wetlands Policy (2010, following Bowen and Simpson 2010; Bowen 2013 and Thomas *et al.* 2010).

Functional Group can be generated automatically from species name during data analysis from master list.

3) Calculate Crown Cover

Crown cover is a measure used to classify vegetation structural type and is used in the OEH Vegetation Type Standard (Sivertson 2009). It is derived for each species in the over storey stratum of the plot by dividing the sum of canopy extent of all trees of that species by the area of the plot.

$$CC(plot)_i = \sum_{j=1}^{n_i} CE_{ij} / Area * 100$$

Where there are $j = 1$ to n_i trees of species i in the plot

4) Calculate Foliage Cover

Foliage Cover (FC) is the percentage of the sample site occupied by the vertical projection of foliage and branches (Walker and Hopkins 1998). Equivalent to the amount of shadow that would be cast on the ground if there were a light source directly overhead. Also referred to as "canopy cover" (Ayers et al 2009; DECC 2011). To derive percentage foliage cover for the plot $FC_{(plot)}$, crown cover $CC_{(plot)}$ for each species is multiplied by the average Crown openness (CO) for each species. Crown openness, also known as crown type, is illustrated in Supplement 2C.

$$CO(plot)_i = \frac{1}{n_i} \sum_{j=1}^{n_i} CO_{ij}$$

Where there are $j = 1$ to n_i trees of species i in the plot.

So FC for species i for the plot is derived using:

$$FC(plot)_i = CC_i * CO(plot)_i$$

5) Calculate Dead canopy percentage for each plot

Dead canopy (plot): is the average DC of all trees of each species for the plot expressed as a per cent.

$$\mathrm{DC}plot_i = \frac{1}{n_i} \sum_{j=1}^{n_i} DC_{ij}$$

Where there are $j = 1$ to n_i trees in the plot for species i

6) Calculate the percentage of dead limbs for the plot

% Dead limbs (total) is calculated as the average % dead limbs as a proportion of total limbs for the plot.

2.11 Evaluation

For each survey occasion, Spearman rank correlations will be calculated between the historical dry period frequency and the number of plant species on the banks and in the water to determine the contribution of Commonwealth environmental water to species diversity. Similar analyses will be conducted for abundance and cover of species and function groups. The recruitment and condition of key riparian species (river red gum, black box, coolabah and river cooba) will be analysed with respect to the duration of watering using univariate and graphical methods to determine the contribution of Commonwealth environmental water to populations of long-lived organisms.

For floodplain and riparian vegetation communities (dominated by flood dependent trees in the overstorey) temporal changes in tree canopy condition statistics with Commonwealth environmental watering will be analysed using graphical and univariate analysis methods. Changes in tree condition will be analysed in the context of antecedent wetting, climate (particularly temperature) and seasonal effects. Similar analyses will be conducted using metrics of vegetation community condition which incorporate elements of structure and cover. Multivariate analyses (using measures of dispersion from MDS plots) will be used to detect changes across multiple elements of the vegetation community in relation to the duration of watering.

Multiple regression will be used to determine effects on plant condition and diversity in the context of antecedent wetting, climate (particularly temperature), seasonal effects, adjacent landuse and disturbance.

The use of fixed sites which are monitored each year will provide data with a range of antecedent watering conditions (including sites that are not watered) thus enabling more sophisticated analyses (using Boosted Regression Trees) to be used to determine the effects of watering within the context of antecedent conditions to be determined. Data from IMEF monitoring that occurred in both drought conditions (2002-2009) and wet conditions (1998-2000, 2010/2011) provide key baselines from which to assess the benefit of environmental watering. Because of the effort required, however, analyses for routine reporting will however focus on the recently collected plant data rather than attempting a full analysis of all collected data. In addition, data collected as part of River Red Gum health monitoring in Murrumbidgil Swamp in 2012/13 and vegetation diversity and condition data from Lake Waljeers, Lake Ita and the Great Cumbung Swamp in 2012/13 can also be used to contribute to baseline data.

2.11.1 ***Data management***

Following identification of the species that were unknown, data will be transferred from field data sheets to intermediate tables within a Microsoft Access database. Data in intermediate tables will be verified by QA/QC staff. The original datasheets will be scanned and copies of the data stored at the University of Canberra.

2.12 Health and safety

For details on health and safety please refer to the Workplace Health and Safety Plan for the Lower Lachlan river system Selected Area (WHS 202.1) in appendix 3.

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SITE Code.	Date:

LTIM Lower Lachlan River System

Supplement 2A: Wetland groundcover survey data sheets.

Wetland Transect Survey

Site information

Date		**Site Name**	
Site Code			
Recorders			
Gauge depth		**Est Avge Depth**	
		Est Max Depth	
Time since last inundation			

Transect 1

AMG grid reference	zone	Easting
	datum	Northing
Transect Direction		

Transect 2

AMG grid reference	zone	Easting
	datum	Northing
Transect Direction		

Photo Notes

Panoramic photo series taken from long-term photo point? y / n
Number of photos________

Start and finish time of photos ____________

Site Sketch

(provide a detailed site sketch including distances of bare, vegetated and wet areas; note location and orientation of transects within broader landscape features)

SITE Code.	Date:

LTIM Lower Lachlan River System

	Transect 1									
Quadrat [1]	1	2	3	4	5	6	7	8	9	10
% Water										
% Debris/litter										
% Bare ground/mud										
% Vegetation Cover										
Water depth (m)										
Disturbance (%)										
Timber length (m)[2]										
Soil Moisture [3]										

	Transect 2									
Quadrat [1]	1	2	3	4	5	6	7	8	9	10
% Water										
% Debris/litter										
% Bare ground/mud										
% Vegetation Cover										
Water depth (m)										
Disturbance (%)										
Timber length (m)[2]										
Soil Moisture [3]										

[1] equally spaced between 0 m and end of transect [2] Total linear length of timber >0. 1 m [3] 0 = dry; 5 = inundated

:

#	Transect:	Quadrat	1			2			3			4			5			6			7			8			9			10		
	Species	Stage	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H

* Stage = Vegetative (V), Flowering (FL), Fruiting (FR), Seeding (S) or Dead (D)

= number of individual plants in 1 x 1 m quadrat; C = % cover to nearest 10% or 1% for < 10%); H = average height of plants

:

#	Transect:	Quadrat	1			2			3			4			5			6			7			8			9			10		
	Species	Stage	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H	#	C	H

* Stage = Vegetative (V), Flowering (FL), Fruiting (FR), Seeding (S) or Dead (D)
# = number of individual plants in 1 x 1 m quadrat; C = % cover to nearest 10% or 1% for < 10%); H = average height of plants

:

Supplement 2B: Measures of cover

In this study cover is measured as “percent foliage cover” and is the area that is covered by a vertical projection of the plants foliage and small branches or the shadow cast on the ground rather than “projected foliage cover” that was suggested in the LTIM standard method. This is applied to **ALL** vegetation measures in the monitoring (e.g. trees, shrubs, ground, individual species, etc.). An example of “percent foliage cover” is provided in Figure 6.

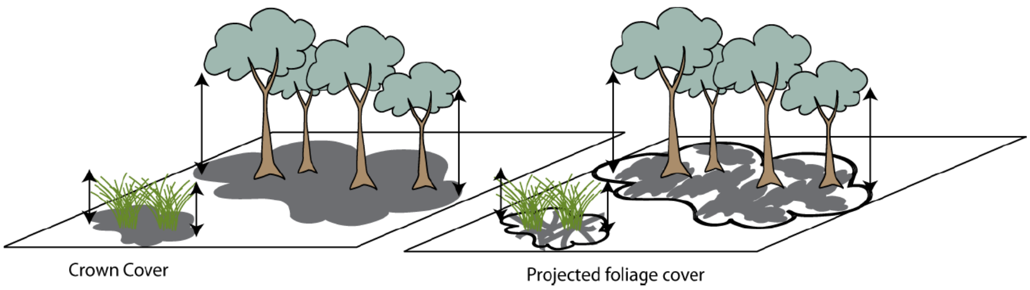

Figure 6. Crown (or canopy) cover (CC, left) and Percent Foliage Cover (%FC, right). The picture (from Roberts and Hale 2013) was intended to represent projected foliage cover on the right but – for the detail shown in this picture – equally well represents %FC; which is what is ultimately reported in this study. CC is a function of crown extent and plot area. CC and Crown Openness at the plot scale are then used to calculate %FC .

Percent foliage cover (%FC) has been chosen as the measure of cover used in this method as projective foliage cover is difficult to measure in the field especially for understorey species.

Note: Difference between projective foliage cover and percent foliage cover:

- Projective foliage cover (pfc) is equivalent to the vertical shadow cast by an individual crown’s **photosynthetic material only** (leaves, phyllodes, needles)
- Percent foliage cover (%FC) , is equivalent to the amount of shadow that would be cast on the ground if there were a light source directly overhead and consists of both photosynthetic material and small twigs and branches

Supplement 2C: Canopy openness estimate

In some RRG communities CO will be much less than 40 % especially in poor (>80% dead canopy) and intermediate poor (41-80% dead canopy) communities.

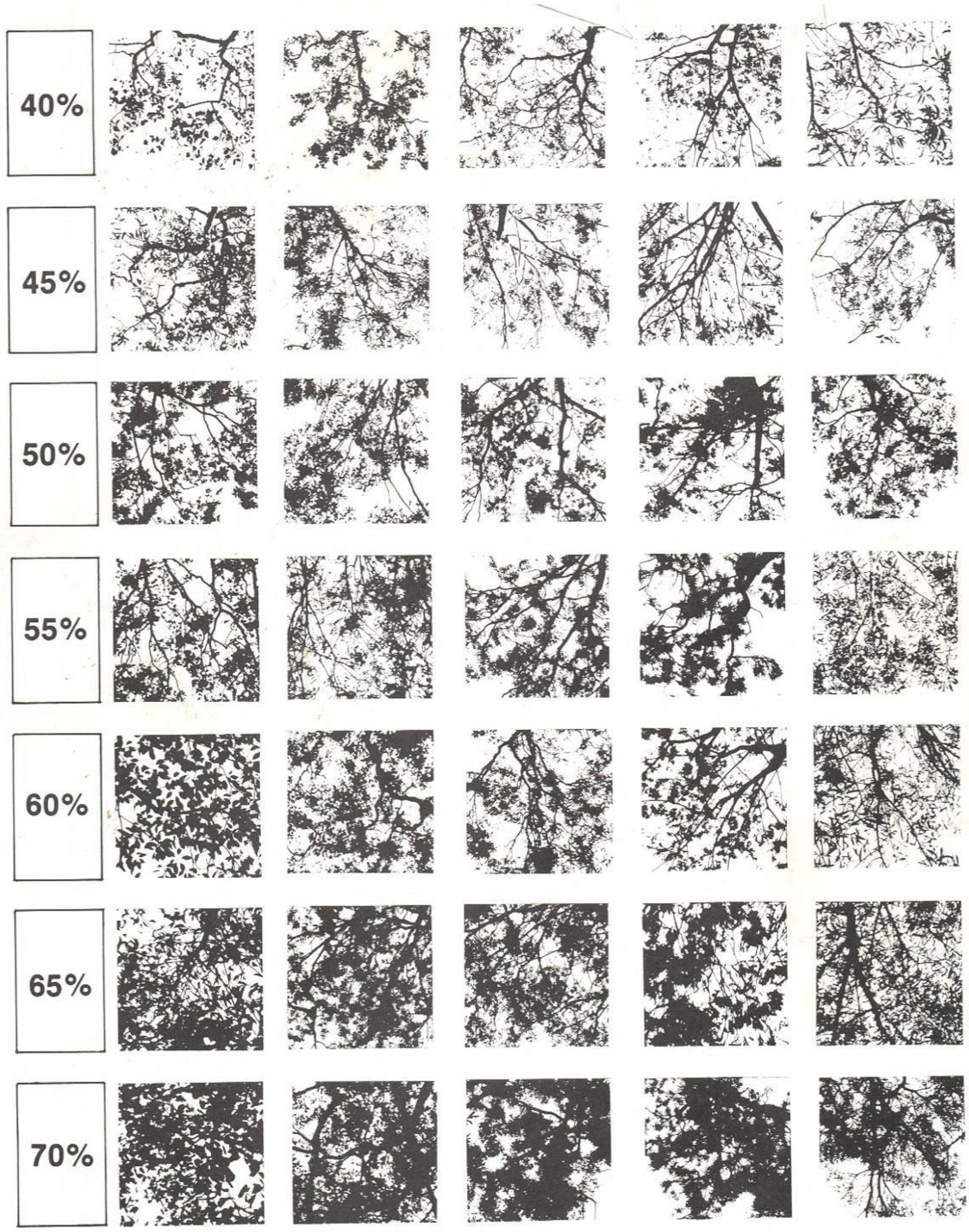

Figure 5 Crown types. Estimate the openness of individual tree or shrub crowns by matching the crown with a photograph. The rows show similar crown types for different leaf sizes (large to small, left to right); *Acacia* phyllodes are in the right hand row. Most Australian woody plants are in the range 40 per cent to 70 per cent.

Source: DECC (2011) pg. 86. from Figure 6, p. 71 of Walker and Hopkins 1998).

Supplement 2D: Flood Dependent vegetation data sheets (from OEH)

Location			Survey Name	Plot No.	Recorders		
Date		Site No.					
AMG grid reference	zone datum		Easting		Northing		Position in quadrat
Base Plot size		Orientation of 0.1ha plot		marked			

Structure & Composition (within 0.04 ha quadrat)

		Site Photo Number
Keith Class		NE
Regional Veg Class (BVT)		N
BioMetric Type (or NVCA)		SW
Flooding Status:		S

Land Use (dominant)	nature conservation	travelling stock route	forestry	grazing	grazing / cropping	cropping	other:
Land Cover (upper stratum)	none	native	environmental planting	native plantation	exotic plantation	exotic other:	
Land Cover (ground stratum)	none	native	environmental planting	native plantation	exotic crop	exotic other:	
Age structure	early regeneration	advanced regeneration	uneven age	mature	senescent		

Site History	Freq. code	Age code	Land Manager Survey: categories, quantities, comments
Grazing management			not grazed set stocked rotational / cell grazing
Farming			none direct drill disc plough tyned implement mouldboard rotary hoe
Erosion control			none contour cultivation contour banks mulching other
Pasture improvement rates (fertiliser) kg/ha			none <125 126-250 >250
Pasture improvement rates (lime/dolomite) t/ha			none <2 2-4 4-7 >7
Timber extraction (incl. firewood)			
Regrowth management			
Weed control			
Pest animal control			
Burning			

Frequency: 0=no record, 1=rare (>5yrs), 2=occasional (2-5yrs), 3=frequent (<2yrs). Age: R=recent (<3yrs), NR=not recent (3-10yrs), O=old (>10yrs)

Plot Disturbance	Severity code	Age code	Observational evidence:
Clearing (inc. logging)			
Firewood collection			
Grazing			
Fire damage			

Severity: 0=no evidence, 1=light, 2=moderate, 3=severe Age: R=recent (<3yrs), NR=not recent (3-10yrs), O=old (>10yrs)

SITE No.

Date.

OEH VEGETATION FIELD SURVEY FORM
Flood Dependent Communities – Floristics

(within 0.04 ha quadrat)

Sub-Stratum L M T	Growth form	Field name	Species name	% Cover	No of individuals	Field No.	Ht (m)
L	-	Ave Water Depth in cm					
L	-	Flooding (% of plot)					
L	-	Wet Soil (% of plot)					
L	-	Litter / submerged Litter					
L	-	Bare Ground / Submerged Bare Ground					

Growth form:T=tree, M=mallee tree, S=shrub, Y=mallee shrub, Z=heath shrub, C=chenopod shrub, G=tussock grass, H=hummock grass, D=sod grass, V=sedge, R=rush, E=fern, F=forb, L=vine, A=cycad, P=palm, X=xanthorrhoea, U=samphire shrub.

SITE No.

Date:

OEH VEGETATION FIELD SURVEY FORM

Flood Dependent Communities – Floristics (cont.)

(within 0.04 ha quadrat)

Sub-Stratum L M T	Growth form	Field name	Species name	% Foliage cover	No of Individuals	Field No.	Ht. (m)

Growth form:T=tree, M=mallee tree, S=shrub, Y=mallee shrub, Z=heath shrub, C=chenopod shrub,
G=tussock grass, H=hummock grass, D=sod grass, V=sedge, R=rush, E=fern,
F=forb, L=vine, A=cycad, P=palm, X=xanthorrhoea, U=samphire shrub.

SITE No.
Date:

OEH VEGETATION FIELD SURVEY FORM –

Flood Dependent Communities – tree health and site flooding data. Tree health data

(within 0.04 ha and 0.1 ha quadrat)

Plot 0.04/ 0.1 ha	Tree No	Stem No	Species name	Tag No	DbH (cm)	Crown Extent (m^2)	% Canopy Openness	% Dead Canopy	Ht (m)	Dead limbs /live limbs	Fruit / Flower / bud Fr/F /B	hollows	nests

CE=Crown extent (of each tree), CO = Canopy openness the percent of the sky obscured by leaves and small branches
Used to derive %Foliage cover (for tree as a whole), DC Dead canopy % of present foliage that is dead, Limb = main stem from common trunk
(i.e. if tree has 4 and 2 are dead = (2/4).

Site Flooding Parameters (within 0.04ha)

% plot flooded	% plot wet (soil)	%open water (surface free of veg)	Av Water depth (cm)	% submerged bare ground	% submerged vegetated (species)	%bare ground (surface)	Time since last flood (<1, 1,2,5,etc,years)

Site Recruitment (within 0.04ha and 0.1 ha)

Plot	Species Name (if known)	Seedlings stems < 10cm dbh and < 1m	Saplings <10cm dbh and > 1m	Plot	Species Name (if known)	Seedlings (<10 cm dbh <1 m tall)	Saplings < 5cm dbh and > 1m
0.04 ha				0.1ha			
0.04 ha				0.1 ha			

SITE No.

Date:

NSW GOVERNMENT Environment & Heritage Portfolio

OEH VEGETATION FIELD SURVEY FORM –

Flood Dependent Communities – tree health and site flooding data.

Tree health data

(within 0.04 ha and 0.1 ha quadrat)

Plot 0.04/ 0.1 ha	Tree No	Stem No	Species name	Tag no	DbH (cm)	CE (m^2)	CO	%DC	Ht (m)	Dead limbs /live limbs	Fruit / Flower / bud Fr/F /B	hollows	nests

CE=Crown extent (of each tree), CO = Canopy openness the percent of the sky obscured by leaves and small branches used to derive %Foliage cover (for tree as a whole see), DC Dead canopy % of present foliage that is dead, Limb = main stem from common trunk (i.e. if tree has 4 and 2 are dead =(2/4).

3 Riverine fish methods

3.1 Overview

These methods describe a customised monitoring strategy to be employed for the following evaluations;

- Basin (Category 1) Evaluation of the response of river fish to Commonwealth environmental water delivery
- Area (Category 3) Evaluation of the response of river fish to Commonwealth environmental water delivery within the selected channel reach (Zone 1).

3.2 Evaluation questions

3.2.1 Basin evaluation questions

Small and large-bodied fish

Long term (five year) questions:

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to native fish diversity?

Short-term (one-year) questions:

- What did Commonwealth environmental water contribute to native fish community resilience?
- What did Commonwealth environmental water contribute to native fish survival?

3.2.2 Selected Area evaluation questions

Small and large-bodied fishes

Long-term (five-year) questions:

- What did Commonwealth environmental water contribute to native fish abundance and diversity?
- What did Commonwealth environmental water contribute to native fish abundance and resilience and condition?

Short-term (one-year) questions:

- What did Commonwealth environmental water contribute to native fish abundance?
- What did Commonwealth environmental water contribute to native fish recruitment?
- What did Commonwealth environmental water contribute to native fish resilience?
- What did Commonwealth environmental water contribute to maintenance of drought refugia for native fish?
- What did Commonwealth environmental water contribute to native fish survival?

The process for evaluating these questions is illustrated in Figure 1, with components covered by this protocol highlighted in blue.

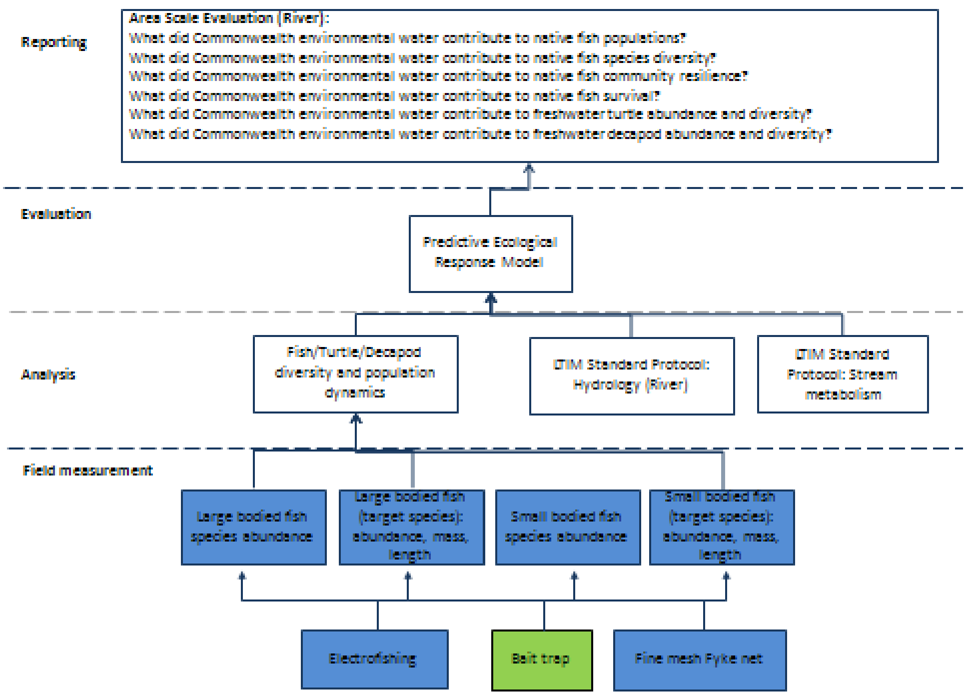

Figure 1: Revised schematic of key elements of the LTIM Standard Protocol: Riverine Fish Sampling

3.3 Relevant ecosystem types

Rivers are the ecosystems relevant to fish.

3.4 Relevant flow types

All flow types are relevant to fish.

Annual sampling in Zone 1 for Basin-scale assessment (following Category 1 riverine fish sampling methods, Hale et al 2013) will not allow an assessment of the outcome of any specific single fresh, bankfull or overbank flow event, but represents the overall response of fish assemblages to the combination of natural and managed hydrological conditions experienced within a single zone on an annual basis.

3.5 Overview and context

Fish are an integral component of aquatic ecosystems and have been used as an indicator of aquatic ecosystem health in several large river health monitoring programs in south-east Australia (Davies et al. 2010, Muschal et al. 2010). The advantages of incorporating fish as indicators of aquatic ecosystem condition include (Harris 1995); i) Fish are relatively long-lived and mobile, reflecting both short and longer-term and local to catchment scale processes, ii) They occupy higher trophic levels within aquatic ecosystems, and in turn, express impacts on lower trophic level organisms, iii) They are relatively easily and rapidly collected and can be sampled non-destructively, iv) They are typically present in most waterbodies, and v) Biological integrity of fish assemblages can be assessed easily and interpretation of indicators is relatively intuitive. Further, as fish have a high public profile, with significant recreational, economic and social values, they foster substantial public interest (MDBC 2004).

Aspects of native fish diversity, abundance, reproduction, growth and survival and dispersal were identified by Gawne et al (2013) as priority indicators relevant to monitoring the outcomes of environmental flow delivery in the lower Lachlan system.

Historically, 14 species of native fishes occupied the lower Lachlan catchment. Recent monitoring indicates that 10 of these species are still present, with four species locally extinct or exceedingly rare: The critically endangered flat-headed galaxias (*Galaxias rostratus*), endangered southern pygmy perch (*Nannoperca australis*) and southern purple spotted gudgeon (*Mogurnda adspersa*) and the non-threatened Murray-Darling rainbowfish (*Melanotaenia fluviatilis*). Of the 10 extant species, the threatened olive perchlet (*Ambassis agasizzii*), silver perch (*Bidyanus bidyanus*) and freshwater catfish (*Tandanus tandanus*) are at very low abundance and/or have a very restricted distribution. Only two species; carp-gudgeons (*Hyseleotris* spp) and bony herring (*Nematalosa erebi*) could be considered widespread and abundant. The natural fish assemblage is dependent on a range of habitat types within the system. Many of the smaller-bodied and most highly threatened species are wetland dependant while the larger-bodied species are largely (but not entirely) restricted to river channel habitats. All are dependent on flow events to provide spawning triggers, boost primary and micro-invertebrate production, provide connectivity between habitats (both lateral and longitudinal connectivity). All are dependent on the maintenance of quality refugia during drought periods to ensure resilience of the system.

Flow plays an important role in the life-cycle of native fishes from larval through to adult life stages. Water may inundate habitat needed for reproduction, triggering a spawning response, create a boost in primary production that improves recruitment success, improve habitat condition through maintaining natural geomorphic processes or stimulate in-stream migration (Figures 2 and 3).

River channel dependent species require flow triggers to initiate spawning (golden perch and silver perch), or recruitment success may be heavily dependent on nutrient inputs to the river channel following overbank flows (Figure 4). The seasonality of these flow triggers is critically important. Further, sediment transport and scouring during high flow events is essential to maintenance of deep pools and the input of large woody debris habitat. Freshes also provide movement triggers and facilitate longitudinal connectivity within the system. Persistence of these species is dependent on the provision of natural spawning triggers and subsequent boosts in primary production to facilitate successful recruitment as well as longitudinal connectivity within the river channel network.

For all fish species, access to high quality refugia during drought periods is critically important for ecosystem resilience, as unlike vegetation, many species of invertebrates, waterbirds and turtles, fish have no mechanisms to cope with the loss of water for even very brief periods of time.

CED landscape fish diversity

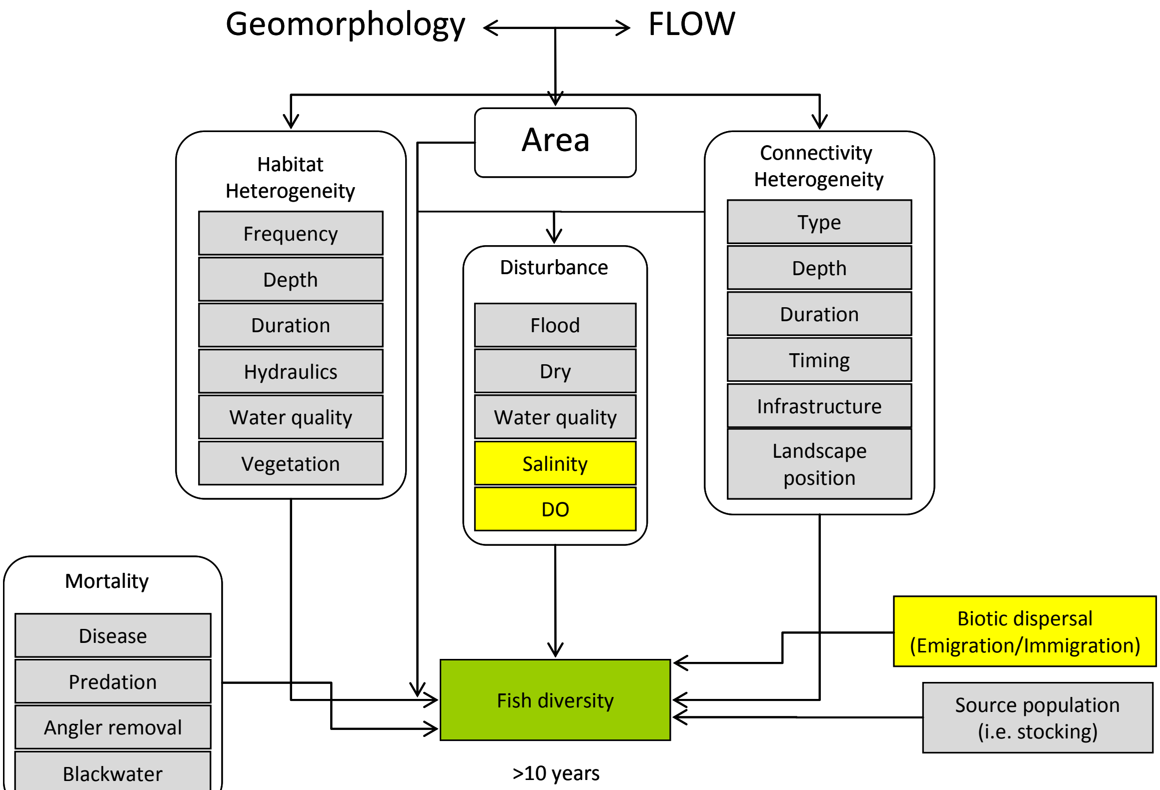

Figure 2. Revised landscape fish diversity CED. Yellow boxes indicate other CEDs.

CED fish condition

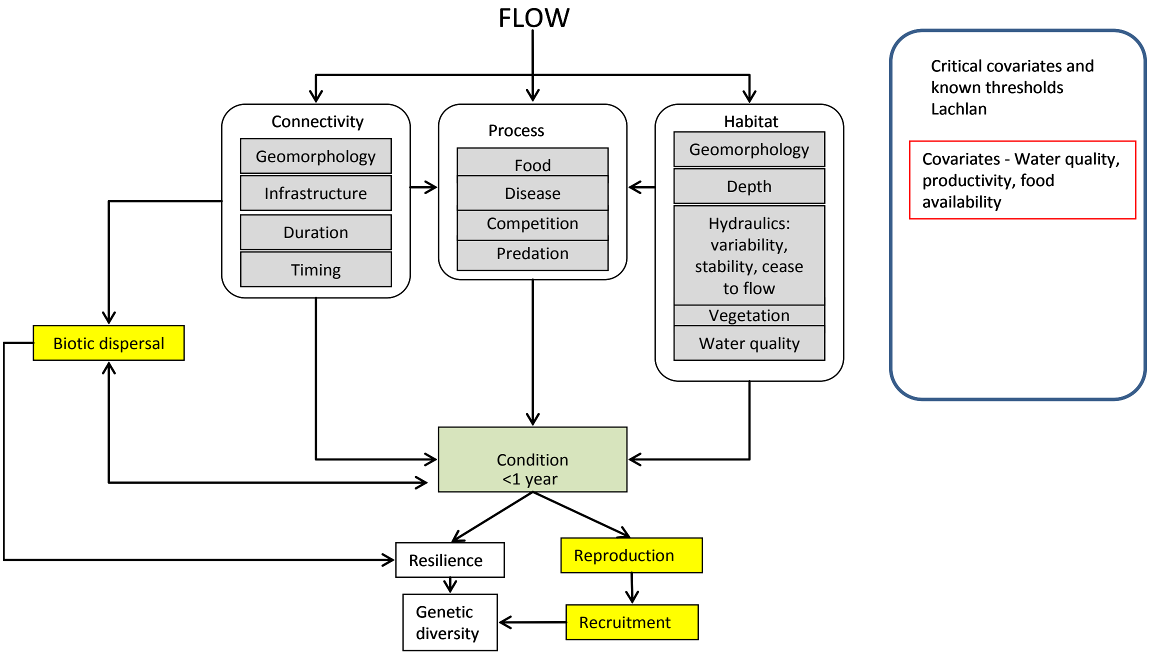

Figure 3. Revised fish condition CED. Yellow boxes indicate other CEDs.

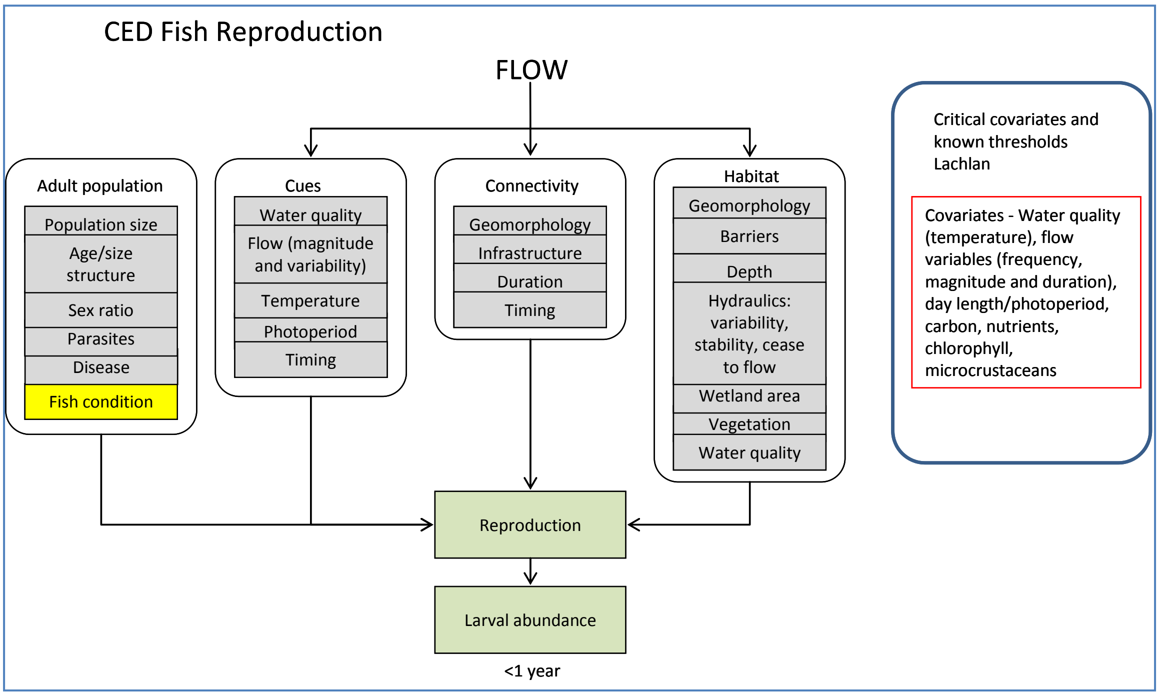

Figure 4. Revised fish reproduction CED. Yellow boxes indicate other CEDs.

3.6 Complementary monitoring and data

Whilst older Museum records exist, the collection of standardised data on fish populations within the lower Lachlan catchment did not commence until 1994 (Harris and Gehrke 1997). Numerous projects have been undertaken since then (Growns 2001, Growns 2008, McNeil *et al.* 2008, Price 2009, Davies *et al.* 2010, Gilligan *et al.* 2010, Wallace and Bindokas 2011) and additional unpublished data collected by NSW Department of Primary Industries (Fisheries) are available. Most of these data are held by NSW DPI (Fisheries). The remainder is available in technical reports published by MDFRC and SARDI. Most significant are samples collected annually at seven sites within the lower Lachlan River channel (see Gilligan *et al*. 2010) between 2007 and 2012. These data are accompanied by data on water quality, micro-invertebrates, benthic and epi-benthic macro-invertebrates, aquatic macrophyte cover and diversity and structural aquatic habitat variables collected over a portion or all of the same period. Even longer time-series of fish assemblage data (commencing in 1994 and 1998) are available from two of these locations. Only a limited amount of fish assemblage data are available from distributary channels and floodplain wetland systems within the Lachlan.

We are aware of two other projects which plan to collect fish data from within the study area over the study period. The Invasive Animals CRC plans to continue to collect data from the seven sites established by Gilligan *et al*. (2010) between 2015 and 2017 as part of its carp biocontrol M&E program. This project adheres to SRA sampling protocols. The second is a NSW DPI olive perchlet monitoring program in the Lake Brewster area which samples annually to determine the local status of this population. Sampling for this project occurs within the outlet channel of Lake Brewster (Mountain Creek) and in the Lachlan River immediately downstream of Brewster Weir.

3.7 Representative species from life-history guilds

The six ‘representative’ species we propose to target are:

- Equilibrium: Murray cod (*Maccullochella peeli*) and freshwater catfish (*Tandanus tandanus*)
- Periodic: Golden perch (*Macquaria ambigua*) and bony herring (*Nematalosa erebi*)
- Opportunistic: Carp-gudgeons (*Hypseleotris* spp) and unspecked hardyhead (*Craterocephalus stercusmuscarum*).

All six species are present within Zone 1 of the lower Lachlan catchment. Both of the periodic and opportunistic species, and one of the equilibrium species (Murray cod) are present in sufficient abundance to ensure required sample sizes are collected (for age and age-structure data). However, freshwater catfish are currently uncommon within the study area (listed as an endangered population under the *NSW Fisheries Management Act 1994*) and while we propose to collect population information on catfish we will not be undertaking destructive sampling of catfish to determine age. No other equilibrium species are present in the focal reach.

3.8 Monitoring locations

The lower Lachlan selected area can be partitioned into five spatially, geomorphologically and hydrologically distinct river channel zones at a broad landscape scale (Figure 5).

Basin-scale analysis of riverine fish assemblages and other vertebrates will be undertaken within Zone 1 (Lachlan River channel between Brewster Weir and Booligal). Representative of the main Lachlan River channel, this zone contains relatively high abundances of the required target species (with potentially limited numbers of freshwater catfish). Situated in the upper reaches of the selected area, this zone will also receive Commonwealth Environmental Water during each year of the LTIM project.

The remaining zones differ significantly from Zone 1 in terms of fish assemblages but will not be monitored as part of the LTIM project.

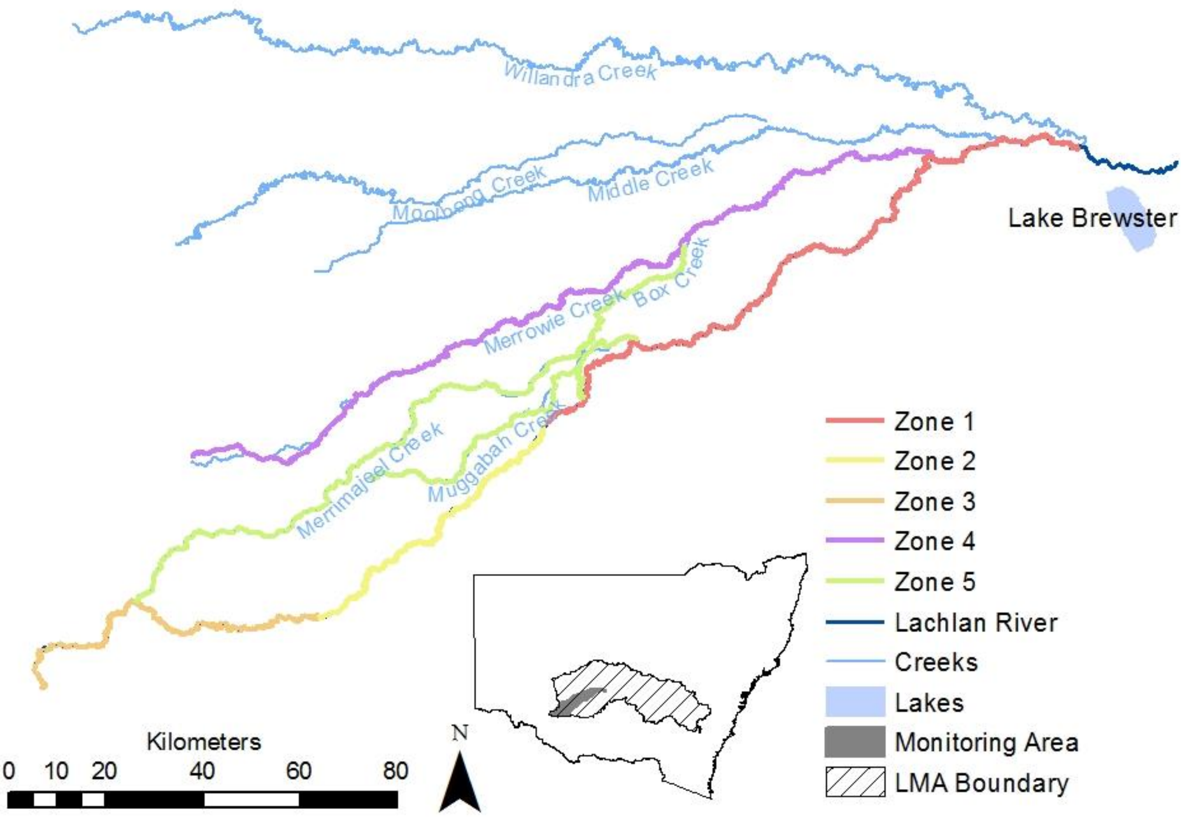

Figure 5 Map showing extent of Lachlan River Selected Area, Basin-scale sampling reach and additional sampling zones.

Site placement within the zones

NSW DPI has pre-existing data from 20 riverine sites within the Lachlan River Selected Area (Figure 6). Of these, 7 sites are established monitoring sites that have been sampled annually between 2007 and 2012. The remaining sites have been sampled between 1 and 3 times between 2001 and present. Sites required will be drawn from these existing sampling locations (where they were selected randomly), or, new randomly selected sampling locations will be generated in a GIS.

The 100 km reach specified as the maximum distance within which the 10 riverine fish monitoring sites can be selected (Hale *et al.* 2013) will extend for 100 km kilometres downstream from the Willandra Weir to the township of Hillston (Figure 56).

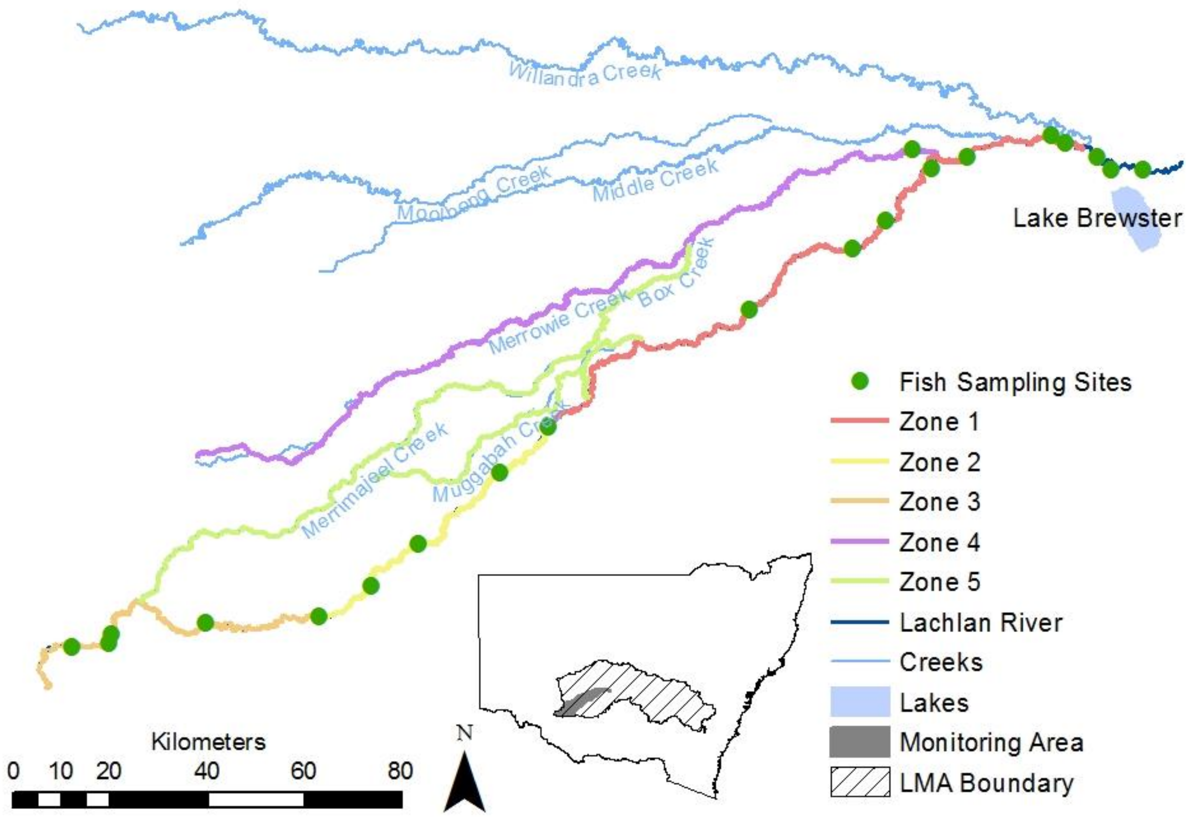

Figure 6. Map of sampling sites within the Lower Lachlan River System Selected Area for Riverine Fish.

3.9 Monitoring timing

Annual sampling in Zone 1 for Basin-scale assessment will be undertaken between March – May each year as specified by the standard methods (Hale *et al.* 2013).

3.10 Monitoring protocol

3.10.1 Equipment

- Electrofishing boat and equipment
- Backpack electrofisher and equipment
- 12 x fine meshed fyke nets (10 plus two spares) per site, with anchors and stakes
- Electrofishing and boating personal protective equipment
- GPS
- GPS coordinates of site structure (passive sample waypoints and electrofishing units)
- Passive sample waypoints determined using random number generator (sample locations within sites)
- Data sheets
- Large (1000 mm) and small (300 mm) measuring boards;
- Hanging scales with bag for large fish (1 - 50 kg capacity with 10 g accuracy) and bench scales with tray for smaller fish (0-1000 g capacity to 0.1 g accuracy)
- Water quality meter (pH, DO, Temperature, Conductivity, Turbidity)
- Eskies and ice for storing fish / fish heads for otolith analysis
- Sample jars, preservative and blank specimen labels
- Otolith dissection tools
- Otolith envelopes
- Ethics and sampling permits

Additional sampling equipment to Cat 1 requirements (see Section 3.8.2);

- 12 x collapsible shrimp traps (10 plus two spares) per site

3.10.2 Protocol

Basin-scale annual assessment (Zone 1)

Annual sampling for basin-scale analysis within zone 1 will follow the standard methods for riverine fish as specified by Hale *et al.* (2013). However, in order to improve comparability with historical data (SRA, NSW DPI) the following additional protocols and augmentations at each site have been proposed;

1. The amount of sampling effort per 90 second electrofishing 'shot' is to be partitioned between littoral/structural and open water habitats at a ratio of 5:1 in order to maintain comparability with CPUE data generated using the standard SRA protocol. This means that within any single electrofishing operation, 75 seconds should be used to sample littoral/structural habitats and 15 seconds of sampling should be undertaken in open-water habitats < 4 m deep.
2. Length data from all species is recorded for all operations of every gear type (with sub-sampling of 20 individuals per shot/net/trap) to allow generation of SRA metrics. This includes alien and both large and small bodied species.
3. The individual weight of the first 50 individuals measured for length of each non-target species will also be recorded.
4. Ten unbaited collapsible shrimp traps will be set for the duration of the electrofishing operations (minimum of 1.5 hours) to maintain consistency with SRA protocol.

Basin evaulation otolith analysis (Zone 1)

Basin evaluation otolith analysis within zone 1 will utilise published otolith procedural protocols (Campana 2001; Secor et al 1992) as specified by Hale *et al.* (2013).

The five 'representative' species we propose to undertake otolith analyses are:

- Equilibrium: Murray cod (*Maccullochella peeli*)
- Periodic: Golden perch (*Macquaria ambigua*) and bony herring (*Nematalosa erebi*)
- Opportunistic: Carp-gudgeons (*Hypseleotris spp*) and unspecked hardyhead (*Craterocephalus stercusmuscarum*).

3.11 Quality Assurance/Quality Control

QA/QC activities specific to this protocol include:

- NSW DPI staff are permitted to sample fish in NSW waters under a NSW Section 37 permit.
- NSW DPI will apply to undertake research on fish under a research authority granted by the NSW Fisheries Animals Care & Ethics Committee.
- NSW DPI electrofishing operators are certified under the NSW DPI Electrofishing Training schedule (Wooden et al. 2013) and operate under the requirements of the Australian Code of Electrofishing Practice.
- Electrofishing equipment is serviced by the manufacturer (Smith-Root Pty Ltd) on an annual basis.
- Fyke nets and collapsible shrimp traps are checked for holes or damage prior to every field trip and during each trip, and damaged nets either repaired or replaced.
- Scales are calibrated following manufacturers specifications prior to every field trip.
- A select sample of voucher specimens of those species groups typically difficult to identify in the field (see Muschal et al. 2010, MDBA (2012) Supplement 3A) will be preserved for ID verification in the laboratory.
- A sub-sample of otoliths will be read twice to validate the readings.
- Following confirmation of the identity of those species where voucher specimens were collected, data will be transferred from field data sheets into intermediate tables within a Microsoft Access database (the I&I NSW Freshwater Fish Research Database - FFRD) and the original datasheets stored in fire-proof safes. Data in intermediate tables will be processed through a series of 50 range-checks to identify any outliers and inconsistencies in data recording. All potential errors are referred to the senior operator responsible for data collection at that site for confirmation and/or correction. The corrected intermediate tables are then appended into the FFRD for storage. A level 3 data audit is also undertaken by the supervising scientist after each year's sampling in order to ensure compliance with sampling protocols.

3.12 Data analysis and reporting

3.12.1 Generation of metrics and indicators

Small and large-bodied fishes

Relative abundance

Raw catch and effort data for each sampling operation (electrofishing shot or net/trap set) will be recorded. Processed data for fish abundances will be reported as standardised catch-per-unit-effort (CPUE) per method. Electrofishing CPUE will be standardised to catch per minute of electrofishing (power on time). Fyke net and shrimp trap CPUE will be standardised to catch per net hour.

Population structure data

Each individual measured/weighed will be assigned a unique identification code based on its sampling location, operation and sequence on the raw data sheets. This identifier will be used to label any otoliths collected and can subsequently be used to assign the ageing result from otolith analysis to each sample. Raw length, weight and age data for each individual will be provided to CEWO as required.

The abundance (CPUE) or proportion of new recruits within populations will be derived using a similar process to that applied to generate recruitment metrics for the SRA (Robinson 2012). For large bodied and generally longer living species (>three years), an individual will be considered to be a recruit if its body length is less than that of a one year old of the same species. For small bodied and generally short lived species that reach sexual maturity in less than 1 year, recruits will be considered to be those individuals that are less than the species known average length at sexual maturity. The recruitment length cut-offs used for both large and small bodied species will be derived from either length at age data generated by this program or from scientific literature.

The abundance (CPUE) or proportion of sexually mature adults within populations will be derived using a similar process as that above, but based on the length at sexual maturity of both large and small bodied species.

Individual body condition

Established length – weight relationships for each species (MDBC 2004, NSW DPI unpublished data) will be used to estimate the expected weight of individuals based on their length. Relative body condition of each individual will be calculated as = recorded weight /expected weight.

Fish assemblage condition

Using the Sustainable Rivers Audit data analysis methods described by Robinson (2012), eight fish metrics will be derived from the data collected on each sampling occasion. The eight metrics will then be aggregated to produce three fish condition indicators and these indicators will then be used to derive an overall Fish Condition Index (ndxFS). The SRA derived Indicators will be: (1) *expectedness* (provides a comparison of existing catch composition with historical fish distributions), (2) *nativeness* (an indicator of the dominance of native versus alien fish in the assemblage), and (3) *recruitment* (an indicator of the extent of native fish recruitment within the zone). These indicator scores are scaled between 0 and 100 and are condition rated as (Extremely Poor (0-20), Very Poor (21-40), Poor (41-60), Moderate (61-80), Good (81-100). SRA condition scores can be compared across time and before and after flow events, with an overall expectation that condition ratings will improve over time.

3.12.2 Data analyses

Basin scale analyses

Small and large-bodied fishes

Long-term (five-year) questions:

- What did Commonwealth environmental water contribute to native fish populations in the lower Lachlan River?
- What did Commonwealth environmental water contribute to native fish diversity in the lower Lachlan River?

Short-term (one-year) questions:

- What did Commonwealth environmental water contribute to native fish community resilience in the lower Lachlan River?
- What did Commonwealth environmental water contribute to native fish survival in the lower Lachlan River?

Selected Area analyses

Small and large-bodied fishes

Long-term (five-year) questions:

- What did Commonwealth environmental water contribute to native fish abundance and diversity?

  Long term changes in CPUE of individual species and native species richness will be analysed using parametric univariate ANOVA using year as a factor. In the same way, changes in fish assemblages will be analysed using non-parametric PERMANOVA (Primer 6).

- What did Commonwealth environmental water contribute to native fish resilience and condition?

  Long term changes in individual body condition and CPUE or proportion of new recruits and sexually mature individuals within populations will be analysed using parametric univariate ANOVA using year as a factor. Long-term changes in length-frequency distributions of individual species will be undertaken using Kolmogorov-Smirnov tests for those species where > 50 individuals are collected. Long term changes in fish assemblage condition (expectedness, nativeness and recruitment indicators and overall fish condition index) will be analysed using parametric univariate ANOVA using year as a factor.

Short-term (one-year) questions:

- What did Commonwealth environmental water contribute to native fish abundance?

  Analyse the effect size of changes in CPUE of individual species in relation to flow components (categorical variable) or hydrological parameters (continuous variables).

- What did Commonwealth environmental water contribute to native fish recruitment?

  Analyse the effect size of changes in CPUE of new recruits in relation to flow components (categorical variable) or hydrological parameters (continuous variables).

- What did Commonwealth environmental water contribute to native fish resilience?

Analyse the effect size of changes in individual body condition in relation to flow components (categorical variable) or hydrological parameters (continuous variables).

- What did Commonwealth environmental water contribute to maintenance of drought refugia for native fish?

Analyse the species composition of fish assemblages found within refugia in relation to the assemblage structure found within that zone prior to cease to flow conditions and if possible to the assemblage found in the zone once base flow conditions return.

- What did Commonwealth environmental water contribute to native fish survival?

Analyse changes in CPUE, size frequency distributions and relative body condition of species isolated within drought refugia through time.

3.13 Data management

Following confirmation of the identity of those species where voucher specimens were collected, data will be transferred from field data sheets into intermediate tables within a Microsoft Access database (the I&I NSW Freshwater Fish Research Database - FFRD). Data in intermediate tables will be processed through a series of 50 range-checks to identify any outliers and inconsistencies in data recording. All potential errors are referred to the senior operator responsible for data collection at that site for confirmation and/or correction. The corrected intermediate tables are then appended into the FFRD for storage. A level 3 data audit is also undertaken by the supervising scientist after each year's sampling in order to ensure compliance with sampling protocols.

The original datasheets will be scanned and copies of the data stored at the University of Canberra. The original data sheets will be stored in fire-proof filing cabinets at the Narrandera Fisheries Centre.

3.14 Health and safety

For details on health and safety please refer to the Workplace Health and Safety Plan for the Lower Lachlan river system Selected Area (WHS 202.1) in appendix 3.

3.15 References

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Supplement 3A: Murray Darling Basin Authority - Sustainable Rivers Audit Protocol for Fish Theme sampling – Implementation Period 8: 2012-13

Introduction

This protocol applies to the sampling of SRA sites as part of the Fish Theme. It was developed by the MDBA's SRA team in consultation with the SRA Joint Venture Committee, Independent Sustainable Rivers Audit Group, the Jurisdictional Managing Agencies (JMA) and the Fish Taskforce.

Prerequisites

The following prerequisites must be met before applying this protocol:

- a current sampling plan has been received from the Authority office
- the site has been validated in accordance with the Site Validation protocol
- field staff meet the requirements of their respective JMAs and agencies in applying this protocol, and
- field staff must comply with the requirements of the Australian Code of Electrofishing Practice.

Sampling principles

The staff undertaking sampling must adhere to following principles, which are fundamental to the application of this protocol

- Sampling is to take place between 1 November and 30 April. In the North of the Basin (specifically the Paroo, Warrego and Condamine) the sampling period may extend to the end of May if temperatures earlier in the season are too high to work.
- Sampling is not to take place during periods of high flow, either natural or from impoundment releases. High flows are those which in the judgement of the field operators would pose an occupation health and safety risk or compromise catch efficiency to unacceptable levels.
- The Authority office must be notified as soon as practicable by the sampling agency or the JMA of any change to the application of this protocol or methods deployed at a site during a site visit in the event of equipment malfunction, site abandonment or disruption to a sampling event.
- Each major habitat type present at a site must be sampled at least once and then remaining sampling effort should occur in the most abundant habitat types. Recognised habitat types are pool edges, middle portions of pools, runs and riffles, slow-flowing back waters, emergent vegetation, submerged vegetation, large woody debris and debris dams.
- Sites must be sampled using the most appropriate methods, as listed in Tables 6.1 and 6.2. It is likely that both backpack and boat electrofishing will be used at most sites.
- Data are only to be recorded for fish greater than 15 mm total length.

- All caught fish are released live, except where State noxious or alien fish policies require otherwise or where samples are required as voucher specimens (see Section 0 Voucher specimens).

Deployment of sampling methods

Fish sampling will be conducted by electrofishing (boat, bank-mounted and backpack) and by use of bait-traps. Given the wide variety of site conditions in the Basin (from small upland streams to large lowland rivers) the teams will need to make a site-specific assessment of conditions. This assessment will need to identify the type of habitats present and their relative abundance, after which a decision can be made on the appropriate mix of sampling methods. In particular, the site should be assessed to identify all habitats that can be electrofished by boat, bank-mounted and/or backpack methods, and the proportion suitable for each method should be determined.

Guidance on the selection and deployment of fish sampling methods is provided in the following tables.

The broad mix of sampling methods to be deployed under different site conditions is described in Table 2, and guidance on their application is provided in Table 2.

Table 1: Choice of fish sampling method under varying site characteristics

SITE CHARACTER	APPROPRIATE METHODS
Large river sites: >15 m wetted channel width (as estimated by sampling teams)	• **Adopt large boat electrofishing.** • **Include backpack shots as necessary to sample each wadeable habitat type at least once.** • **Deploy 10 bait-traps.**
Small river sites: <15 m wetted channel width (as estimated by sampling teams)	• **Adopt small boat electrofishing** • **Include backpack shots as necessary to sample each wadeable habitat type at least once** • **Deploy 10 bait-traps.**
Wadeable habitats	• **Adopt backpack electrofishing. However, bank-mounted electrofishers can be used instead of backpack electrofishers for sites with electrical conductivity levels between 1500 µS/cm and the detection limits of the bank-mounted unit, provided agencies accept their use.** • **Deploy 10 bait-traps.**

Table 2: Application of fish sampling methods

METHOD NAME	APPLICATION
Boat electrofishing	• Deploy 12 shots. • Note: A shot is 90 seconds of accumulated power-on time. • In portions of streams >15 m wetted channel width (as estimated by sampling teams), adopt alternate shots alongside both banks. • In portions of streams <15 m wetted channel width (as estimated by sampling teams), adopt zigzag coverage of sampled area. • Deploy two mid-channel shots when mid-channel water depth <4 m.
Backpack (and Bank-mount) electrofishing	• Deploy 8 shots. • Note: A shot is 150 seconds of accumulated power-on time. • In portions of streams <10 m wetted channel width (as estimated by sampling teams), adopt zigzag coverage of sampled area. • In streams >10 m wetted channel width (as estimated by sampling teams), adopt alternate shots alongside both banks. • Where electrical conductivity is >1500 µS/cm and where agencies accept their use, bank-mounted electrofishers can be used in place of backpack electrofishers using the same procedures.
Bait-trap	• Deploy 10 bait-traps for 2 hours (± ½ hour depending on duration of electrofishing effort). • Only deploy at locations with depth <1 m. • Do not use bait or chemical light sticks in the traps. • Set traps in slow-flowing or backwater areas independent of electrofishing sites. • Pool the catch from all traps and record as a single event.

Table 3: Number of electrofishing shots required with each type of electrofishing gear

METHOD	PROPORTION OF SITE								
	<1/8	1/8	¼	3/8	½	5/8	¾	7/8	**All**
Boat	0	0	4	5	6	8	9	11	**12**
Backpack	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**8**	**8**

Bait-trap placement

Sampling practices guided by Table 3 above and as adopted during Implementations Periods 1–6 should continue to be used.

Measurement of individuals and subsampling

Fish smaller than 15 mm may be recorded but should not be reported as core SRA data as they will not be used in the analysis. A subsample of 50 individuals per species captured by each method (i.e. boat electrofishing, backpack electrofishing and bait-traps) used at each site should be measured for the listed attributes below. The subsample begins with the first individual of each species collected from each method and continues until the 50th individual. During electrofishing operations, in the shot/replicate where the 50th fish is found, all individuals present should be measured and recorded in order to avoid any bias in the size of fish selected for the subsample. For bait-traps the catch is pooled prior to counting and measuring, each fish is identified, and the first 50 of each species are measured. An effort should be made to reduce bias in sub-sampling the pooled catch, e.g. use a small aquarium dip-net to net the pooled catch. (Note: NSW DPI prefers to collect the data for each trap independently and then, using random sampling of the data, generate a compliant pooled data return for MDBA.) If the number of individuals captured by each sampling method is less than 50, all of them should be measured for the attributes listed below.

Data to be recorded for each individual are outlined below.

1) *Length:* Caudal fork length for species with a forked tail and total length for species with round tails are to be measured. Approximate length should be estimated for damaged fish and this will be considered equivalent to a measured length during data analysis. Length should be measured to the nearest mm using a measuring board.
2) *Weight:* If weight is to be recorded for that species (refer to Table 6.3), then each individual fish should be blotted dry and measured on a balance with a suitable range for individual being measured:
    a. for fish >50 g, record weight to nearest gram, or
    b. for fish 50 g or less, record weight to nearest 0.1 g.
3) *Health and condition:* For data requirements see Section 0 Fish health condition.
4) *Voucher specimens:* These are to be collected if that species requires a voucher specimen (refer to Table 3 and Voucher specimens).

Species list

The species list is a combination of those species thought to have occurred in the Basin under reference conditions, those species caught during previous sampling events and those alien species expected to be caught in future sampling.

The list may be updated from time-to-time where new species are identified, taxonomy revised or data collection requirements change. Those species for which voucher specimens should be collected or weight recorded are indicated in this list. Requirements for voucher specimens are presented below.

When identifying alien species such as carp and goldfish, field teams should be aware that there is the possibility of hybridisation. Jurisdictions may decide whether or not they wish to record the presence of hybrids. However, in doing so they should be aware that when the data are received by the MDBA, any hybrids will be assigned to a single parent taxon (e.g. carp or goldfish) based on which parent stock the body dimensions of the hybrid most resemble. This will therefore require that jurisdiction field teams either record hybrids as a single parent taxa (e.g. carp or goldfish) immediately in the field, **OR** record in the field as hybrids and take appropriate notes to allow matching to either parent taxa prior to transmission of data to MDBA.

Table 4: Murray–Darling Basin SRA fish taxa, including whether they require voucher specimen collection and/or weighing

TAXA CODE	SCIENTIFIC NAME	COMMON NAME	GET VOUCHER SPECIMEN	RECORD WEIGHT
ACAFLA	*Acanthogobius flavimanus*	Yellowfin goby	YES	
ACABUT	*Acanthopagrus butcheri*	Black bream		
AFUTAM	*Afurcagobius tamarensis*	Tamar River goby	YES	
ALDFOR	*Aldrichetta forsteri*	Yellow-eyed mullet	YES	
AMBAGA	*Ambassis agassizii*	Olive perchlet	YES photo only	**YES**
AMOBIF	*Amoya bifrenatus*	Bridled goby	YES	
ANGAUS	*Anguilla australis*	Short-finned eel		
ANGREI	*Anguilla reinhardtii*	Long-finned eel	YES	
ARGHOL	*Argyrosomus hololepidotus*	Mulloway		
ATHMIC	*Atherinosoma microstoma*	Small-mouthed hardyhead	YES	
BIDBID	*Bidyanus bidyanus*	Silver perch	YES[a]	**YES**
BIDWEL	*Bidyanus welchi*	Welch's grunter	YES[a]	
CARAUR	*Carassius auratus*	Goldfish		
CARCAR	*Carassius carassius*	Crucian carp	YES	**YES**
CRAAMN	*Craterocephalus amniculus*	Darling River hardyhead	YES	**YES**
CRAFLU	*Craterocephalus fluviatilis*	Murray hardyhead	YES	**YES**
CRASTE	*Craterocephalus stercusmuscarum fulvus*	Unspecked hardyhead	YES	
CYPCAR	*Cyprinus carpio*	Common carp		
GADBIS	*Gadopsis bispinosus*	Two-spined blackfish		
GADMAR	*Gadopsis marmoratus*	River blackfish		
GALBRE	*Galaxias brevipinnis*	Climbing galaxias	YES	**YES**
GALMAC	*Galaxias maculatus*	Common galaxias	YES	
GALFUS	*Galaxias fuscus*	Barred galaxias	YES	
GALOLI	*Galaxias olidus*	Mountain galaxias	YES	
GALROS	*Galaxias rostratus*	Flat-headed galaxias	YES	**YES**
GALSP1	*Galaxias* sp1	Obscure galaxias	YES	
GALSP2	*Galaxias* sp2	Riffle galaxias	YES	**YES**
GALTRU	*Galaxias truttaceus*	Spotted galaxias	YES	**YES**
GAMHOL	*Gambusia holbrooki*	Gambusia		
GEOAUS	*Geotria australis*	Pouched lamprey	YES	**YES**
HYPGAL	*Hypseleotris galii*	Firetail gudgeon	YES[b]	
HYPSPP	*Hypseleotris* spp.	Carp gudgeons (lumped)	YES[b]	
LEIUNI	*Leiopotherapon unicolor*	Spangled perch		
LIZARG	*Liza argentea*	Flat-tailed mullet	YES	
MACAMB	*Macquaria ambigua ambigua*	Golden perch		
MACAUS	*Macquaria australasica*	Macquarie perch		
MACCOL	*Macquaria colonorum*	Estuary perch		**YES**
MACMAC	*Maccullochella macquariensis*	Trout cod / Bluenose cod	YES[c]	
MACPEE	*Maccullochella peelii peelii*	Murray cod	YES[d]	
MELFLU	*Melanotaenia fluviatilis*	Murray–Darling rainbowfish	YES[e]	
MELSPL	*Melanotaenia splendida tatei*	Desert rainbowfish	YES[e]	**YES**
MISANG	*Misgurnus anguillicaudatus*	Oriental weatherloach	YES	
MOGADS	*Mogurnda adspersa*	Southern purple-spotted	YES	

		gudgeon	photo only	
MORMOR	*Mordacia mordax*	Short-headed lamprey	YES	
MUGCEP	*Mugil cephalus*	Sea mullet	YES	
MYXELO	*Myxus elongatus*	Sand mullet	YES	
NANAUS	*Nannoperca australis*	Southern pygmy perch		
NANOBS	*Nannoperca obscura*	Yarra pygmy perch		**YES**
NEMERE	*Nematalosa erebi*	Bony herring		
NEOHYR	*Neosilurus hyrtlii*	Hyrtl's tandan		
ONCMYK	*Oncorhynchus mykiss*	Rainbow trout	YES[f] <100 mm	
PERFLU	*Perca fluviatilis*	Redfin perch		
PHIGRA	*Philypnodon grandiceps*	Flathead gudgeon	YES	
PHIMAC	*Philypnodon macrostomus*	Dwarf flathead gudgeon	YES	**YES**
PORREN	*Porochilus rendahli*	Rendahl's tandan		
PSEOLO	*Pseudogobius olorum*	Blue-spot goby		
PSEURV	*Pseudaphritis urvillii*	Congolli		
REDMAC	*Redigobius macrostoma*	Large-mouthed goby	YES	
RETSEM	*Retropinna semoni*	Australian smelt		
RUTRUT	*Rutilus rutilus*	Roach	YES	**YES**
SALTRU	*Salmo trutta*	Brown trout	YES[f] <100 mm	
TANTAN	*Tandanus tandanus*	Freshwater catfish		
TASLAS	*Tasmanogobius lasti*	Lagoon goby		
TINTIN	***Tinca tinca***	**Tench**		**YES**

[a] *Bidyanus bidyanus* and *Bidyanus welchi* may both be in the Paroo and voucher specimens and/or colour images are required for confirmation.
[b] *Hypseleotris* species should be collected in Queensland valleys to determine if *Hypseleotris galii* is present. For all other valleys the genus is lumped.
[c] *Maccullochella macquariensis* to be photgraphed when individual >120 mm and a voucher specimen collected when <100 mm.
[d] *Maccullochella peelii peelii* to have voucher specimen collected for small fish (<120 mm) in regions where *Maccullochella macquariensis* occurs.
[e] *Melanotaenia fluviatilis* and *Melanotaenia splendida tatei* may both be in the Paroo, Warrego and Middle to Upper Darling and voucher specimens and or colour images are required for confirmation.
[f] Small trout (<100 mm) should have voucher specimens collected to ensure *Salmo trutta* and *Oncorhynchus mykiss* are distinguished.

Voucher specimens

Voucher specimens are to be collected for rare species, uncertain species and for notable range extensions of any species. Required species are shown in the Get Voucher column of Table 5. Note the following recommendations for voucher collections.

- Collect at least three specimens where possible, covering a range of size and colouration.
- Preserve specimens in 90–100% alcohol.
- Label each voucher sample with the following information: SRA site ID, State, river name, date collected and collector's name.
- Use a container of adequate size so that fish are not bent or crammed in, and ensure adequate preservative concentration is maintained.
- Obtain good quality digital images of all live specimens depicting body colouration and fin shape.

Note: Good quality digital images of live specimens depicting body colouration and fin shape are an acceptable alternative when specimens are too large to be effectively preserved and for those species identified in Table 5 above.

Identification of the specimen is a three-stage process.

1. Return specimens to the sampling team's laboratory and use collective knowledge and identification aids to confirm identification.
2. If uncertainty remains, use a known specialist in that particular taxon to confirm the specimen's identification.
3. If a specialist is not available or any uncertainty remains, send the specimen to the following fish taxonomist, who will confirm identification or, in conjunction with the Authority, determine a process to have the specimen identified.

   Tarmo Raadik
   Arthur Rylah Institute for Environmental Research
   123 Brown Street
   Heidelberg Vic 3084

Fish health and condition

The presence of any abnormality sighted on any part of a measured fish should be recorded on the field sheet. At least one side of the fish should be checked completely for abnormalities. Abnormalities are to be assessed only on the measured subsample of each species.

Those fish abnormalities that are considered reportable are listed in Table 6. The fact that a handled fish exhibits one or more abnormalities must be indicated by listing the health code against attribute 'HealthCode' in the data return. A 'HealthCode' entry is recorded as a continuous sequence of the codes available in Table 6. Examples of valid entries include 'D', 'DWLP' and 'PLWD'. The codes 'yes' or 'true' can be used when an abnormality is observed but the descriptive health code has been misplaced, lost or forgotten. This ensures that the presence of all abnormalities is recorded even if the type of abnormality is lost.

Table 5: Reportable abnormalities exhibited by handled fish

HEALTHCODE	ABNORMALITY DESCRIPTION
D	**Deformity (skeleton deformities, blindness, fin deformities, asymmetrical, etc)**
F	**Fin condition poor (broken, eroded fins)**
S	**Lesions (skin abnormality with raised and or discoloured scales)**
U	**Ulcers (skin is broken, crater like, redness)**
T	**Tumour (localised abnormal growth)**
W	**Wounds (e.g. bird strikes, hook wounds)**
G	**Fungus**
L	***Lernaea* spp. (but only where a notable number are present. This is defined as: If fish <100 m total length, report any *Lernaea* sp.; If fish >100 mm total length, report if more than 3 *Lernaea* sp.)**
P	**Other visible parasites**
O	**Other: the abnormality must be photographed and described and/or a specimen preserved**
Yes **True**	**Either of these codes can be used when an abnormality is observed but the above list has been misplaced, lost or the health code has been forgotten**

LTIM Monitoring – Electrofishing data sheet

Date: ______________________ Selected Area: ______________________

Zone: ______________________ Site: ______________________

EF Unit	Shot	Species	TL (mm)	SL (mm)	FL (mm)	Weight (g)	Recapture (0,1)	Tag #

Example: LTIM Monitoring – Fine-mesh fyke field data

Date: ______________________________ Selected Area: ______________________________

______

Zone: ______________________________ Site: ______________________________

Fyke 1 of 10
Time set: ______________________________

PS waypoint: ______________________________
Time retrieved: ______________________________

Abundances:

Species	Sub-sample (proportion)	Count

Standard lengths of two target small-bodied species (refer to LTIM protocol)

Species	Standard lengths (mm) of first (random) 20 individuals
Hypseleotris	

Fyke 2 of 10
Time set: ______________________________

PS waypoint: ______________________________
Time retrieved: ______________________________

Abundances:

Species	Sub-sample (proportion)	Count

Standard lengths of two target small-bodied species (refer to LTIM protocol)

Species	Standard lengths (mm) of first (random) 20 individuals
Hypseleotris	

4 Fish (Larvae)

4.1 Overview

This protocol describes the methods that will be used to monitor larval fish for both Basin scale (specified by the CEWO) and the Area scale evaluation.

4.2 Evaluation questions

4.2.1 Basin evaluation questions

- **Short-term (one-year) questions:**
  - What did Commonwealth environmental water contribute to native fish reproduction?
  - What did Commonwealth environmental water contribute to native larval fish growth?
  - What did Commonwealth environmental water contribute to native fish survival?

- **Long-term (five-year) questions:**
  - What did Commonwealth environmental water contribute to native fish populations?
  - What did Commonwealth environmental water contribute to native fish species diversity?

The process for evaluating these questions is illustrated in Figure 1, with components covered by this protocol highlighted in blue. Note that the boxes marked in red for otolith examination and daily age and growth are optional (category 2) monitoring associated with this method.

4.2.2 Selected Area evaluation questions

- **Short-term (one year) evaluation questions:**
  - What did Commonwealth environmental water contribute to native fish reproduction in the lower Lachlan River catchment?
  - What did Commonwealth environmental water contribute to native larval fish growth in the lower Lachlan River catchment?

Long-term (five year) evaluation questions:

- What did Commonwealth environmental water contribute to native fish populations in the lower Lachlan River catchment?
- What did Commonwealth environmental water contribute to native fish species diversity in the lower Lachlan River catchment?

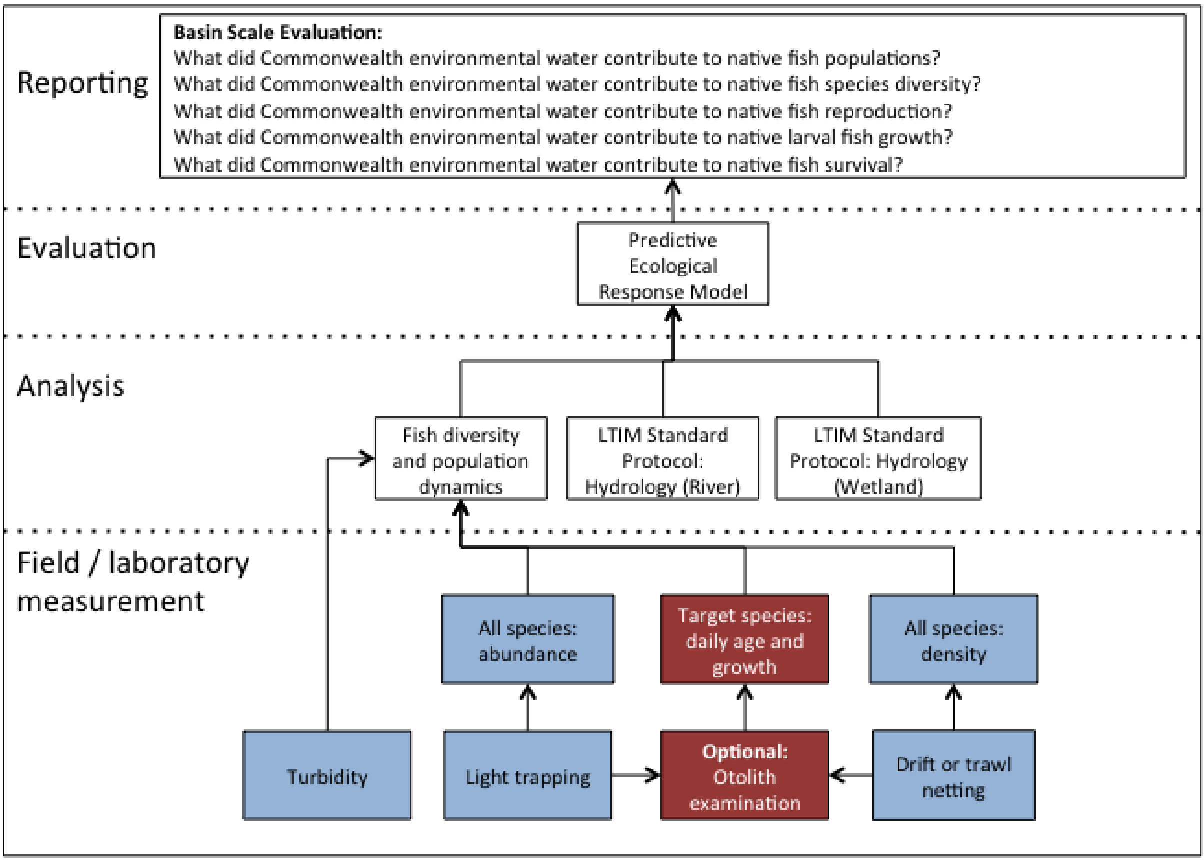

Figure 1: Schematic of key elements in LTIM Standard Protocol: Fish (Larvae).

4.3 Relevant ecosystem types

Rivers.

4.4 Relevant flow types

These methods describe annual monitoring conducted during the period August to February of each year independent of specific watering events. The methods are therefore relevant to all flow types.

4.5 Overview and context

A common goal of many environmental flow regimes is the maintenance and enhancement of the native fish community (King *et al.* 2010). This strategy is based on the premise that aspects of the flow regime are linked to key components of the life history of fish, including pre-spawning condition and maturation, movement cues, spawning cues and behaviour, and larval and juvenile survival (e.g. Junk *et al.* 1989; Humphries *et al.* 1999; King *et al.* 2003; Balcombe *et al.* 2006). Since the strength of recruitment, is largely driven by spawning success and growth and survival of young, understanding how the flow regime influences the early life history of fishes is critical to managing fish populations (King *et al.* 2010). This document provides an overview of the methods of evaluating the contribution of Commonwealth Environmental Water releases to native fish spawning, larval fish growth and survival and recruitment to the population.

These methods describe monitoring required for the Basin Evaluation and Selected Area Evaluation of fish breeding in response to Commonwealth environmental water. The methods describe the sampling design and protocol for fish larvae in rivers for the LTIM project.

This protocol describes sampling fortnightly for 5 sampling events between September through to February each year to measure:

- Catch-per-unit-effort (CPUE) of each larval fish species in rivers using:
  - Light traps
  - Fixed position drift nets in flowing sites or towed trawl nets in low/no current sites.
- Collection of water quality sample or *in situ* measurement of turbidity

4.6 Monitoring locations

4.6.1 Protocol

LTIM for Basin-scale evaluation and area scale evaluation has adopted a hierarchical approach to sample design (see Gawne et al. 2013). The spatial hierarchy for fish (river) monitoring is as follows:

Selected Area → Zone → Site

Please refer to LTIM Standard Protocol: Fish (River) for more detail on the nested hierarchical approach design adopted for LTIM fish sampling.

4.6.2 Site placement within zones

Basin Methods

Larval fish monitoring for Basin and Selected Area analysis will take place at a subset of the same sites specified for monitoring of fishes in the channel (see LTIM Standard Protocol: Fish (River). The rationale underlying this is to seek as much synergy as possible among the three different monitoring components for fishes. For basin evaluation larval fish sampling will be undertaken in one zone at three sites:

- Three channel sites (also sampled for adult fish – see map):
  - Lanes Bridge / Moora Farm
  - Hunthawang
  - Willanthry

Selected Area Methods

Selected Area Evaluation will be made using the same sites as for basin methods. The zone used for basin- evaluation (zone 1) is typified by being a higher gradient tributary zone with a larger proportion of native fish present. Specifically, this monitoring regime will be able to detect the contribution of Commonwealth Environmental Water to:

- Enhancing native fish spawning and recruitment in zone 1 (where reasonable populations of the target native species are already present)

4.6.3 Sample placement within sites

Equipment

- GPS
- Possibly a boat, depending on access

Up to three different larval sampling gears will be used within the three channel sites of the zone targeted for both basin and area evaluations: Light traps, drift nets, and larval tows/trawls. Upon inspection of field sites, it is most likely that drift nets will be employed in channel habitats as there will be sufficient flow. For further detail on why these three methods have been selected, and gear specifications, refer to Section 1.6.

Ten **light traps** will be randomly allocated within each site. The same randomisation approach recommended in LTIM Standard Protocol: Fish (River) will be used, with the following caveat: light traps must be positioned within slackwater. The set of 10 random PS waypoints will be used (see LTIM Standard Protocol: Fish (River)). The closest slackwater to that waypoint will be used for positioning of light traps. If no slackwater is available within 20m either side of the waypoint another random waypoint will be selected.

Light traps will be used for larval assemblage composition and potentially for relative abundance comparisons/contrasts among areas. Their efficacy is heavily dependent on turbidity, so any comparisons of relative abundance among areas will be dependent on the inter-area differences in turbidity levels.

Larval density is measured using stationary drift nets for higher current areas and towed nets for low current pools.

Three **Drift nets** per site (total of nine per zone, per sampling event) will be positioned in water with a moderate velocity, preferably where the discharge is concentrated through a narrow section of the river (a funnel effect). Ideally, drift nets will not be closer than 100 m to each other.

If a site does not contain suitable water for setting drift nets (too slow, wide, deep, etc.) then a boat will be used for taking **larval trawls**. Three replicate five-minute trawls at approximately ½ m per second will be allocated to each site (nine five-min trawls per area, per sampling event). To ensure samples are independent, the water column in any space must only trawled once.

4.7 Sampling protocol

4.7.1 Equipment

- Ethics and fisheries permits from relevant institutions.
- Light traps.
- Larval drift nets.
- Boat.
- Data sheets

4.7.2 Protocol

Timing of sampling

At each site, larval sampling will take place over five sampling events between August and February inclusive. These sampling events will be event based, though will be taking in consideration the seasonal requirements of the target native fish species in terms of other factors required for the onset of spawning (day length, temperature etc.). These are referred to as the five 'sampling events' below. Sampling will be undertaken following Commonwealth Environmental water released in the months between August and February. In the Lachlan river catchment selected area these flows are most likely to be released earlier in that period due to restrictions of releasing Commonwealth water associated other flow releases for irrigation.

Indicative timing of larval fish monitoring in the Lachlan River selected area (grey bars indicate time of sampling).

	Watering event									
Weeks	0	1	2	3	4	5	6	7	8	9
Sampling										

Sampling

The sampling procedure is the same for Riverine fish.

The six 'representative' species we propose to target are:

- Equilibrium: Murray cod (*Maccullochellapeeli*) and freshwater catfish (*Tandanustandanus*)
- Periodic: Golden perch (*Macquaria ambigua*) and bony herring (*Nematalosaerebi*)
- Opportunistic: Carp-gudgeons (*Hypseleotris* spp) and unspecked hardyhead (*Craterocephalus stercusmuscarum*).

All six species are present within Zone 1 of the lower Lachlan catchment. *In situ* measurements of turbidity will be taken each fortnight via calibrated meter.

Modified quatrefoil light traps will be used (see Humphries et al. 2002). Mesh will be fitted around the light traps to eliminate larger fish from entering the trap, and eating the sample (3 mm knot-to-knot). The ten light traps set within each of the three sites will be set in the afternoon and retrieved the following morning. Set and retrieval times will be recorded, so that relative abundance can be expressed as catch-per-unit-effort (CPUE). Each light trap will be 'baited' with a yellow 12 h light stick.

If **drift nets** are appropriate for the site, they will be constructed of 500 µm mesh, have an opening diameter of 50 cm, tapering over 1.5 m to an opening of 9 cm, to which a reducing bottle fitted. Positioning of drift nets is explained earlier. Volume through the net will be estimated so that larval abundances in drift nets can be expressed as a density: number of individuals per m^3. Volume sampled by the net is estimated as $\pi r^2 \cdot v \cdot t$, where *r* is radius in metres, *v* is mean velocity in m s^{-1}, and *t* is time set in seconds.

If **larval trawls** are appropriate then larval tow nets will be exact dimensions to the stationary drift nets. Similarly, volume through the net will be estimated using a flow meter attached to the front of the net. Velocity of the boat will be no less than ½ m per second, to avoid fish swimming away from the net. Larval trawls will take place during the night in the channel (so that in channel drift nets will be comparable to trawl nets), and abundances will be expressed as number of individuals per cubic metre of water sampled.

Processing

Entire samples will be preserved individually in 90% ethanol and returned to the laboratory for larval identification and enumeration.

4.8 Data analysis and reporting

4.8.1 Basin-scale evaluation

Turbidity

Turbidity measures will be recorded as mean turbidity per site per sampling event and assessed against Light trap abundance data for all sites.

Relative abundance estimation

Light-trap abundances will be expressed as ‘catch-per-unit-effort’ (CPUE), where the units are number of individuals per trap per hour of deployment. Drift and trawl net abundances will be expressed as densities; number of individuals per cubic metre of water filtered (see Section 4.7.2).

Community data

CPUE data will be provided at the level of the site (species by site abundance matrices). Abundance data is reported for each species as the mean CPUE for the site. Data will be provided separately for each sampling method:

1. Light-trap channel;
2. Drift net OR larval trawl channel.

4.8.2 Area-scale evaluation

Short-term (1 year) questions

- What did Commonwealth environmental water contribute to native fish reproduction in the lower Lachlan River catchment?

  Larval fish abundance (described above in 4.7.2) will be analysed using parametric univariate ANOVA using year as the factor. In the same way, changes in larval fish assemblages will be analysed using non-parametric PERMANOVA (Primer 6). Analyse the effect size of changes in CPUE of larval fish for each species in relation to flow components (categorical variable) or hydrological parameters (continuous variables). Interpretation of results will be set in the context of covariates relevant to larval fish in the Lachlan River system (see CED following).

- What did Commonwealth environmental water contribute to native larval fish growth in the lower Lachlan River catchment?

  The contribution of commonwealth environmental water to larval fish growth (and hence recruitment) will be determined by analysing age vs length ratios using parametric univariate ANOVA using year. Interpretation of results will be set in the context of covariates relevant to growth and survival of larval fish in the Lachlan River system (see below).Analyse the effect size of changes in growth (age vs. length ratio) in relation to flow components (categorical variable) or hydrological parameters (continuous variables).

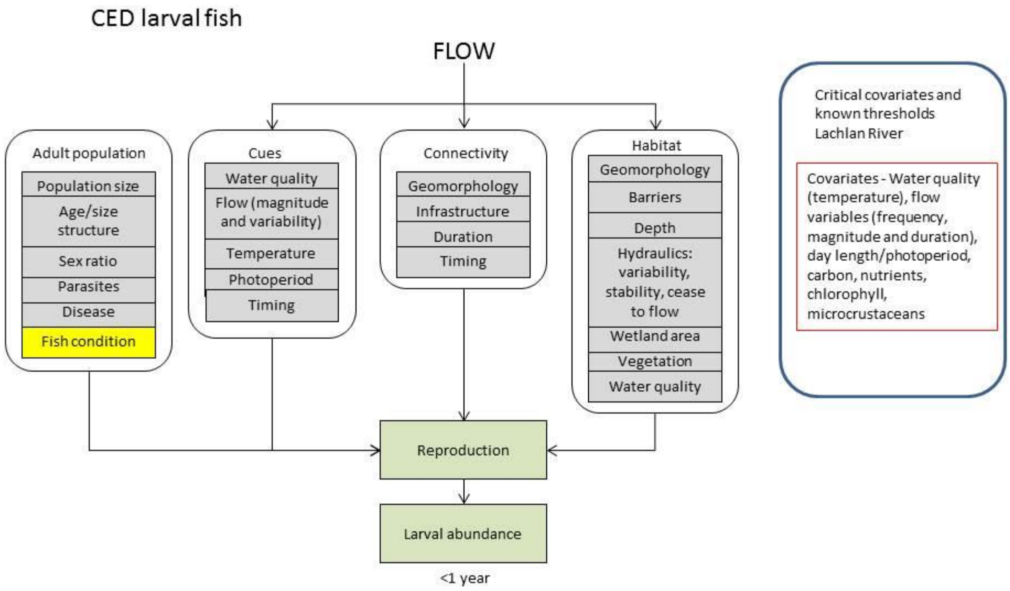

Figure 2. Larval fish abundance cause and effect for the Lachlan River Selected area.

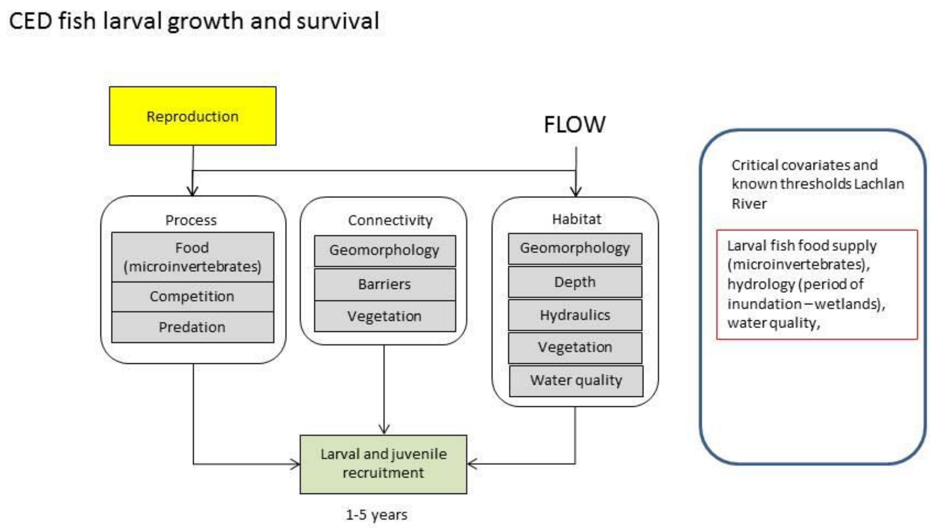

Figure 3.Larval fish growth and survival cause and effect diagram for the Lachlan River selected area.

Long-term (five year) evaluation questions:

- What did Commonwealth environmental water contribute to native fish populations in the lower Lachlan River catchment?

Larval fish abundance (described in 4.7.2) will be analysed using parametric univariate ANOVA using year. In the same way, changes in larval fish assemblages will be analysed using non-parametric PERMANOVA (Primer 6). Analyse the effect size of changes in CPUE of larval fish for each species in relation to flow components (categorical variable) or hydrological parameters (continuous variables). Interpretation of results will be set in the context of covariates relevant to larval fish in the Lachlan River system . This will be analysed over the 5 years to gauge the contribution of Commonwealth environmental water to native fish populations in the lower Lachlan River catchment.

- What did Commonwealth environmental water contribute to native fish species diversity in the lower Lachlan River catchment?

  Larval fish abundance (described above in 4.7.2) will be analysed using parametric univariate ANOVA using year. In the same way, changes in larval fish assemblages will be analysed using non-parametric PERMANOVA (Primer 6). Analyse the effect size of changes in CPUE of larval fish for each species in relation to flow components (categorical variable) or hydrological parameters (continuous variables). Interpretation of results will be set in the context of covariates relevant to larval fish in the Lachlan River system (see below). This will be analysed over the 5 years to gauge the contribution of Commonwealth environmental water to native fish diversity in the lower Lachlan River catchment.

4.8.3 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

4.9 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan. QA/QC activities specific to this protocol include:

- It is the responsibility of the provider to have specific fisheries and ethics permits with them while sampling.
- 10% of samples will be re-processed by a different observer. If significant differences (>10%) are present between the two observers for a given sample, processing of 10 samples by both observers at the same time will be undertaken to ensure comparative abundance and identification between observers is achieved.

4.10 Health and safety

A complete HSE plan has been included in the monitoring and evaluation plan (section appendix 3)

4.11 References

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Brooks S and Wealands S (2014) Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.3/2013 Revised Jan 2014

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Humphries P., King A.J. & Koehn J.D. (1999) Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia. Environmental Biology of Fishes, 56, 129–151.

Junk W.J., Bayley P.B. & Sparks R.E. (1989) The flood pulse concept in river-floodplain systems. Can. Sp. Pub. Fish. Aq. Sci., 106, 110–127.

King A.J., Humphries P. & Lake P.S. (2003) Fish recruitment on floodplains: the roles of patterns of flooding and life history characteristics. Can. J Fish. Aq. Sci., 60, 773–786.

King, A. J., Ward, K. A., O'Connor, P., Green, D., Tonkin, Z. and Mahoney, J. (2010) Adaptive management of an environmental watering event to enhance native fish spawning and recruitment. Fresh. Biol. 55, 17–31.

Secor, D.H., Dean, J.M., and Laban, E.H. 1992. Otolith removal and preparation for microstructural examination. *In*Otolith Microstructure Examination and Analysis. *Edited by* D.K. Stevensen and S.E. Campana. Can. Sp. Pub. Fish. Aq. Sci.,. 117. pp. 19-57.

LTIM Monitoring – Larval fish light trap data sheet (channel)

Date: ______________________ Selected Area: ______________________

Zone: ______________________ Site: ______________________

Trap #	Time set	Time retrieve	Trap #	Time set	Time retrieve	Trap #	Time set	Time retrieve

LTIM Project Monitoring – Larval fish drift/trawl data sheet (channel)

Date: ____________________________ Selected Area: ____________________________

Zone: ____________________________ Site: ____________________________

Drift/trawl #	Time start/set	Time finish/retrieve	Mean velocity	Drift/trawl #	Time start/set	Time finish/retrieve	Mean velocity

5 Waterbird Breeding

5.1 Evaluation questions

This monitoring protocol addresses the following Basin and Area evaluation questions:

- **Long-term (five-year) question:**
    - What did Commonwealth environmental water contribute to waterbird populations?

- **Short-term (one-year) and long-term (five year) questions:**
    - What did Commonwealth environmental water contribute to waterbird breeding?
    - What did Commonwealth environmental water contribute to waterbird chick fledging?
    - What did Commonwealth environmental water contribute to waterbird survival?

The process for evaluating these questions is illustrated in Figure 1, with components covered by this protocol highlighted in blue.

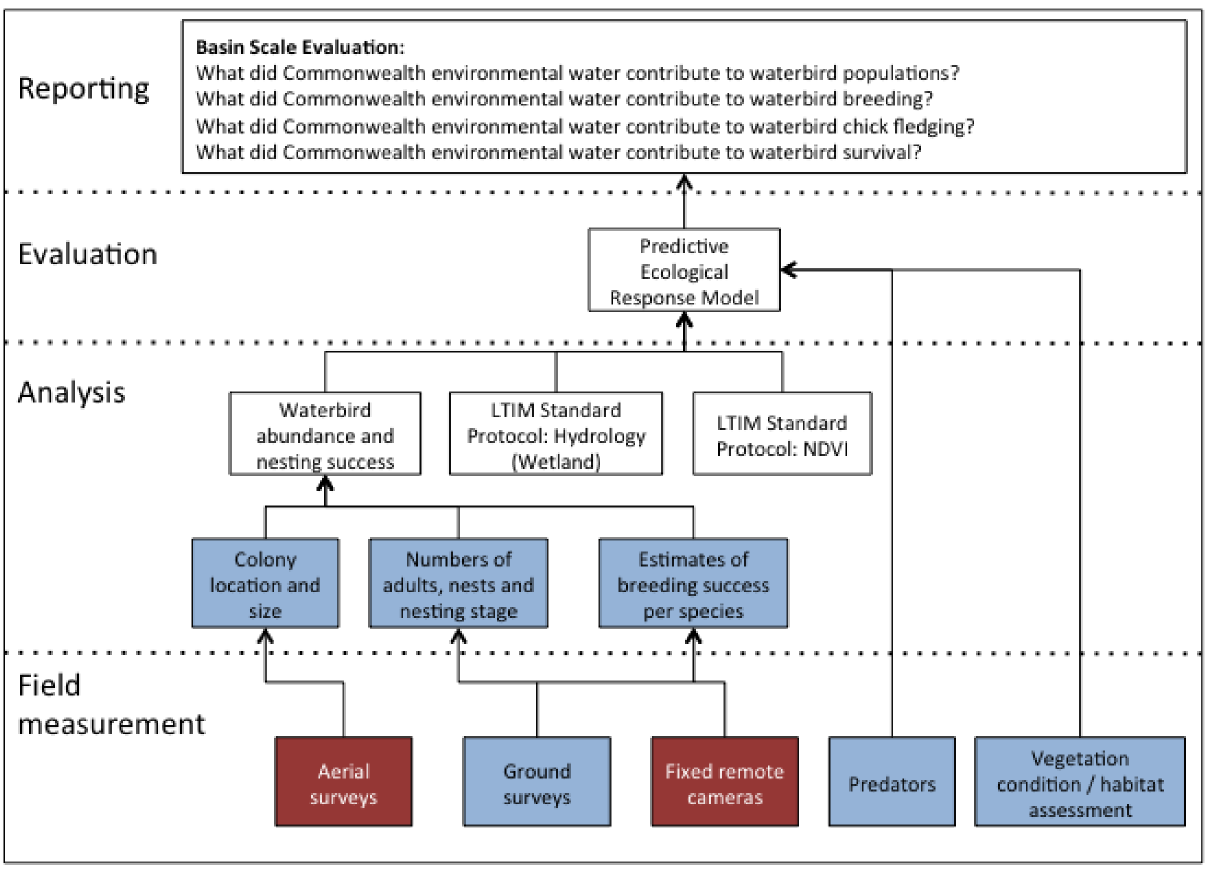

Figure 1: Schematic of key elements in LTIM Standard Protocol: Waterbird Breeding.

5.2 Relevant ecosystem types

Wetlands and floodplains.

5.3 Relevant flow types

Freshes, bankfull, overbank (infrastructure assisted)

5.4 Overview and context

This protocol describes event based monitoring to detect the effect of Commonwealth environmental water on breeding of colonial nesting waterbirds for the Lachlan River system Selected Area.

However, to inform Basin scale evaluation the methods will also meet the minimum requirements detailed below with respect to:

- Site establishment.
- Frequency of ground surveys.
- Field measures.
- Reporting of results.

The measurements for this protocol comprise:

- Waterbird breeding measures (fortnightly over the duration of a breeding event):
  - Identity of species breeding.
  - Number of adults.
  - Number of nests.
  - Number of nests in stages: eggs, early stage nestling (< 2 weeks old); later stage nestling (2 – 5 weeks old).
  - Fledgling estimate.

- Covariates
  - Vegetation type and condition.
  - Number of nests in each vegetation / habitat type.
  - Predators.

Key references used in the development of this protocol include the Living Murray (TLM) program (e.g. MDFRC 2011); *Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting* (Wetlands International 2010) and methods from the *National Waterbird Assessment* (Kingsford et al. 2012).

5.5 Complementary monitoring and data

The field measures required for the assessment of waterbird breeding are specific to this protocol. However, existing breeding information for each Selected Area should be used in the first instance to aid in identifying potential monitoring locations (sites).

Records of colonial waterbird breeding in the Lachlan Catchment are available from as early as 1899 (Table 1). Site selection for the monitoring of waterbird breeding has been based upon expert knowledge and historical data. Species such as Ibis and Spoonbills which are most responsive to flooding and changes in hydrology have been recorded breeding in large numbers (~160,000 in 1984; Marchant and Higgins 1990) in the Booligal Wetlands with a frequency of about 1:3.5 years.

Table 1: Historical records of colonial waterbird breeding in the Lachlan Catchment (source: K Brandis, 2014. National Colonial Waterbird Breeding Database)

SPECIES	YEAR BREEDING RECORDED	WETLANDS
Australian Pelican	1964, 1971, 1975, 1985, 1989, 2006	Lake Cowal, Lake Brewster, Lake Cargelligo
Glossy Ibis	1984, 1985, 1990, 1991, 2010	Booligal Swamp, Lake Gunbar, Cuba Dam, Lignum Lake
Straw-necked Ibis	1964, 1978, 1984, 1985, 1989, 1990, 1991, 1992, 1993, 1996, 1998, 2000, 2010	Lake Cowal, Murrumbidgil Swamp, Booligal Swamp, Cuba Dam, Great Cumbung Swamp, Lignum Lake
Royal Spoonbill	1978, 1984, 1985, 1990, 1991, 2006, 2010	Murrumbidgil Swamp, Lake Cowal, Booligal Swamp, Cuba Dam, Peppermint Swamp, Lake Merrimajeel, Lignum Lake, Lake Cargelligo
Great Cormorant	1964, 1990, 2006	Lake Brewster, Lake Cowal, Cuba Dam, Lake Cargelligo
Intermediate Egret	1899, 1989, 1990	Lower Gum Swamp, Peppermint Swamp
Little Egret	1989, 1990	Booligal
White-necked (Pacific) Heron	1975, 1978, 1989, 1990, 2006	Murrumbidgil Swamp, Booligal Swamp, Peppermint Swamp, Lake Cargelligo

In addition, diversity data for non-breeding birds, including cryptic species, will also be opportunistically collected during waterbird breeding surveys. See the LTIM Standard Protocol: Waterbird Diversity.

5.6 Sites, survey types and timing

5.6.1 Establishing sites

Monitoring of colonial waterbird breeding will be undertaken in the Booligal Wetlands. Historically, the Booligal Wetlands have been the site of frequent breeding events involving a diverse group of species (Table 1). The Booligal Wetlands are predominantly channelised Lignum with stands of River Red Gums, Black Box and River Cooba (Lachlan River Working Group, 2014). The methods for surveying colonial waterbird breeding that will be used the Lachlan have been chosen based upon previous studies and are specific to channelized lignum wetlands.

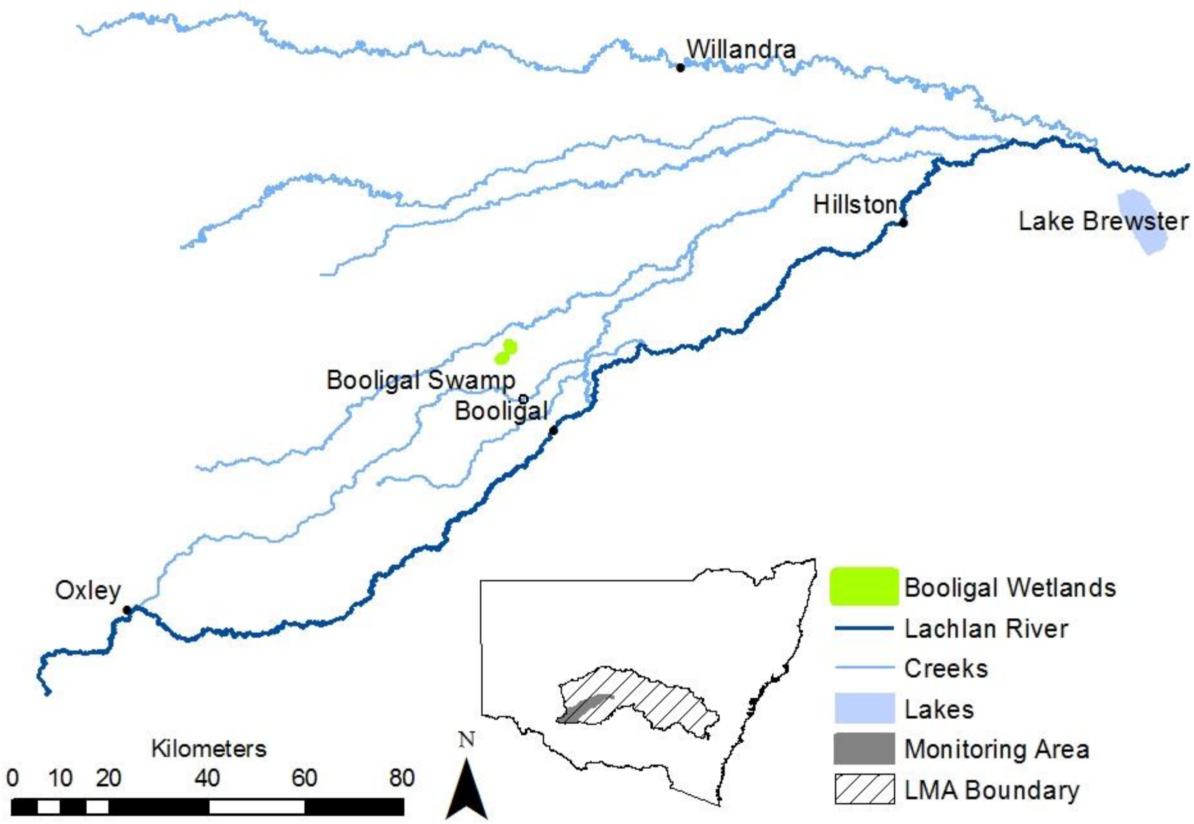

Figure 2 Map of lower Lachlan showing locaito0n of Booligal swamp (Booligal wetlands).

Table 2. Records of breeding by colonial waterbirds in the Lachlan catchment (source. Brandis, K. 2014 National Colonial Waterbird Breeding Database.)

WETLAND COMPLEX	INDIVIUDAL WETLANDS	SPECIES RECORDED BREEDING	MONITORING CATEGORY	ZONE
Booligal Wetlands	Merrowie Creek	Glossy Ibis; Straw-necked Ibis; Little Egret, Royal Spoonbill; White-necked Heron	Cat 1	4
	Booligal Swamp	Glossy Ibis; Straw-necked Ibis; Little Egret, Royal Spoonbill; White-necked Heron	Cat 1	5
	Upper Gum Swamp	Glossy Ibis; Straw-necked Ibis; Little Egret, Royal Spoonbill; White-necked Heron	Cat 1	5
	Lower Gum Swamp	Intermediate Egret	Cat 1	5
	Merrimajeel Swamp	Glossy Ibis; Straw-necked Ibis; Little Egret, Royal Spoonbill; White-necked Heron	Cat 1	5
	Murrumbidgil Swamp	Glossy Ibis; Straw-necked Ibis; Little Egret, Royal Spoonbill; White-necked Heron	Cat 1	

As this is an event based monitoring program, sampling locations and times are determined by the use or planned use of Commonwealth environmental water, and the likelihood of colonial nesting species establishing at a site that could receive Commonwealth environmental water. Species included in this protocol are:

- Ibis.
- Egrets.
- Herons.
- Cormorants, Darter.
- Pelicans.
- Spoonbills.

If breeding by colonial waterbirds is established in the Booligal Wetlands we will implement our breeding monitoring protocol. If the timing aligns with the annual October Waterbird Survey of Eastern Australia run by the Centre for Ecosystem Science, University of New South Wales, then an aerial survey of waterbird abundance and diversity will be undertaken as part of this survey. This data may then contribute to the Basin and Area scale data collection.

For Basin evaluation, data are reported on an assessment unit defined by a colony of nesting waterbirds. Colonies are defined as a single location supporting breeding birds located close enough in distance to interact socially; i.e. a clear aggregation of nesting waterbirds in the landscape. Therefore a site may comprise multiple assessment units (colonies) within a single wetland or wetland complex.

5.6.2 Survey type and timing

Event based monitoring of colonial waterbird breeding will be undertaken at the Booligal Wetlands. A combination of aerial and ground surveys will be used to identify the specific location of the colony or colonies. Aerial surveys will only be used if the timing corresponds with that of the Eastern Australia Aerial Survey of Waterbirds in October each year. Alternatively all surveys will be ground based either on foot or using small boats to get around the colonies. Ground surveys will be used to delineate the colony boundaries, determine vegetation type, waterbird species composition, total number of nests and the stages of nesting.

For the duration of breeding by Straw-necked ibis, Glossy ibis, Australian White ibis, or Royal Spoonbills a subset of marked nests will be visited fortnightly to measure reproductive success for these species. These species typically nest in colonies within the channelized lignum. These species have been shown to be sensitive to changes in water levels (Brandis et al. 2011), therefore regular monitoring at each stage of chick development (fortnightly visits) is crucial for assessing the contribution of Commonwealth Water contributed to waterbird breeding.

Surveys of tree nesting species such as Cormorants, Darters and Egrets will be timed to co-incide with development stages. Due to the difficulties associated with accessing nests in trees data collected will include nest activity i.e. adults on nest/eggs, presence of chicks and stage of chick development. Obtaining accurate chick counts may not be feasible but records of nesting and nest success will be collected. These species do not appear to be as sensitive to changes in water depth.

Estimates of total nests successfully fledged will be extrapolated from the monitored sub-set, assuming it is not feasible to monitor all nests in the colony.

To minimise disturbance to the colony All ground surveys of the colonies will be limited to two hour periods, either in early morning (6-11 am) or late afternoon (3-8 pm) to avoid causing heat stress to nesting birds and their offspring. This approach has worked effectively in previous studies of large waterbird colonies in the Lowbidgee which recorded high levels of nesting success (Brandis et al. 2011b)

5.7 Aerial surveys (reconnaissance, delineating colony boundaries)

5.7.1 Reconnaissance flights

Aerial surveys can be undertaken to assist in identification of breeding occurrences and breeding success during watering or flooding events. In the first instance, these will be reconnaissance surveys and rely heavily on information compiled regarding nesting locations within the Selected Area prior to the first flight, under the premise that colonial nesting waterbirds are generally faithful to previously used sites. If reconnaissance flights capture early breeding stages, consideration should be given to a second aerial survey 4 – 6 weeks later to identify potential additional colonies.

Colony boundaries will be delineated during the first ground survey for waterbird breeding, and checked during subsequent survey trips. This will enable accurate mapping of boundaries, the ability to adjust boundaries as the colony progresses and provide a spatial template within which we can randomly select nests for monitoring.

5.7.2 Aerial counting techniques

Prior to deploying to the field, flight paths must be established. These should be designed to most effectively capture all major breeding colonies (> 150 nests) within a site. There are a variety of techniques, dependent on the size and shape of the site and the distribution of colonies (Figure 3).

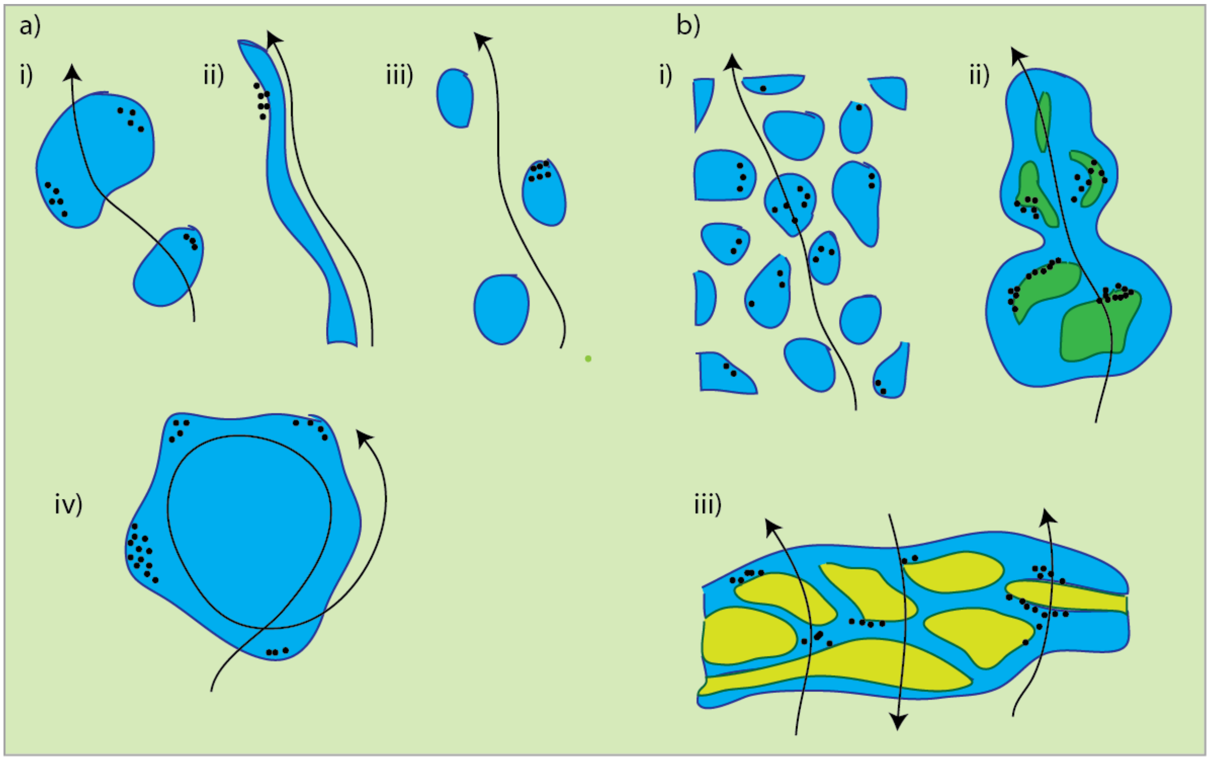

Figure 3: Illustration of aerial counting options for assessing nesting colonies (modified from Braithwaite et al. 1986). a) total counts where an assessment is obtained for the total nesting colonies (indicated by the dots) on, for example i) discrete waterbodies of less than about 50 ha; ii) a river channel; iii) small impoundment; iv) large lake or impoundment with nesting predominantly along shorelines. b). Transect counts with counting limited to nests within a band at ground level of 100m either side of the aircraft; i) on a landscape dotted with wetlands, each usually of less than 1 ha of surface water; ii) a floodplain with inter-dispersed water and land; iii) a braided river channel.

This protocol requires a minimum of two observers (in addition to the pilot) in the plane. The observers on each side of the plane estimate numbers of waterbirds on their side of the aircraft, recording the information on small tape recorders for later transcription (Kingsford et al. 2012). Care must be taken to ensure that nesting birds are not distressed leading to abandonment of nests.

The location (as a point or a polygon) of each colony must be recorded together with:

- Species composition.
- Estimates of the number of active nests.
- Breeding stage – i.e. eggs/chicks/ runners present?
- Colony boundary.
- Nesting vegetation type.

Observers (two for each flight) should independently identify and record species abundances and numbers of nests and broods. Where no birds, nests or broods are observed, a zero count is to be recorded (Kingsford et al. 2012).

Where the species of waterbird cannot be determined with confidence, record as categories: spoonbills, egrets, cormorants (‘pied’, or ‘black’), ibis, and ‘white birds’ (egrets and spoonbills), and be as specific as possible, e.g. ‘unidentified breeding egrets (40 nests), seemed large’ (which implies they were probably Eastern Great Egret).

5.8 On-ground surveys

5.8.1 Equipment: Identification guides

A good field guide must be taken on all field trips. Most waterbirds are quite conspicuous and, with notable exceptions, straightforward to identify in good conditions if care is taken. The most frequently encountered problem is identifying birds at long range in the extensive and flat terrain preferred by most congregatory waterbirds. This is when the additional power of a telescope is needed, but at some sites, a certain proportion of the birds will often remain unidentified because they are too distant to see properly (Wetlands International 2010), and because some colonial nesting species tend to ‘hide’ their nests in screening foliage, e.g. Nankeen Night Heron and Glossy Ibis.

The recommended field guides are: Simpson and Day (2010 - 8th edition), Slater et al. (2009), Morecombe (2003)and Pizzey and Knight (2007). We will use Simpson and Day (2010) and professional knowledge and experience in the identification of waterbirds.

5.8.2 Equipment: Field survey

- Compass.
- Camera (35 mm format camera - dSLR - with 50–150 mm zoom lens, automatic exposure).
- Watch.
- Maps of Selected Area including assessment site information.
- 2B pencils, sharpener and eraser.
- Hand held tally counter.
- Simpson and Day (2010) Field Guide to the Birds of Australia.
- Binoculars or Telescope (for on-ground surveys/validation – see below).
- Field note book or datasheets and/or field computer.
- Appropriate field clothing/safety gear – first aid kit, hat, sunblock etc.

5.8.3 Breeding surveys

Once breeding colonies have been identified at Booligal Swamp and monitoring has been requested, monitoring will occur every two weeks to obtain a measure of overall breeding success. Surveys will be undertaken either by small boat or foot. If the timing is suitable (see above) aerial surveys may be done by in conjunction with the Eastern Australia Aerial Waterbird Survey (UNSW). Surveys of lignum nesting species (Ibis, Spoonbills) will continue fortnightly until chicks have fledged and it is no longer possible to associate chicks with specific nests (Brandis et al. 2011). Tree nesting species (Cormorant, Darters, Egrets, Herons) will be surveyed in conjunction with chick development stages (see Section 1.6.2).

Depending upon the size of the colony or colonies that establish in the Booligal Wetlands, either a complete count will be undertaken or a subset will be surveyed and extrapolated to estimate the total abundance and reproductive success. Historical records of breeding at the Booligal Swamps range from colony sizes of 200 -160,000 birds (K Brandis, 2014).

Intensive waterbird breeding monitoring using the Category 1 standard methods will be restricted to previously used lignum wetlands in the Booligal Wetlands. Field measures specified in the LTIM Standard Protocol: Waterbird Breeding (Hale et al. 2014) include:

- Position of the colony (as a polygon).
- Number of nests of each colonial nesting waterbird species in each vegetation species in the following categories:
    - River red gum.
    - Black box.
    - River cooba.
    - Paperbark.
    - Other tree.
    - Lignum.
    - Other shrub.
    - Tall emergent aquatic (reeds, Phragmites, Typha, etc.)
    - Aquatic sedge/grass/forb.
    - Dead trees.
- Number of nests in breeding stage categories:
    - Eggs.
    - Early stage nestling (< two weeks old).
    - Late stage nestling (2 – 5 weeks old, whether in nests or crèched outside).
- Number of adults present in a colony.
- Dominant vegetation type and condition score (at the commencement of breeding - first survey only - see 1.8.5 below).
- Observations of predators.

These data will be collected through repeat ground surveys conducted by two field staff.

As straw-necked ibis are particularly sensitive to sudden changes in water level real-time information on the status of nesting birds and water levels is needed during breeding events to support adaptive management of environmental water (Brandis et al 2011a; Brandis et al. 2011b).

Although the standard methods request monthly ground surveys, this survey intensity will not provide adequate information to address the short and long-term evaluation questions for waterbird breeding responses in the Lachlan. The breeding period for straw-necked ibis, from laying to chicks leaving their nests and taking short flights (flapper stage), is around 45-53 days (*Brandis et al, 2011a).* If monitoring is scheduled monthly and the first survey is at egg stage, the second survey a month later will be at a development stage where chicks are off the nests and success rates for individual nests cannot be measured. To ensure that Basin and Selected Area objectives can be evaluated, we plan to undertake ground surveys at fortnightly intervals, with the first survey taking place after eggs are laid, thus ensuring accurate estimates of the number of nests successfully fledged and mean number of chicks per nest for a subsample of nests. The three month breeding period is assumed to be a large enough window to cover the period from birds pairing up, laying and incubating eggs, rearing chicks and cover the period of post-fledging dependency in the three ibis species (*Brandis et al, 2011a*). *This approach* *worked effectively during monitoring undertaken by UNSW in the Lowbidgee floodplain in 2010-11 (Brandis et al. 2011b).*

During the first colony survey, as close as possible to colony establishment, the boundary of the colony will be mapped using a differential GPS mounted on a boat to provide a framework for random sampling of a subset of nesting sites. Where a nesting site is defined as a group of nests on a clump of lignum separated from another clump of lignum by open water or non-flattened vegetation. A representative sub-set of nests will be monitored for the three month breeding period. All nests will be recorded with GPS and marked using coloured tape and given a unique identifier as per methods developed by Brandis et al. (2011a). Selected nests will be monitored throughout the breeding period from *egg to fledgling development stages* through repeat field surveys by trained observers. The deployment of fixed cameras (camera traps) for monitoring breeding success are included as an optional method for measuring reproductive success in the Category 1 standard methods. However, repeat visits by field personnel provide a number of advantages over the fixed cameras including eliminating the potential risk of camera failure; allowing for information to be collected on a larger number of nests; the presence of new starters and changes to the colony boundary. Brandis et al. (in press) demonstrated in a comparison of breeding success by repeat visits to straw-necked nests by investigators with the results from analysing images from camera traps that the presence of investigators did not impact breeding success or rates of predation.

In addition to reproductive success data hydrological indicators relevant to waterbird breeding will be measured in the Category 1 sites. These include continuous measurement of water depth (as per ***LTIM Standard Protocol: Hydrology (Wetland)***) and replicate spot measurements of water quality (dissolved oxygen, turbidity, conductivity, and temperature) at each nesting site.

5.8.4 Covariates

Vegetation type and condition

The dominant vegetation type of the colony to be identified using the interim ANAE typology developed for the MDB (see (Brooks et al. 2013), and includes the following:

- Open water (no vegetation).
- River red gum forest.
- River red gum woodland.
- Black box forest.
- Black box woodland.
- Coolibah.
- Standing dead trees.
- River cooba.
- Paperbark.
- Lignum.
- Other shrub.
- Saltmarsh.
- Tall emergent aquatic (reeds, phragmites, Typha, cumbungi etc).
- Aquatic sedge/grass/forb.
- Freshwater grasses.
- Freshwater forb.

Each breeding colony will have the corresponding dominant vegetation class and condition score recorded during the first nesting survey. This is a qualitative ranking and is summarised in Table 3

Table 3: Vegetation condition ranks for colonial nesting locations. Use only for live vegetation, not for species which prefer to nest in dead trees.

RANK	DESCRIPTION
Good	**Vegetation structure in dominant layer healthy, good cover (>70%) with virtually no weeds evident. No obvious indication of altered processes which may affect vegetation condition.**
Moderate	**50-70% cover in dominant vegetation layer, some areas of dead branches present, or limited evidence of disease (i.e. die back), shrub layer more sparse, less connected and somewhat patchy. Some evidence of weeds and or indication of altered processes**
Poor	**Significant loss, <30%, of cover in dominant vegetation type, considerable amount of weeds, large number of dead branches, crown highly patchy. Stands of vegetation patchy and disconnected, considerable or obvious evidence of altered processes (i.e. drowned stumps).**

Predators and Reasons for Nest Desertion/Failure

Known predators at colonies are humans, dingos (wild dogs), foxes, cats, Australian raven, swamp harrier and wedge-tailed eagle. Any evidence or observation of nest contents or adult bird predation by these or other species should be recorded. Also, mass nest desertion can occur if water levels drop suddenly around the nests or if the ground below the nest dries out (or if islands become connected to the main shore, for ground-nesting species), and these events and the likely triggers for desertion/nesting abandonment should be recorded.

5.9 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC requirements specific to this protocol, which should be captured in the Quality plan are described briefly below.

All Waterbird Breeding assessments within a Selected Area, where possible, should be undertaken by the same experienced observers to maintain consistency over time. All observers must undergo training prior to undertaking monitoring surveys, including calibration against experienced observers to ensure standardisation of measurements. Training and calibration procedures must be documented in the MEP and relevant records maintained.

Identification of difficult to see species will often differ between observers. To minimise the variance associated with different observers, a minimum of two staff are assigned to Waterbird Breeding assessments, particularly when aerial methods are used. Where there are significant differences in original observer scores, observers will discuss their rationale and where appropriate adjust scores to mutually agreed values. For aerial surveys this should be done immediately after flights to get agreement on species identifications.

5.10 Data analysis and reporting

5.10.1 Waterbird breeding data

The variables that will be reported for each colony for each survey are:

- Location (polygon of the colony).
- ANAE Wetlandid.
- Size of wetland surrounding colony (ha).
- Number of nests of each species per vegetation type / structural habitat.
- Number of nests in each nesting stage for each species.
- Estimate of number of nests successfully fledged for each species (i.e. one or more chicks fledged per nest) since last survey.
- Estimate of the mean number of chicks thought to have fledged per successful nest for each species, where possible (for nests fledged since last survey).
- Number of adults of each species.
- Vegetation type, condition scores.
- Observations of colony level disturbance (e.g. predators, other disturbance agents, or probable causes of colony desertion).

5.11 EVALUATION

Basin-scale evaluation questions for waterbirds see Fig. 3

Long-term (five-year) question:

- What did Commonwealth environmental water contribute to waterbird populations (Cat 1 and Cat 2)?
- What did Commonwealth environmental water contribute to waterbird species diversity (Cat 2)?

Short-term (one-year) and long-term (five year) questions:

- What did Commonwealth environmental water contribute to waterbird breeding?
- What did Commonwealth environmental water contribute to waterbird chick fledging?
- What did Commonwealth environmental water contribute to waterbird survival?

Selected Area evaluation questions for waterbirds:

- What did Commonwealth environmental water contribute to waterbird populations and waterbird species diversity at key wetlands in the Lachlan Catchment?

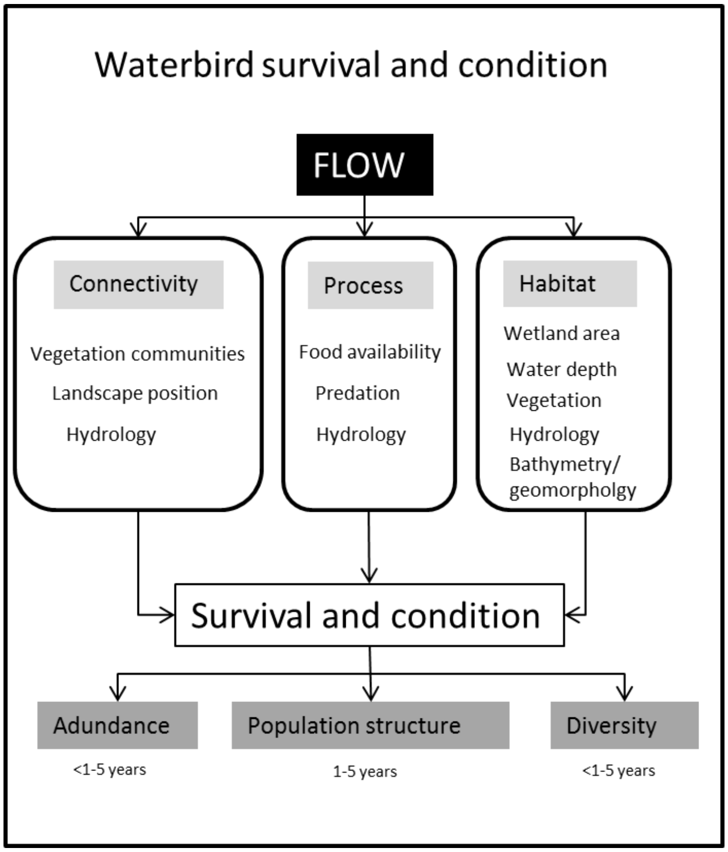

Figure 4: Waterbird survival and condition conceptual diagram.

Expected outcomes:

- Local increases in waterbird abundance in response to Commonwealth environmental watering (Fig.3).
- Local increases in waterbird diversity in response to Commonwealth environmental watering (Fig. 3).
- Local increases in waterbird species of conservation significance (i.e. threatened species, JAMBA, CAMBA and ROKAMBA species) in response to Commonwealth environmental watering.

What did Commonwealth environmental water contribute to **waterbird breeding**? See Fig 4

Expected outcomes:

- Local increases in non-colonial waterbird breeding activity (total number of breeding species and total number of broods) following Commonwealth environmental watering.
- Initiation of nesting activity in straw-necked ibis, glossy ibis and royal spoonbill colonies as a result of watering actions targeting known colony sites.
- Maintenance of stable water levels in colony sites using Commonwealth environmental water to support successful breeding of colonial waterbird species.
- Maintenance of water levels in feeding habitats using Commonwealth environmental water to support successful breeding and recruitment of colonial waterbird species.

What did Commonwealth environmental water contribute to **waterbird chick fledging and waterbird survival**?

Expected outcomes

- Maintenance of stable water levels in colony sites using Commonwealth environmental water to ensure successful fledging of chicks.
- Maintenance of water levels in feeding habitats using Commonwealth environmental water to support successful breeding and recruitment of colonial and non-colonial waterbird species.

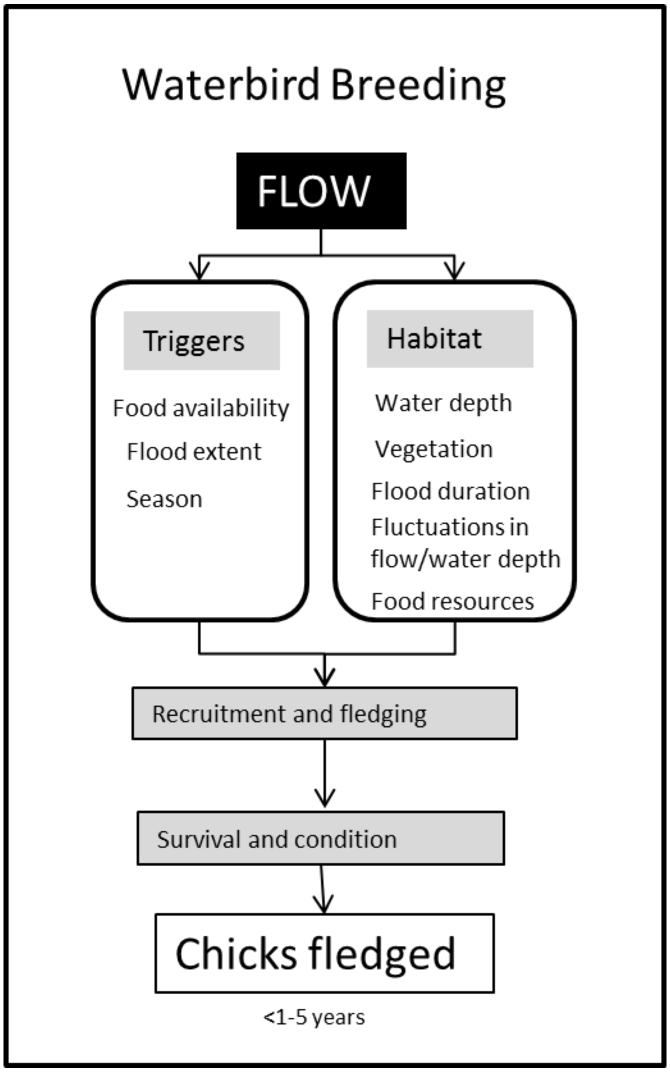

Figure 5: Waterbird breeding and conceptual diagram. Evaluation – area scale evaluation, how we will use these data to evaluate area scale questions.

5.12 Data analyses

5.12.1 *Breeding data*

The following metrics will be calculated for each colony:

- Estimates of total abundance by species breeding at each colony site.
- Identify phenology of breeding by tracking egg and chick development using survey data.
- Calculate mean clutch size for each species in each colony.
- Extrapolate results where reasonable to obtain and estimate for the entire colony.

These data will then contribute to answering the area and basin scale questions.

5.12.2 Reproductive success

Calculated as the hatching rates for each species in each colony. Data will be categorised into three groups: egg, chick and nest. Success will be determined for periods between surveys. For example, if at the end of each time period between surveys the nest contained eggs or chicks it was scored 1, if neither then 0. Data will be further analysed based upon date of first survey of that site. All survey sites will be initially sampled at egg stage. Date of first survey will be used as a surrogate for laying period in data analyses. Analyses were grouped based upon date of first survey of that site.

5.12.3 Breeding models

Generalised additive models (GAM) will be developed to understand the relationships between variables for breeding of ibis and spoonbills. Several models will be developed including the relationship between between clutch sizes, lay date (relative to the delivery of water) and nest site size and hydrological variables including water depth.

5.12.4 Colony conditions

We will also monitor water depth and water quality (pH, conductivity, dissolved oxygen, turbidity and temperature) at each colony at each survey time.

5.12.5 Analysis Software

All statistical modelling will be undertaken using RStudio Version 0.98.501 and spatial analyses will be done using ArcGIS Version10.

5.13 Waterbird Diversity

Multivariate analyses (PRIMER 2002) will be used to investigate differences in waterbird species assemblages within (before and after Commonwealth environmental watering) and among water years. Waterbird species will be separated into functional feeding groups as per Hale et al. (2013) to investigate differences in waterbird assemblages among wetlands. Waterbird data (maximum counts averaged across survey periods) will be fourth root transformed to control for multiple zeros and large values present in the data sets (Quinn and Keough 2002). The transformed abundance data will be examined using the Bray-Curtis measure of similarity (Bray and Curtis 1957) and subjected to non-metric Multi-Dimensional Scaling (nMDS) to demonstrate patterns in waterbird assemblages in the wetlands. One-way Analysis of Similarity tests (ANOSIM) will be used to detect significant differences in species assemblages among wetlands and water years. For significant relationships, the contribution made by particular species to identified differences at the sites was determined by analysis of Similarity Percentages (SIMPER) (Clarke and Warwick 2001).

5.14 Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the colony.

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

5.15 Health and safety

For details on health and safety please refer to the Workplace Health and Safety Plan for the Lower Lachlan river system Selected Area (WHS 202.1) in appendix 3.

5.16 References

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Supplement 5A: Waterbird species and codes

Census of Australian Vertebrate Species (CVAS) codes sourced from
http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/afd/search/biocode

TERM	DEFINITION
Colonial breeding waterbirds (based on Jaensch 2002)	***Target species*** **CAVS: 0106: Australian pelican *Pelecanus conspicillatus*** **CAVS: 0179: Australian white ibis *Threskiornis molucca*** **CAVS: 0203: Black swan *Cygnus atratus*** **CAVS: 0977: Cattle Egret *Ardea ibis*** **CAVS 8731: Darter *Anhinga novaehollandiae**** **CAVS 8712: Eastern Great Egret *Ardea modesta*** **CAVS 0187: Glossy ibis *Plegadis falcinellus*** **CAVS 0096: Great cormorant *Phalacrocorax carbo*** **CAVS 0186: Intermediate Egret *Ardea intermedia*** **CAVS 0097: Little Black Cormorant *Phalacrocorax sulcirostris*** **CAVS 0185: Little Egret *Egretta garzetta*** **CAVS 0100: Little Pied Cormorant *Microcarbo melanoleucos*** **CAVS 0192: Nankeen Night Heron *Nycticorax caledonicus*** **CAVS 0099: Pied cormorant *Phalacrocorax varius*** **CAVS 0181: Royal spoonbill *Platalea regia*** **CAVS 0180: Straw-necked ibis *Threskiornis spinicollis*** **CAVS 0069: White-necked heron *Ardea pacifica**** **CAVS 0182: Yellow-billed spoonbill *Platalea flavipes**** **[* NB these species often nest 'singly' away from colonies]** ***Other non-target colonial species*** **CAVS 0060: Great crested grebe *Podiceps cristatus*** **CAVS 0062: Hoary-headed grebe *Poliocephalus poliocephalus*** **CAVS 0059: Eurasian coot *Fulica atra*** **CAVS 0146: Black-winged stilt *Himantopus himantopus*** **CAVS 0147: Banded stilt *Cladorhynchus leucocephalus*** **CAVS 0148: Red-necked avocet *Recurvirostra novaehollandiae*** **CAVS 0125: Silver gull *Chroicocephalus novaehollandiae*** **CAVS 0111: Gull-billed term *Gelochelidon nilotica*** **CAVS 0112: Caspian tern *Hydroprogne caspia*** **CAVS 0110: Whiskered tern *Chlidonias hybrida***
Waterbirds (from DSE 2009)	**Anatidae (swans, geese, ducks)** **Podicipedidae (grebes)** **Anhingidae (darters)** **Phalacrocoracidae (cormorants)** **Pelecanidae (pelicans)** **Ardeidae (herons, egrets, night herons, bitterns)** **Threskiornithidae (ibises, spoonbills)** **Accipitridae (hawks, harriers) not included in aerial surveys** **Rallidae (crakes, rails, gallinules)** **Scolopacidae (snipe, godwits, curlews, sandpipers, stints, phalaropes)** **Recurvirostridae (stilts, avocets)** **Charadriidae (plovers, dotterels, lapwings)** **Laridae (gulls, terns)** **Alcedinidae (azure kingfisher), and** **Slyviidae (old world warblers)**

Supplement 5B: Example waterbird breeding field sheet

<table>
<tr><td colspan="6">WATERBIRD BREEDING FIELD SHEET: Page ---------------- of ------------------</td></tr>
<tr><td>Site name</td><td colspan="2"></td><td>Total site wetland area (ha)</td><td colspan="2"></td></tr>
<tr><td>Date:</td><td colspan="2"></td><td>Name of Recorder:</td><td colspan="2"></td></tr>
<tr><td>Survey start time:</td><td colspan="2"></td><td>Survey end time:</td><td colspan="2"></td></tr>
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<tr><td>Observer 1:</td><td colspan="2"></td><td>Observer 2:</td><td colspan="2"></td></tr>
<tr><td>Approach type:</td><td colspan="3">A. Aerial observer
B. On-ground observer</td><td colspan="2">% of wetland of site/wetland
wet………………………..%</td></tr>
<tr><td>Count method:</td><td colspan="2">1. Total count
2. Proportion</td><td></td><td colspan="2">Proportion surveyed:……….%</td></tr>
<tr><td colspan="6">GPS co-ordinates and/or tracks for site/sub-sampled area boundaries and survey route/location
Attach a mud map as required:</td></tr>
<tr><td colspan="6">Survey area (ha):</td></tr>
<tr><td colspan="6">Notes: e.g. number of colonies, mixed species colonies, etc</td></tr>
</table>

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<tr><th colspan="4">WATERBIRD BREEDING FIELD SHEET: Page ---------------- of ------------------</th></tr>
<tr><td>Site name</td><td></td><td>Total site wetland area (ha)</td><td></td></tr>
<tr><td>Date:</td><td></td><td>Name of Recorder:</td><td></td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Key: Vegetation codes (dominant vegetation used in nesting):

River red gum forest = RRGf; River red gum woodland = RRGw; Black box forest = BBf; Black box woodland = BBw; Coolibah = Cool; River cooba = RCb; Paperbark = Pb; Lignum = Lig; Other shrub = OS; Saltmarsh = SM; Tall emergent aquatic (reeds, phragmites, Typha, cumbungi etc) = TEA; Aquatic sedge/grass/forb = AqSGF; Freshwater grasses = FGr; Freshwater forb = FFb

Dominant vegetation code and area of colony (% and ha):</td></tr>
<tr><td colspan="4">Vegetation condition (first nesting survey only):

Assign ranking of Good, Moderate or Poor to each dominant vegetation type in which colonial nesting is occurring.

Comments:</td></tr>
</table>

Species	Number of nests	Number of adults	Number of live young per successful nest	Number of fledging per nest	Vegetation condition rank

WATERBIRD BREEDING FIELD SHEET: Page ---------------- of ------------------					
Site name			**Total site wetland area (ha)**		
Date:			**Name of Recorder:**		

6 Stream metabolism

6.1 Evaluation questions

This monitoring protocol addresses the following Basin and Area evaluation questions:

- **Short-term (one-year) and long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to patterns and rates of decomposition?
  - What did Commonwealth environmental contribute to patterns and rates of primary productivity?

The process for evaluating these questions is illustrated in Figure 1 with components covered by this protocol highlighted in blue.

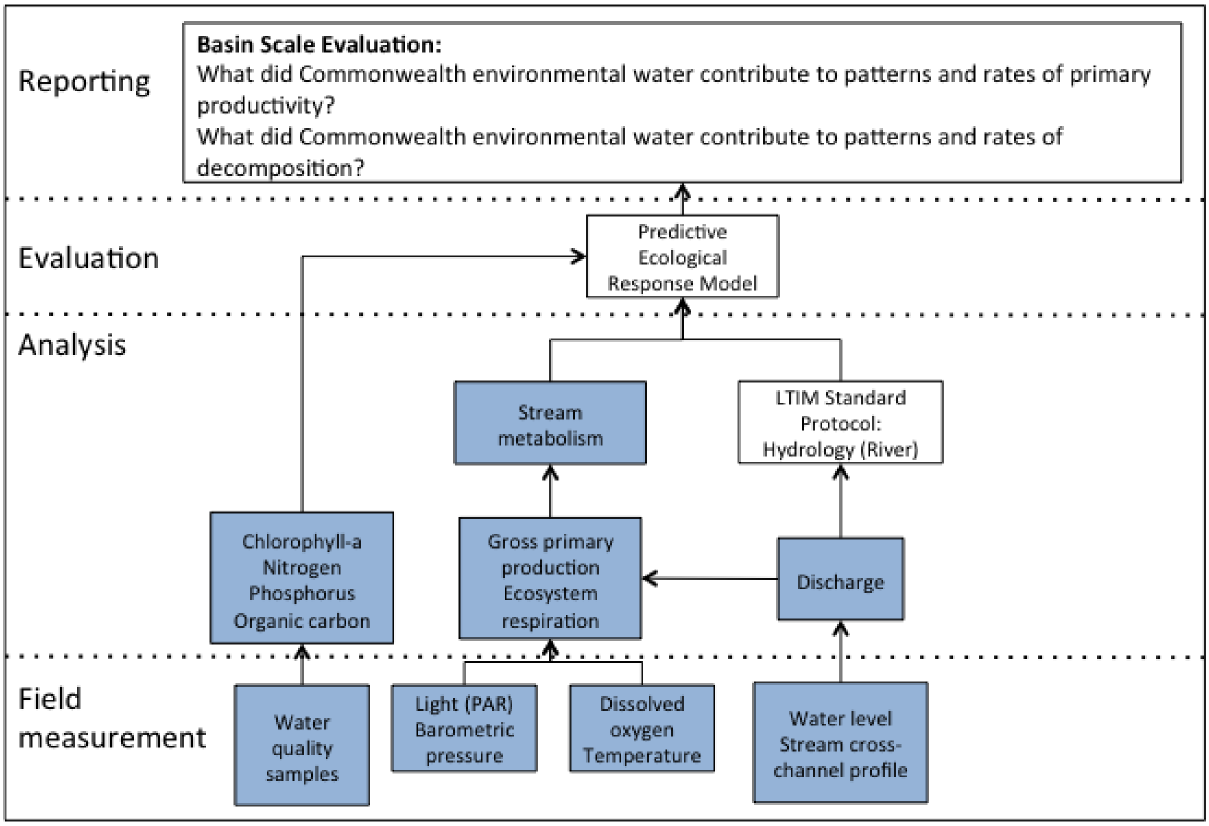

Figure 1: Schematic of key elements of the LTIM Standard Protocol: Stream metabolism.

6.2 Relevant ecosystem types

River.

6.3 Relevant flow types

Fresh, bankfull, overbank.

6.4 Overview and context

Under the LTIM program, stream metabolism is measured for two purposes:

1. To inform the Basin-scale quantitative evaluation of fish responses to Commonwealth environmental water (see LTIM Standard Protocol: Fish (River)).
2. To detect changes in primary productivity and decomposition in river in response to Commonwealth environmental water.

This protocol uses the replicate single station open water method and comprises:

- Water level and stream characteristics (which may be available from an established gauging station).
- Discrete water quality samples (chlorophyll-a, total nitrogen, NOx, NH_4, total phosphorus, PO_4, dissolved organic carbon).
- *In situ* logging within the water column (dissolved oxygen, temperature) at every stream metabolism site.
- Logging of photosynthetically active radiation (PAR) and barometric pressure in a nearby terrestrial location, with the potential for a single PAR / barometric pressure station to capture all stream metabolism sites within 100 km.

This protocol is based on the single station open water stream metabolism method as detailed in Grace, M. and Imberger, S. (2006) Stream Metabolism: Performing and Interpreting Measurements, Monash University (available to read online at: http://www.yumpu.com/en/document/view/5585275/stream-metabolism-faculty-of-science-monash-university).

6.5 Complementary monitoring and data

Hydrological measures of stream discharge will be used to inform the interpretation of stream metabolism. Details of the methods used to collect hydrological information are included within the River Hydrology standard operating procedure.

6.6 Monitoring locations

6.6.1 Protocol

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy for stream metabolism is as follows:

Selected Area → Zone → Site

A ‘zone’ is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

Zones have been matched to the fish monitoring sites, as these sites are known to have good access and will be visited monthly:

The Lower Lachlan river system Selected Area can be partitioned into five spatially, geomorphologically and hydrologically distinct river channel zones at a broad landscape scale (Figure 2).

Zone 1	Lachlan River channel between Brewster Weir and Booligal.
Zone 2	Lachlan River channel between Booligal and Corrong.
Zone 3	Lachlan River channel between Corrong and its terminus in the Great Cumbung Swamp
Zone 4	Merrowie Creek
Zone 5	Torringany, Box, Merrimajeel and Muggabah Creek system.

The monitoring of stream metabolism has been mandated for sites at which fish monitoring occurs. We have selected Zone 1 as the zone for the monitoring of Basin-scale indicators as it is likely to receive Commonwealth Environmental Water during every year of the program.

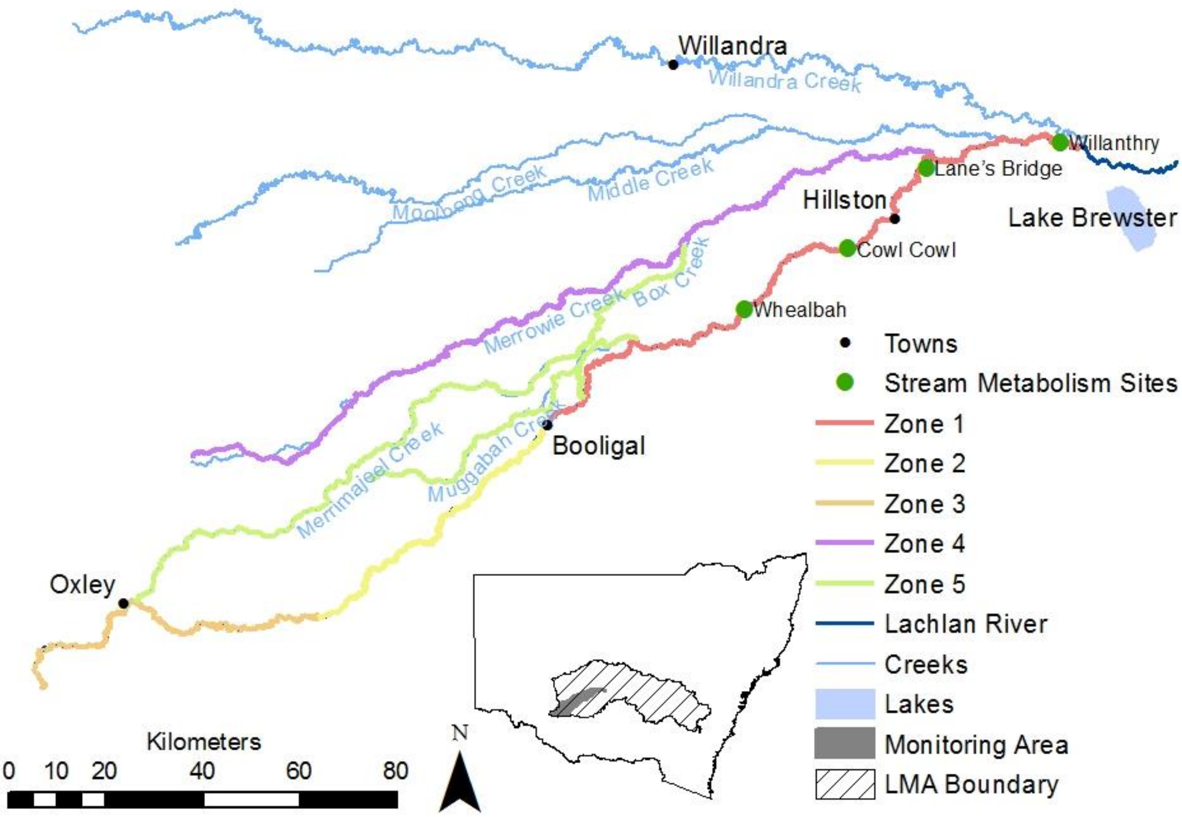

Figure 2. Map of zones and sampling sites.

6.6.2 Sites placement within zones.

A site is the unit of assessment nested within a zone and in this instance will be a section of river.

Stream metabolism is required to inform the Basin-scale quantitative evaluation of fish responses to Commonwealth environmental water (see LTIM Standard Protocol: Fish (River)). The sample design for the fish protocol involves a minimum of a single zone with ten sites within a zone distributed over < 100 km of single channel. It is mandated that stream metabolism measurements are located at river sites used for fish monitoring. This may also provide adequate data to assess changes in stream metabolism as a result of Commonwealth environmental water and will be used to provide an evaluation of the Zone response to watering.

Four sites have therefore been selected for Stream metabolism monitoring. These are shown in Figure 2 and are:

- Willanthry
- Lane’s Bridge
- Cowl Cowl and
- Whealbah

With the mobility of fish and the extent over which the metabolism measures integrate, we have coverage over the extent of the 10 fish sites.

6.6.3 Placement of stations

Stations for stream metabolism measures from the water column will be located within a site as follows:

- Open water, mid stream, with sufficient depth that the sensors will not be exposed, nor touch the sediment.
- Well mixed (non-stratified) water column to ensure sample is representative of reach.
- Constant flow (small streams with rocky / riffle or waterfall areas are not appropriate).
- No interference from tributaries, drains or significant groundwater inflows. For the Lachlan system we have identified sites with no major tributary for at least 4km upstream of the logger location.
- Safe to access.
- Protection from vandalism (sampling locations on private property, with landholders permission are preferable).
- Probes should not be located within a macrophyte bed.

Measures of light (PAR) and barometric pressure are to be collected from a nearby terrestrial location (e.g. a fence post within an adjacent property). These measures are to capture the ambient conditions of the surrounding landscape and so should be located in an open area, not impacted by tree canopy or shading. A single station for the measurement of light and barometric pressure may be sufficient to cover the requirements for multiple stream metabolism (water column) sites within a 100 km radius, providing there are no significant differences in ambient conditions (e.g. vastly different altitudes). The Lachlan system is low gradient and for the study reaches chosen, there are no major inflows in the area immediately (within 5km) upstream. As a consequence single station methods are appropriate for measuring metabolism responses to environmental flows.

One important consideration is ‘how far upstream is integrated by a probe in a day?’ A reasonable estimate is provided by 3 v/K, where v is the mean water velocity in m/Day and K is the reaeration coefficient in /Day. As an example, a mean water velocity of 5 cm/s (0.05 m/s) equates to 4.3 km/Day. A typical value for K in a slow flowing river might be 5 /Day. Hence the distance upstream integrated by the probe will be 3 x 4.3/5 = 2.6 km. Both mean water velocity and K are dependent upon discharge, so the upstream distance integrated will change in a non-linear fashion with discharge. Flow at the study sites in the Lachlan system which have been collected as a part of previous work are in the range of 4-8 cm/s , meaning that the distance upstream integrated by each probe will be 2-4km. We have chosen sites where there are no significant inflows or other features (such as significant backwater areas) for >4km upstream.

6.6.4 Timing

Stream metabolism measures will be collected continuously over the period for which water is flowing within the selected river site. Loggers will be maintained continuously in the Lachlan system at all sites, with downloads of data occurring monthly, associated with recalibration of the loggers.

6.7 Flow and stream characteristics

River discharge (ML/day) and mean velocity (m/s) are required to interpret the stream metabolism measures and inform Basin evaluation. The monitoring locations are located such that a permanent stream gauging station adequately captures discharge (refer to Hydrology (River) methods), these data can be accessed and used to inform the modelling.

Mean velocity is calculated as discharge / cross sectional-area. In some circumstances, this may be able to be derived from the nearest gauge (supplemented with some site measures of cross sectional area and water level)

However, if an existing stream gauge does not adequately capture discharge and / or velocity, then a cross-section survey and water level logger will need to be installed (see LTIM Standard Method: Hydrology (River)).

6.8 Water quality samples

Water quality variables are important for interpreting the stream metabolism results and are an input to the ecological response model for Basin scale evaluation. Water samples are collected for: chlorophyll-a, total nitrogen (TN), total phosphorus (TP), nitrate-nitrite (NOx), ammonium (NH_4), filterable reactive phosphorus (FRP) and dissolved organic carbon (DOC). In-situ spot measurements are taken for pH, turbidity and electrical conductivity (EC). As a minimum, these water quality samples and measures are collected when sensors are deployed and at each time the station is serviced and calibrated (≤ 6 weekly intervals). Further samples can be collected during site visits for other purposes.

6.8.1 Equipment

- Nalgene acid-washed 250mL containers.
- Pre-combusted amber-glass jars (DOC).
- 32% HCl (for DOC samples).
- 0.2 μm filters (Advantec; Dublin, USA), filter stage and hand vacuum pump for dissolved nutrients and carbon.

- 47 mm glass fibre (Watman GFC) filters, filter stage and hand vacuum for chlorophyll-a.
- Horiba U-10 water quality meter for pH, turbidity and electrical conductivity measurements.
- Deionised water for sample blanks.
- Eskies and ice for sample preservation and storage.
- Datasheets and/or field computer.
- Chain of custody sheets.
- Copy of this protocol.

6.8.2 Protocol

- Samples and measurements will be collected mid stream and mid depth on a monthly basis.
- The sampler will stand downstream of sample collection point.
- Sampling will avoid surface films, but if present, a description will be entered onto the field sheet.
- For dissolved nutrients (NOx, NH_4, FRP) ,) duplicate 250mL water samples will be filtered on site through 0.2 µm filters into Nalgene bottles and then stored on ice for return to the laboratory. Samples will be frozen within 12 hours of collection and analysed within 14 days. Grab samples were collected seasonally for one year. Concentrations of FRP and NOx will be determined using flow-injection analysis; NH4+ NH3 concentration will be measured using the phenate method (APHA 2005).
- Chlorophyll-a will be measured using duplicate 250 millilitre samples. Samples will be filtered on site through GFC-50 and the filters stored on ice and in the dark. . Samples will be frozen within 12 hours of collection and analysed within 14 days. Frozen filter papers will be extracted in 10mL of acetone in the dark at 4 degrees Celsius for 12 hours. At the end of this time the acetone will be filtered through a GF-C filter to remove any sediment and then chlorophyll-a measured spectrophotometrically (Shimadzu UV-200, Shimadzu, Japan) using standard methods (APHA 2013).
- For DOC, samples will be filtered on site on to 0.2 µm glass fiber filters into pre-combusted amber-glass jars and acidified (to pH < 2) with 32% HCl. All samples will then be refrigerated immediately and organic carbon concentration analyzed using a Shimadzu TOC-V CPH/CPN Total Organic Carbon analyzer (Shimadzu; Tokyo, Japan) upon return to the laboratory (within 72 hours).
- All analyses will take place in the environmental chemistry laboratory at the University of Canberra with QA/QC of samples at the Monash Water Studies Centre, Monash University (see details below).

6.9 *In-situ* logging

Stream metabolism measures for temperature, dissolved oxygen, light (PAR) and barometric pressure are logged at ten-minute intervals. Loggers are deployed continuously as it is expected that all sites in the Lachlan system will be continuously flowing. Loggers will be maintained continuously in the Lachlan system at all sites, with downloads of data occurring monthly, associated with recalibration of the loggers.

6.9.1 Equipment

- Dissolved oxygen (DO) and water temperature will be logged using D-Opto dissolved oxygen sensors (Zebra-Tech; Nelson, New Zealand). Photosynthetic active radiation (PAR) will be measured using an Odyssey PAR logger (Odyssey; Christchurch, New Zealand).

- Barometric pressure will be logged with a Silva Atmospheric Data Centre Pro (Silva; Sollentuna, Sweden).
- Tool kit and spare parts for the multi-parameter probe; including spare batteries
- Metal star pickets and star picket driver or mallet
- Means to attach probe to star picket or permanent structure
- GPS
- Probe calibration log
- Field sheets
- Laptop and data cables for connecting to probes / logger
- Air bubbler with battery (e.g. one suitable for a large fish tank) and a large bucket (e.g. 20 L), for probe calibration.

6.9.2 Protocol

Preparation

- Prior to deployment in the field, all probes will be calibrated according to manufacturer's instructions and results of calibration entered into a calibration log.
- Before leaving the office / laboratory the following will be checked for all electronic equipment (probes, loggers, GPS):
    - Batteries are charged and properly inserted.
    - Previous data downloaded and memory cleared.
    - Check cable and cable connections.
    - Check for any obvious/minor faults on sensors including growth or dirt on the probes or tubing.
    - Check contents and condition of probe toolkit.
    - All equipment listed above is present and in functional order.

Field method – PAR, barometric pressure

- PAR will be measured at 10 min intervals using a logger placed in full light adjacent to the upstream site.
- Barometric pressure will be will be logged at 10 min intervals using a logger placed adjacent to the upstream site.

Field method – water column measures

- Record the following on the field sheet:
    - River name and ANAE Streamid.
    - Date and time.
    - GPS coordinates (latitude and longitude; GDA94).
    - Name(s) of survey team.

- Record site characteristics:
    - Substrate type.
    - Width of channel.
    - Presence of any geomorphic features.
    - Percent canopy cover.
    - Land use immediate adjacent to site.

- Collect water quality samples and spot measures according to instructions in 1.8 above.

- The dissolved oxygen sensor will be calibrated prior to deployment and monthly on site thereafter.
  - Calibration will be according to Zebratec's instructions, calibrating to oxygen free water (1% sodium sulfite Na_2SO_3 solution) and 100% saturation (air saturated water). Calibration to 100% saturation will be carried out by placing the probe in a bucket of stream water which itself is sitting in the stream to ensure thermal control. Air will be bubbled through the water in the bucket for at least 45-60 minutes until a stable reading is found from the probe.

- Loggers will be set to record at ten minute intervals.

- Loggers will be deployed at each site in open water, mid stream and at a depth that will not expose sensors for entire deployment period. Sensors will not be placed in eddies, backwaters or where flow is influenced by structures.

- Deploy loggers.

- Loggers will be downloaded, serviced, cleaned and calibrated monthly.

- Any changes in site conditions will be noted.

6.10 Quality Assurance/Quality Control

All water quality samples will be taken in duplicate, collected stored and analysed according to APHA (2014) protocols. All water quality samples will be taken and analysed in duplicate. All laboratory analyses will be carried out to NATA standards including analysis of blanks. Samples will be held for a maximum time as indicated in the appropriate protocols above. All loggers will be calibrated seasonally (see maintenance table (section 8.3.1)).

6.11 Data analysis and reporting

This method adopts the approach of determining gross primary production (GPP), ecosystem respiration (ER) and reaeration rate (K_{O2}) from the diel dissolved oxygen curves. These parameters will be calculated from the raw data using curve fitting software (Grace et al., unpublished) as provided to the LTIM project via the Govdex website.

The model uses data for dissolved oxygen in mg O_2/L, temperature, PAR and barometric pressure (in atmospheres) at 10 minute intervals, together with information on salinity which will be derived from the monthly EC values. The program provides estimates of GPP and ER in mg O_2 /L/day with uncertainties for each and goodness of fit parameters.

Patterns in ER are indicative of decomposition, while GPP indicates primary production. Correlations between GPP, ER and likely key predictors will be assessed. In particular the effects of 1) water quality parameters and 2) stream height/provision of environmental flows on ER and GPP will be assessed. These relationships are highly non-linear and typified by thresholds in other systems. The majority of analyses are likely to be descriptive based on responses to changes in flow, and illustrated using scatterplots. If the data are available, non-linear multiple regression may be applied to identify key drivers of GPP and ER. Analyses will be stratified seasonally and by antecedent flow conditions to determine contingent responses.

- **Short-term (one-year) and long-term (five year) questions:**
    - What did Commonwealth environmental water contribute to patterns and rates of decomposition?
    - What did Commonwealth environmental contribute to patterns and rates of primary productivity?

Expected relationships between environmental flows deliver and water quality and stream metabolism parameters for the Lachlan system are consistent with the cause and effect diagrams provided in the Program Logic for Basin Level evaluation. ER provides an estimate of patterns and rates of decomposition, while GPP provides an estimate of patterns and rates of primary productivity.

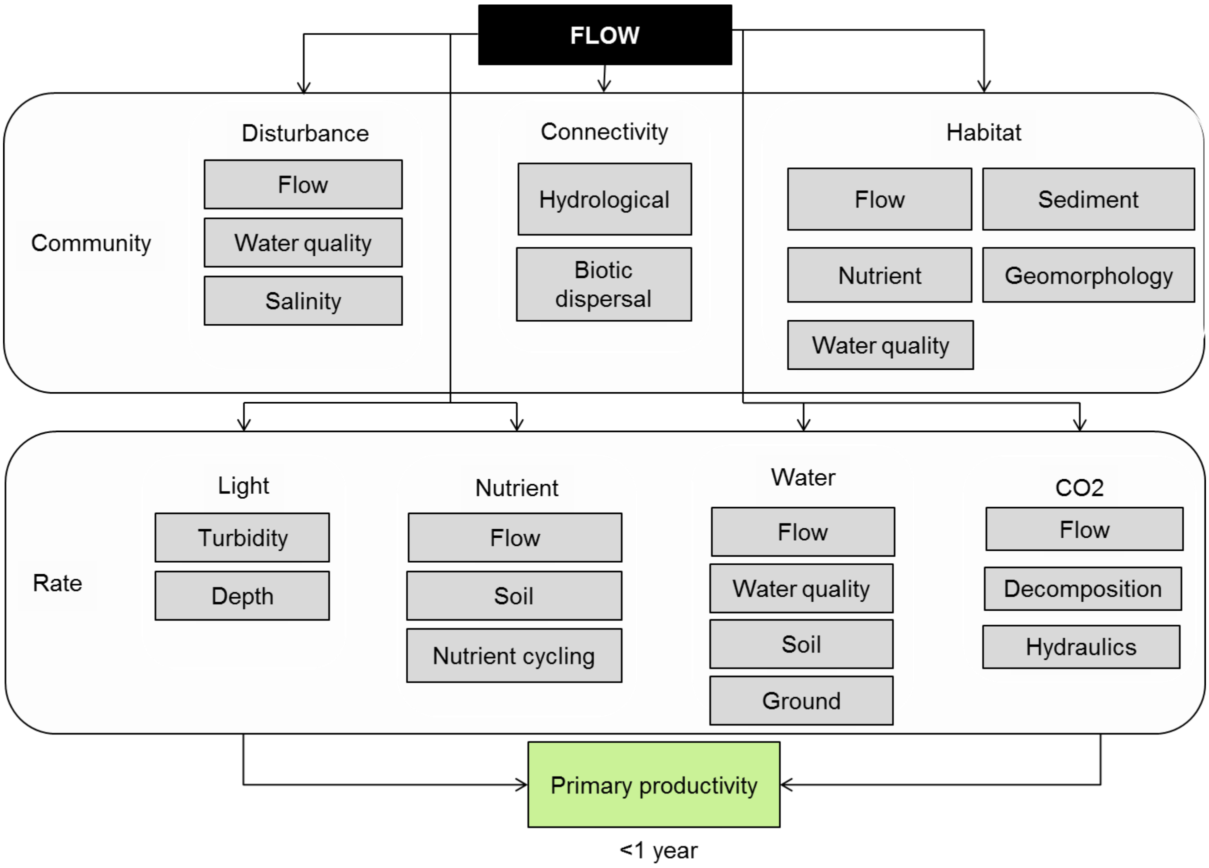

Figure 3 Cause and effect diagram depicting the influence of flow on primary production.

Environmental flows may be expected to influence water quality and stream metabolism in a number of ways.

- Inundation of terrestrial habitat may increase concentrations of N, P and DOC which may in turn support increased GPP (N,P) and ER (DOC).

- Extensive and prolonged inundation of terrestrial habitat may greatly increase DOC and therefore ER, resulting in depleted surface water oxygen levels (a 'blackwater event').
- Increased channel depth may act to shade benthic biofilms and macrophytes, reducing GPP.
- Increased water volumes may dilute phytoplankton cells (resulting in lower GPP) but then provide increased habitat and nutrients (see 1) that may then allow a 'rebound' effect resulting in higher GPP.

These effects act to alter the amount of energy flowing into aquatic food webs and thus to higher consumers such as invertebrates and fish.

6.11.1 Data management

All data provided for this indicator will conform to the data structure defined in the LTIM Data Standard. The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The assessment unit for this indicator is the site (river section). Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

6.12 Health and safety

For details on health and safety please refer to the Workplace Health and Safety Plan for the Lower Lachlan river system Selected Area (WHS 202.1) in Appendix 3 of the M&E Plan.

6.13 References

APHA (2014) Standard methods for the examination of wastewater.. American Public Health Associated. Accessed online at http://www.standardmethods.org/ 26/03/2014.

Grace, M. and Imberger, S. (2006) Stream Metabolism: Performing and Interpreting Measurements, Monash University.

Supplement 6A: Example: stream metabolism data collection sheet

Streamid:		River name:		Date:	
Observers:			Deployment / retrieval		
Stream characteristics:					
Stream width (m):					
Substrate type:					
Geomorphic features:					
Canopy cover (%)					
Adjacent land use:					
Notes:					

Water quality samples (check if collected)

Chlorophyll-a		Total P		FRP	
Total N		NOx		NH_4	
DOC					

In-situ logging

DO calibration (% saturation):			
Oxygen free water		100% saturation	
Logging commence / finish time:			
DO / Temperature sensor depth:			
Notes:			

7 Standard method: Frogs

7.1 Selected area-scale evaluation questions

- **Short-term (one year) evaluation questions:**
    - What did commonwealth environmental water contribute to breeding and recruitment of other vertebrate (frog) species?
    - What did commonwealth environmental water contribute to provision of habitat to support breeding and recruitment of other vertebrate (frog) species?
    - What did Commonwealth environmental water contribute to the maintenance of refuge habitats for other aquatic vertebrates?
- **Long-term (five year) evaluation questions:**
    - What did Commonwealth environmental water contribute to other aquatic vertebrates (frog and turtle) diversity and populations?

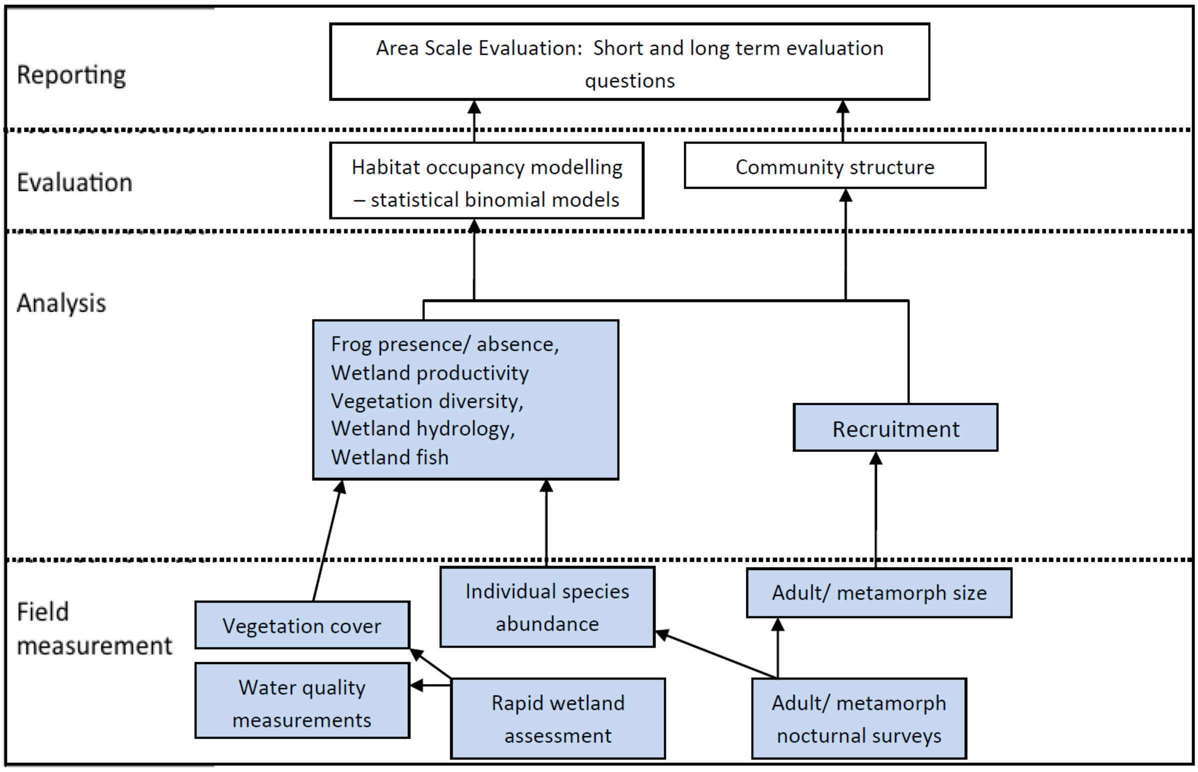

Figure 1: Schematic of key elements of the LTIM Standard Protocol: Frogs and tadpoles.

7.2 Relevant ecosystem types

Wetlands and floodplains.

7.3 Relevant flow types

Bankfull, overbank and overbank (infrastructure assisted).

7.4 Overview and context

Frogs are sensitive to changes in wetland flooding regimes and respond strongly to environmental releases with large increases in breeding activity. Higher levels of tadpole abundance and recruitment are commonly recorded during managed flood events, e.g. (JA Spencer et al., 2010; J Spencer et al., 2011; S. Wassens et al., 2011; S. Wassens et al., 2012). In many areas managed environmental watering is critical for the persistence of flood sensitive frog species. For example, key populations of the vulnerable (EPBC Act 1999) Southern bell frog were successfully maintained using environmental watering in the Lowbidgee floodplain between 2007 and 2010 (S. Wassens, Hall, Osborne, & Watts, 2010).

Frogs exhibit three key responses to flooding: (1) calling activity, (2) tadpole abundance and development, and (3) metamorphosis. Calling activity is a useful measure of the distribution of frogs with respect to underlying hydrological regimes and wetland characteristics (Skye Wassens, 2010; S. Wassens et al., 2010). Calling indicates a specific environmental watering event has created conditions suitable for *attempted* breeding by resident species. Monitoring tadpole communities and defining development stages is important when managing water levels, because it allows for estimation of how close tadpoles are to reaching metamorphosis and, as such, can provide an early indicator on the need for top-up watering. Size structure within populations has proven to be a useful indicator as it provides a measure of the number of individuals recruiting into the adult population.

Frog community responses can be assessed at two spatial and temporal scales: (1) broad scale assessment of occupancy patterns within connected wetlands addressing long-term (five year) objectives) and (2) intensive monitoring of tadpole development and recruitment (which can be carried out in association with wetland fish monitoring) at a subset of connected wetlands or in areas where there are known populations of where threatened of local significant species. Note that small and large fyke nets have the highest probability of detecting tadpoles in large wetland systems, so tadpole surveys can be run concurrently with fish surveys with tadpoles being identified in the field at the same time as fish. However, as tadpoles can be difficult to identify, an experienced amphibian ecologist will be present for initial surveys to ensure staff are properly trained.

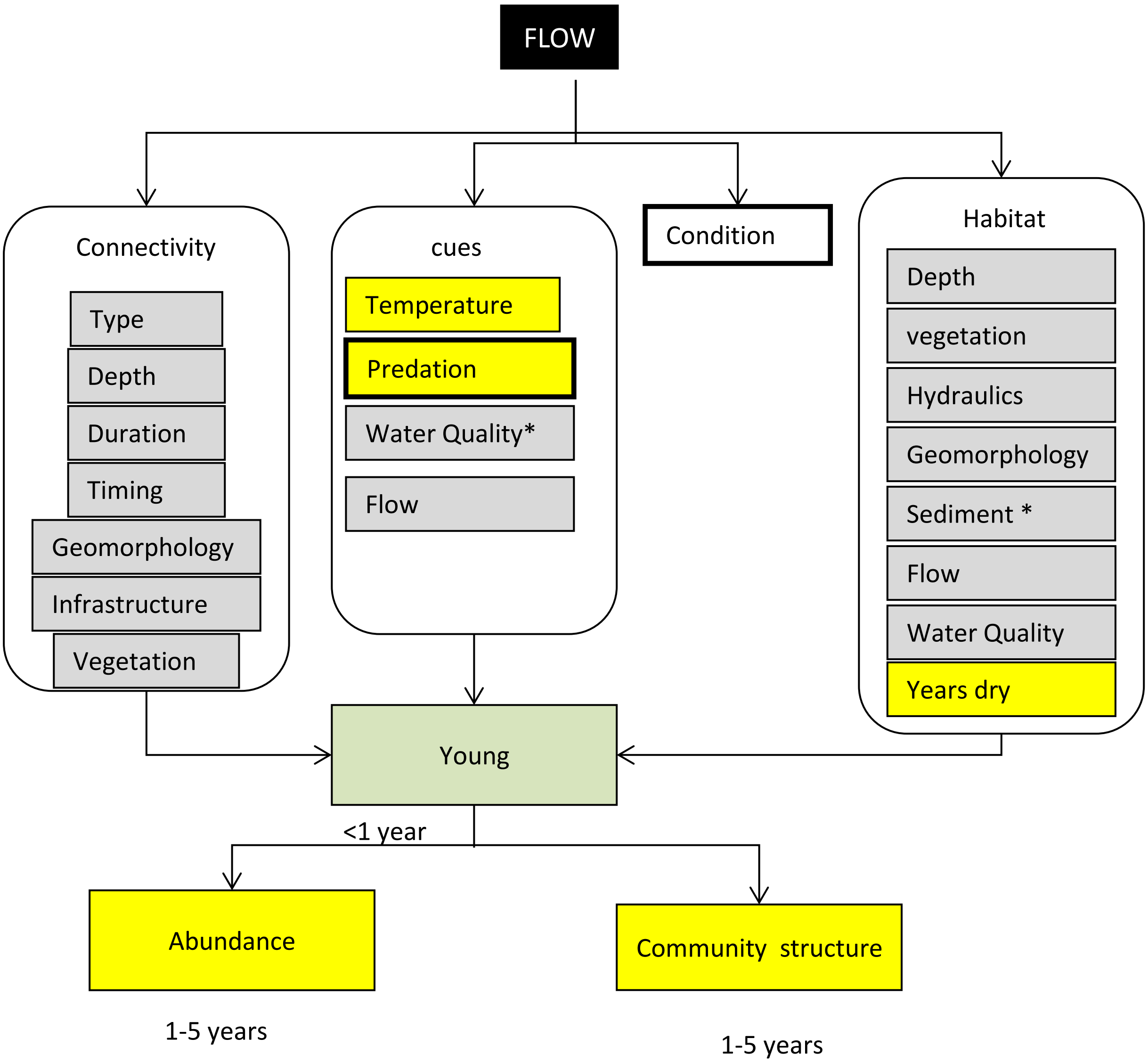

Figure 2: Cause and effect diagram for the response of frogs and their tadpoles to Commonwealth environmental water

7.5 Complementary monitoring and data

7.5.1 Covariates

- Wetland productivity.
- Vegetation diversity (Cat 2).
- Wetland hydrology (Cat 1).
- Wetland fish (Cat 1).

7.6 Monitoring locations

7.6.1 *Zones*

The lower Lachlan selected area can be partitioned into five spatially, geomorphologically and hydrologically distinct river channel zones at a broad landscape scale (Figure 2).

Zone 1	Lachlan River channel between Brewster Weir and Booligal.
Zone 2	Lachlan River channel between Booligal and Corrong.
Zone 3	Lachlan River channel between Corrong and its terminus in the Great Cumbung Swamp
Zone 4	Merrowie Creek
Zone 5	Torringany, Box, Merrimajeel and Muggabah Creek system.

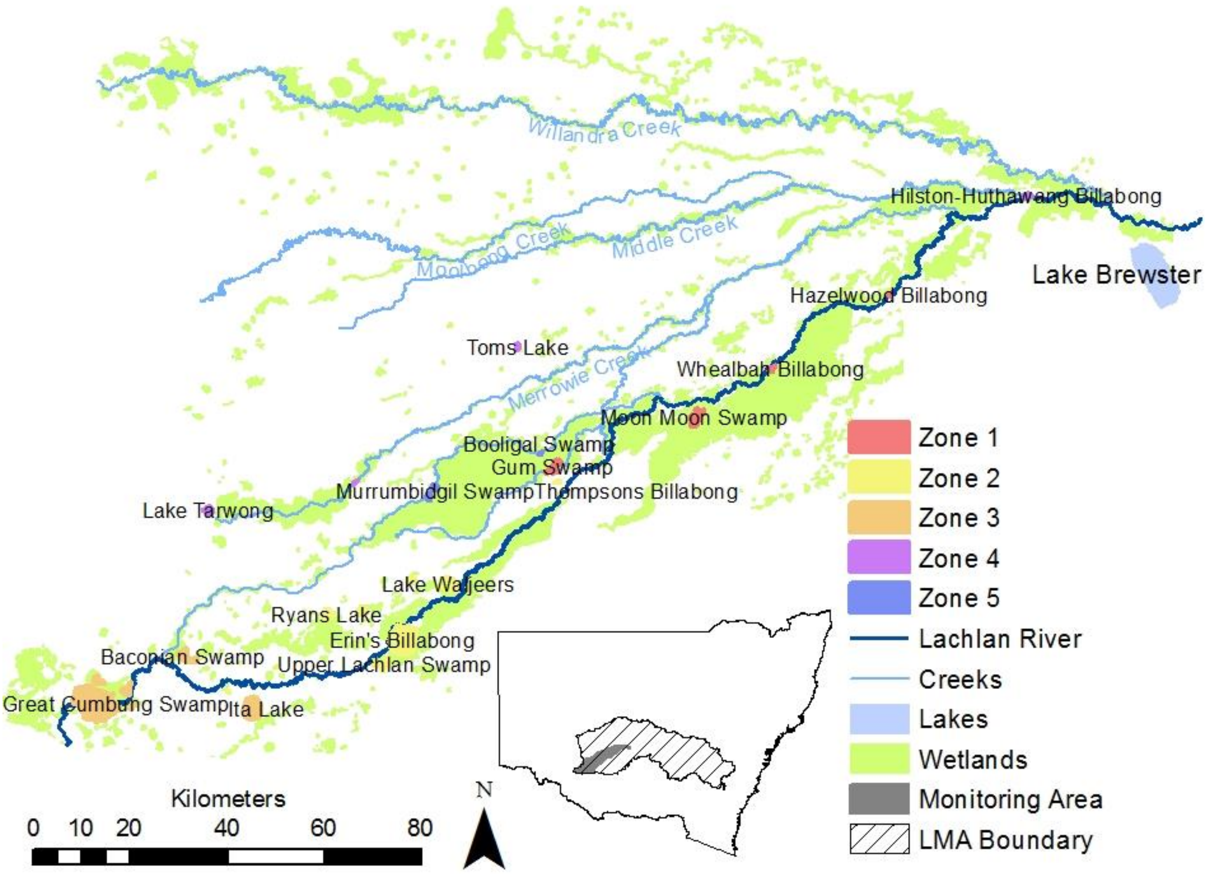

Figure 2. Draft map showing wetland sites and zones

7.6.2 *Site placement within the zones*

We will aim to survey fifteen sites per year, including intensive wetland sites (Table 1) and on-demand sites. The actual number of sites surveyed in any one year will vary depending upon hydrological conditions, i.e. in dry years, fewer than 15 sites may be surveyed, and in wet years more than 15 sites may be surveyed. As not all sites will be watered each year, a subset of wetland sites from Table 1 will be selected based on their hydrological status. When selecting sites, those that have had previous frog surveys will be given a higher priority.

7.6.3 Intensive wetland sites

Each zone contains several wetlands of national and regional significance, which are listed in the Directory of Important Wetlands (Environment Australia, 2001). Many or all of these wetlands will be targets of CEWO, MDBA or NSW OEH environmental flow deliveries.

Table 1. Intensive wetland sites, possibility of watering and methods being applied

ZONE	SITE	YEARS WATERED OUT OF FIVE	PREVIOUS FROG SURVEYS	METAMORPH SIZE DATA	ADULT SIZE DATA
1	Gum Swamp	?		x	x
	Hazelwood Billabong	?		x	x
	Whealbah Billabong	2/5		x	x
	Moon Moon Swamp	2/5	x	x	x
2	Peppermint Swamp	1/5		x	x
	Lake Waljeers	1/5		x	x
	Lake Bullogal	1/5	x	x	x
	Erin's Billabong			x	x
	Ryans Swamp			x	x
3	Ita Lake	1/5	x	x	x
	Baconian Swamp	1/5		x	x
	Great Cumbung Swamp (including marginal lakes)	2/5	x	x	x
4	Lake Tarwong	1/5		x	x
	Cuba Dam	2/5	x	x	x
	Tom's Lake	1/5	x	x	x
5	Upper Gum Swamp	1/5		x	x
	Booligal Swamp	2/5		x	x
	Murrumbidgil Swamp	3/5	x	x	x
	Lake Merrimajeel	1/5	x	x	x
	Lower Gum Swamp	1/5		x	x

Given that the Booligal Wetland complex (Zone 5) is likely to be the wetland that receives environmental water most regularly, we propose to select wetland monitoring sites within this system for basin-scale assessment. The three wetlands selected within this zone will be fixed for the duration of the project. This is not the same zone as is being sampled for riverine fish (Zone 1), but this choice is unavoidable given that (1) all but one of the wetlands within zone 1 (Moon Moon Swamp) are unlikely to receive regular environmental flows and (2) the riverine channels within zone 5 are largely ephemeral and not suitable for basin-scale assessment of riverine channels.

7.6.4 On-demand sites

On demand sites will be selected based on inundation of intensive wetland sites and will be set after initial selection if re-watered. They will allow a greater understanding of the contribution of commonwealth water to frog habitat and refuge and increase understanding of frog response to watering events and habitat occupancy patterns.

7.7 Timing of monitoring

Wetlands will be surveyed three times per year between August and February. This falls across three seasons (winter, spring and summer) allowing for seasonal variation in species. These will be surveyed for adults and metamorphs (Table 1).

7.8 Monitoring protocol

7.8.1 Equipment

Frogs

- 4 x Torch or spotlight with a minimum of 300 Lumens.
- Notebook- Pocket notebooks are far easier to manage than A4 datasheets for general surveys.
- Callipers (for size measurement).
- Disposable gloves.
- GPS.
- Watch (record start and finish times).
- Disinfectant hand wash.
- Optional (handheld temperature/ weather station).

Other considerations

All surveyors must adhere to the NSW OEH hygiene protocol.
http://www.environment.nsw.gov.au/animals/HygieneProtocolForFrogs.htm

Gloves must be worn when handling frogs as contact with sunscreens and insect repellents etc can cause irritation.

7.8.2 Protocol

Adults and metamorphs (Intensive wetland and on-demand sites)

Assessment of frog communities will be undertaken at intensive wetland sites where fish community assessment is also being completed. Adult frogs and metamorphs will be surveyed within each wetland after dark using a 3x10 minute visual encounter (person minutes) and a 3x1 minute audio survey (S. Wassens et al., 2011; S. Wassens et al., 2012). Timed surveys are easier then set transects because variable water levels over time can make the use of fixed transects impractical.

A 15-30 watt spotlight or torch will be used to search for frogs along the wetland edge and into the surrounding terrestrial habitats. All individuals observed will be identified to species and the number recorded (it is possible to identify individuals without capture). When setting call recorders recording period will be set for 3 x 10 minute sets starting from one hour after sun set.

Breeding and size structure (Intensive wetland sites only)

An estimate of breeding activity will be obtained by measuring a subset of 20 individuals, as size structure can give an indication of the number of recently metamorphosed individuals. It is important to note that growth rates can vary between sites. *Limnodynastes tasmaniensis* and *Limnodynastes fletcheri,* two common species across the Lachlan Catchment (Amos, Wassens, & Luck, 2013), will be measured (snout-to-vent length) to give an indication of demographic structure and presence of recent metamorphs. This method was successfully trialled in the Mid-Murrumbidgee between October 2011 and April 2012.

Audio surveys involve listening for the distinct calls of resident frog species, general estimates of the number of calling individuals will be determined using the methodology described by (S. Wassens et al., 2011).

Biophysical surveys (Intensive wetland and on-demand sites)

Rapid on site assessments will be done at each site at the time of each frog survey and based on methodology from (Amos et al., 2013).

Vegetation

Vegetation transects will be used to account for aquatic and riparian vegetation present at each site. Each transect will be spaced 20 metres apart with 1-3 transects per site depending on size of the water body. Sites that have a shore line of <20 m in length will be subject to one transect; sites 20-60 m will be subject to two transects; and sites >60 m will be subject to three transects. Transects are two metres wide and cut directly across the water body, starting from five metres out of the shore to the other side of the wetland or creek line. If that distance is beyond sight, the closest point that vegetation can be identified within sight will be used. In each transect, the most prevalent aquatic vegetation types (>10%), will be identified to species and the percentage cover of each species recorded; less dominant species will be classified into broad categories. Percent cover of litter, bare ground, coarse woody debris, and open water will also be recorded. The number of dead standing timber will be recorded for each transect during the first survey period.

Water quality

Water quality will be measured at three different locations at each site on each survey occasion. Five water quality variables will be measured: temperature (˚C), conductivity (mS/cm), dissolved oxygen (mg/L), pH and turbidity (NTU). Measurements will be made using a handheld YSI within 2-3 m of each other.

7.9 Quality Assurance/Quality Control

Field methodology is based on standard protocols developed by Drs Skye Wassens and Jennifer Spencer from repeated surveys in the Lowbidgee and other systems (JA Spencer et al., 2010; J Spencer et al., 2011; S. Wassens et al., 2011; S. Wassens et al., 2012). On all field occasions involving frog surveys, a research assistant trained in frog identification will be present. Species that are not identifiable on site will be photographed and identified using the following field guides (M. Anstis, 2002; Marion Anstis, 2013). Consultation between trained research assistant and frog experts at Charles Sturt University will be used to identify species from photographs.

7.10 Data analysis and reporting

7.10.1 Frogs

- Site name.
- Lat/long.
- Time start- time finished.
- Surveyor name.
- Number observed (each species).
- Number calling (each species).
- Size structure- Length of two target individuals.

Presence/absence data for frog species repeatedly collected at a number of wetland locations with varying habitat characteristics, for which data describing variables that define those habitat characteristics are also collected, provide the basis for habitat occupancy modelling. Key data included in such modelling are hydrological variables that describe the wetting drying regime and connectivity of the habitat wetland. Statistical binomial models produced using maximum likelihood estimation that incorporate occupancy and detection variables following the techniques of (MacKenzie et al., 2002) are appropriate for the analysis of frog species that can have low detection probabilities. The outputs of such modelling will provide valuable insight into hydrological factors, both directly and indirectly through related vegetation characteristics that are conducive to providing the habitat conditions favourable to frog recruitment in wet periods and refugia in drier periods.

7.11 Data management

Data will be transferred from field data sheets and notebooks into spreadsheet documents. Field data sheets will be scanned and copies provided to the University of Canberra and also Charles Sturt University. Original copies will be stored at Charles Sturt University.

7.12 Health and safety

For details on health and safety please refer to the Workplace Health and Safety Plan for the Lower Lachlan river system Selected Area (WHS 202.1) in appendix 3.

7.13 References

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Wassens, S., Watts, R. J., Spencer, J. A., Howitt, J., McCasker, N. A., Griese, V., . . . Hall, A. (2012). Monitoring of ecosystem responses to the delivery of environmental water in the Murrumbidgee system (Vol. Report 2 (May 2012)): Institute for Land, Water and Society, Charles Sturt University.

Supplement 7A: Data sheets

Name:			**Surrounding land use (land use within 50m)**	
lat/long			Cropping	
			Orchard	
Date:			Pasture	
Connection (filled via)	Flood runner-river		Grazed forest	
	Rain fed		Ungrazed forest	
	Ground water		**Surrounding vegetation**	
	Regulator or Pump		**Over story species %**	
	Distance to nearest waterbody (m)			
History	Date flooded			
	Date previously flooded			
	Hydrology (months wet/year)			
System type	Rain fed depression		**Mid storey %**	
	Ground water depression			
	Back water			
	Ox bow			
	Minor stream			
	River			
	Canal		**Understorey %**	
	Open wetland		tall (>30cm) grasses	
	Forested wetland		short (<30cm) grasses	
	Major storage or lake		tall (>30cm) herbs	
	Area (hectares)		short(<30cm) herbs	
Comments			Logs, sticks and litter	
			Bare ground	
			General wetland characteristics	
			% open water	
			% vegetation	
			DST (approx. number)	
			Continuity % fringing	

Wetland characteristics TRANSECTS		Tran 1	Tran 2	Tran 3	Tran 4	Tran 5	Tran 6
Terrestrial & fringing vegetation	tall (>30cm) grasses						
	short (<30cm) grasses						
	tall (>30cm) herbs						
	Short (<30cm) herbs						
	logs, sticks and litter						
	bare ground						
	inundated %						
	over hanging %						
Soil type	sand (check)						
	loam (check)						
	clay (check)						
Tall Emergent aquatic (>50cm)							
Short Emergent aquatic (<50cm)							
Broadleaf emergent							
Attached floating							
Free floating							
Submerged aquatic							
Standing timber							
Water quality	Temperature						
	DO						
	Conductivity						
	pH						
	Turbidity						
	Depth (@ 1m)						
Sweeps							

8 Hydrology (river): Basin and Selected Area methods

8.1 Overview

This protocol describes the methods that will be used for both Basin Evaluation (specified by the CEWO) and the Selected Area Evaluation. While Basin scale methods consider that the hydrological data collected for these methods will inform only the analysis and evaluation of monitoring outcomes for hydrological connectivity, native fish and water quality, the M&E Providers for the Lachlan River system Selected Area consider hydrological data essential to the evaluation of outcomes for ***all*** indicators.

8.2 Evaluation questions

8.2.1 Basin evaluation questions

This protocol does not directly address specific evaluation questions but is important for informing the analysis and evaluation of outcomes for hydrological connectivity and native fish. It indirectly addresses the following Basin Evaluation questions:

- **Long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to hydrological connectivity?
  - What did Commonwealth environmental water contribute to native fish species diversity?
  - What did Commonwealth environmental water contribute to fish community resilience?

- **Short-term (one year) questions:**
  - What did Commonwealth environmental water contribute to native fish reproduction?
  - What did Commonwealth environmental water contribute to native larval fish growth and survival?

- **Short-term (one-year) and long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to patterns and rates of decomposition?
  - What did Commonwealth environmental contribute to patterns and rates of primary productivity?
  - What did Commonwealth environmental water contribute to temperature regimes?
  - What did Commonwealth environmental water contribute to pH levels?
  - What did Commonwealth environmental water contribute to turbidity regimes?
  - What did Commonwealth environmental water contribute to salinity regimes?
  - What did Commonwealth environmental water contribute to dissolved oxygen levels?

The process for evaluating these questions is illustrated in Figure 1, with components covered by this protocol highlighted in blue.

8.2.2 Selected Area Evaluation questions

This protocol does not directly address specific evaluation questions but is important for informing the analysis and evaluation of outcomes for ***all*** of indicators that are relevant to rivers. The indicators for the Lachlan River system Selected Area that will use hydrological (river) data and the relevant hydrological measures are shown in Table 1. It should be noted that waterbird indicators are only relevant to wetlands in the Lower Lachlan. As such the protocol indirectly addresses the following Selected Area evaluation questions:

- **Long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to sustainable ecosystem diversity?
  - Were ecosystems to which Commonwealth environmental water was allocated sustained?
  - Was water delivered to a representative suite of ecosystem types?
  - What did Commonwealth environmental water contribute to vegetation extent?
  - What did Commonwealth environmental water contribute to microcrustacean community composition?
  - What did Commonwealth environmental water contribute to native fish populations?
  - What did Commonwealth environmental water contribute to native fish species diversity?
  - What did Commonwealth environmental water contribute to fish community resilience?
  - What did Commonwealth environmental water contribute to native fish survival?
  - What did Commonwealth environmental water contribute to sediment transport?
  - What did Commonwealth environmental water contribute to biotic dispersal?
  - What did Commonwealth environmental water contribute to populations of long-lived organisms?

- **Short-term (one year) questions:**
  - What did Commonwealth environmental water contribute to microcrustacean contribution to the abundance of native larval fish?
  - What did Commonwealth environmental water contribute to microcrustacean contribution to the growth of native larval fish?
  - What did Commonwealth environmental water contribute to microcrustacean contribution to the survival of native larval fish?
  - What did Commonwealth environmental water contribute to connectivity of microcrustacean communities between river and wetlands?
  - What did Commonwealth environmental water contribute to native fish reproduction?
  - What did Commonwealth environmental water contribute to native larval fish growth and survival?
  - What did Commonwealth environmental water contribute to other vertebrate reproduction and recruitment?
  - What did Commonwealth environmental water contribute to other vertebrate survival?

- **Short-term (one-year) and long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to the condition of floodplain and riparian trees?

- What did Commonwealth environmental water contribute to vegetation community diversity?
- What did Commonwealth environmental water contribute to vegetation species diversity?
- What did Commonwealth environmental water contribute to microcrustacean productivity?
- What did Commonwealth environmental water contribute to resilience of microcrustacean egg banks?
- What did Commonwealth environmental water contribute to other vertebrate populations?
- What did Commonwealth environmental water contribute to other vertebrate species diversity?
- What did Commonwealth environmental water contribute to hydrological connectivity?
- What did Commonwealth environmental water contribute to patterns and rates of primary productivity?
- What did Commonwealth environmental water contribute to patterns and rates of decomposition?
- What did Commonwealth environmental water contribute to patterns and rates of nutrient cycling?
- What did Commonwealth environmental water contribute to refuges?
- What did Commonwealth environmental water contribute to recovery?
- What did Commonwealth environmental water contribute to fish community resilience?
- What did Commonwealth environmental water contribute to temperature regimes?
- What did Commonwealth environmental water contribute to dissolved oxygen levels?

The process for evaluating these questions is illustrated in Figure 2, with components covered by this protocol highlighted in green.

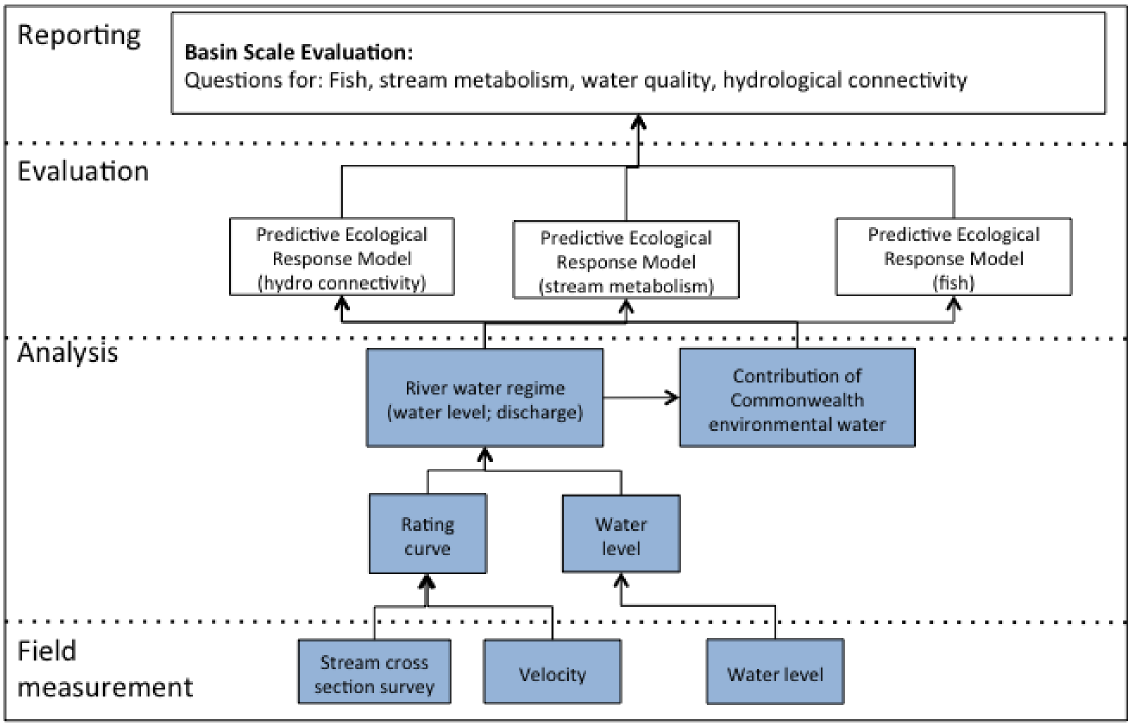

Figure 1: Schematic of key elements of the LTIM Standard Protocol for Basin Evaluation: Hydrology (river).

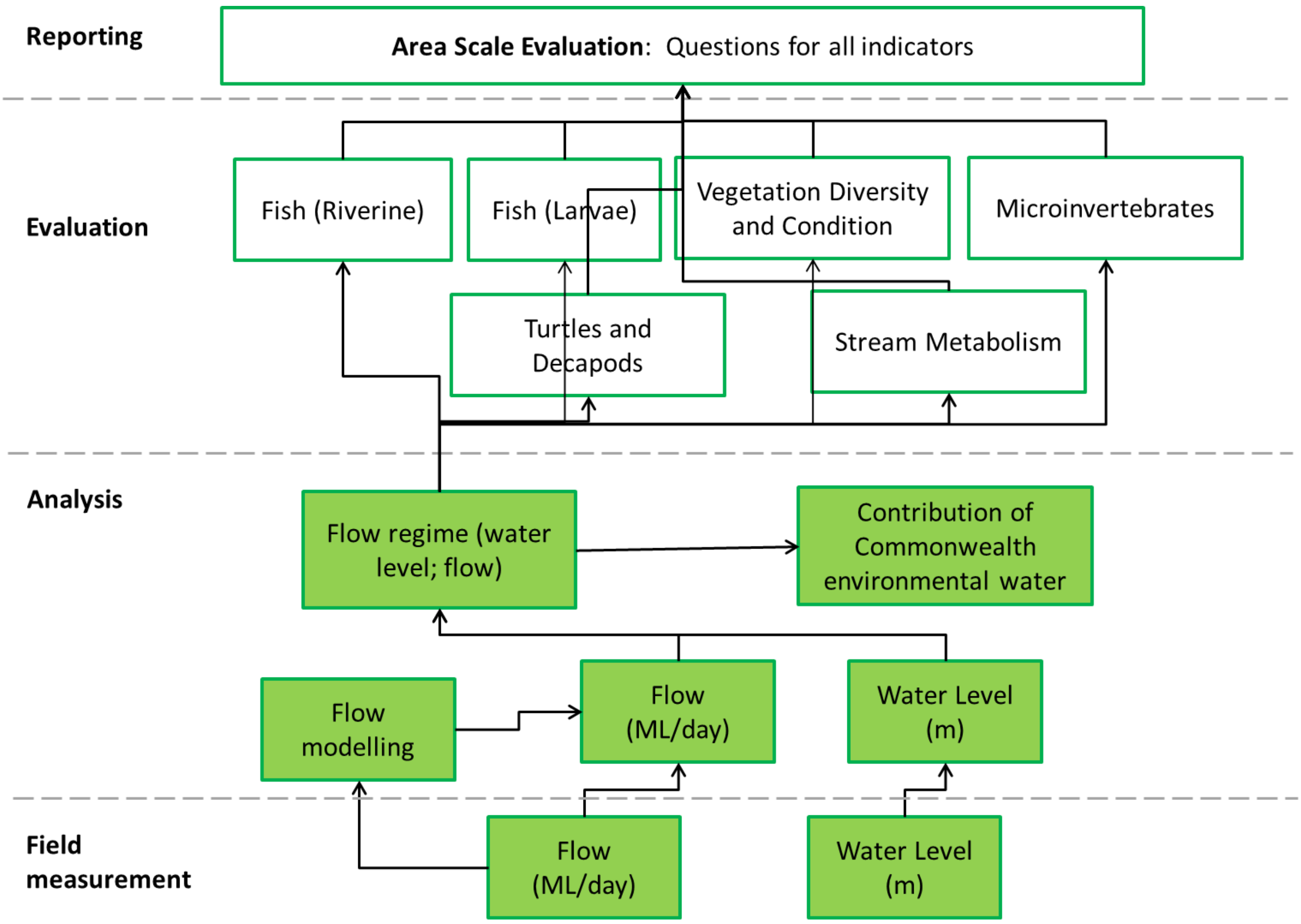

Figure 2. Schematic of key elements of the LTIM protocol for the Area Evaluation: Hydrology (River).

8.3 Relevant ecosystem types

Rivers.

8.4 Relevant flow types

All.

Table 1. Lachlan River System Selected Area indicators and the hydrological metrics used in the Selected Area Evaluation

INDICATOR	USE IN EVALUATION	HYDROLOGY ATTRIBUTES USED IN EVALUATION
Ecosystem Type (Cat 1)	Basin Scale: Validation of hydrological regime	Permanent or temporary surface water (from long term records)
Vegetation Diversity and condition (Cat 3)	Area Scale: Change in vegetation metrics in relation to watering	presence/absence of water; water depth, duration of watering, frequency of watering
Fish (River) (Cat 3)	Area Scale: Change in fish metrics in relation to stream flow attributes	flood pulse duration and magnitude, dry spell duration total flow volume categorical flow component (base flow, freshes, bankfull and overbank) hydrograph – environmental water releases and flow from the nearest gauge
Fish (larvae) (Cat 3)	Area Scale: Assessing larval fish metrics against hydrological attributes	watering event extent - timing, duration, peak flow
Stream metabolism (Rivers) (Cat 1)	Area Scale: Correlation between stream gauge height/discharge and; GPP, ER, WQ parameters. The majority of analyses are likely to be descriptive based on responses to changes in flow, and illustrated using scatterplots.	Stream gauge height/discharge
Turtles and Decapods (Cat 3)	Area Scale: Change in turtle and decapod numbers in relation to stream flow attributes	flood pulse duration and magnitude, dry spell duration and total flow volume categorical flow component categories (base flow, freshes, bankfull and overbank) hydrograph – environmental water releases and flow from the nearest gauge

8.5 Overview and context

8.5.1 Basin scale

At the Basin scale, hydrology (river) is an event based monitoring protocol designed to capture aspects of a rivers water regime that influence behaviour and condition of native fish, stream metabolism, and water quality. In particular, this protocol aims to quantify the effect of Commonwealth environmental water on aspects of river hydrology that are most important for native fish, stream metabolism, and water quality. This protocol is based on a combination of gauging data and hydrological modelling.

8.5.2 Area scale

At the area scale, hydrology (river) is a continuous monitoring protocol designed to capture aspects of a rivers flow regime that will be used to evaluate the effect of Commonwealth environmental water. This protocol is based identifying the attributes that will be used in the evaluation for each of the key indicators within the Lachlan River System Selected Area and comprises a combination of existing gauge data, field measures and hydrological modelling. Key hydrological attributes required are:

- Daily flow data:

  - Presence/absence of water at a site.
  - Frequency and duration of watering.
- River height.

8.6 Complementary monitoring and data

Twelve gauging stations currently operate on the Lower Lachlan River system. The locations are listed in Table 2 and are shown in Figure 3. Historical monitoring activities have relied on gauging data to evaluate outcomes of environmental watering. An assessment of the utility of the existing gauging sites is provided in Supplement 8B.

Table 2. Location of gauging stations in the Lower Lachlan River system.

NUMBER	NAME	LAT	LONG
412005	LACHLAN RIVER AT BOOLIGAL	-33.8695	144.8811
412038	LACHLAN RIVER U/S WILLANDRA WEIR	-33.3497	145.876
412039	LACHLAN RIVER AT HILLSTON WEIR	-33.4873	145.504
412045	LACHLAN RIVER AT CORRONG	-34.2176	144.4638
412078	LACHLAN RIVER AT WHEALBAH	-33.6544	145.2488
412163	MERROWIE CREEK DOWNSTREAM OF OFFTAKE WEIR	-33.3676	145.6017
412194	LACHLAN RIVER AT FOUR MILE WEIR	-34.248	144.1987
412196	LACHLAN RIVER DOWNSTREAM GANOWLIA WEIR (LANES BRIDGE)	-33.3716	145.5925
412012	WILLANDRA @ ROAD BDG	-33.3452	145.8803
412042	WILLANDRA HOMESTEAD	-33.1954	145.1217
412187	WILLANDRA @ YILGA	-33.2222	145.5053
412154	CUMBUNG SWAMP AT END OF SYSTEM	-34.1541	-143.5950

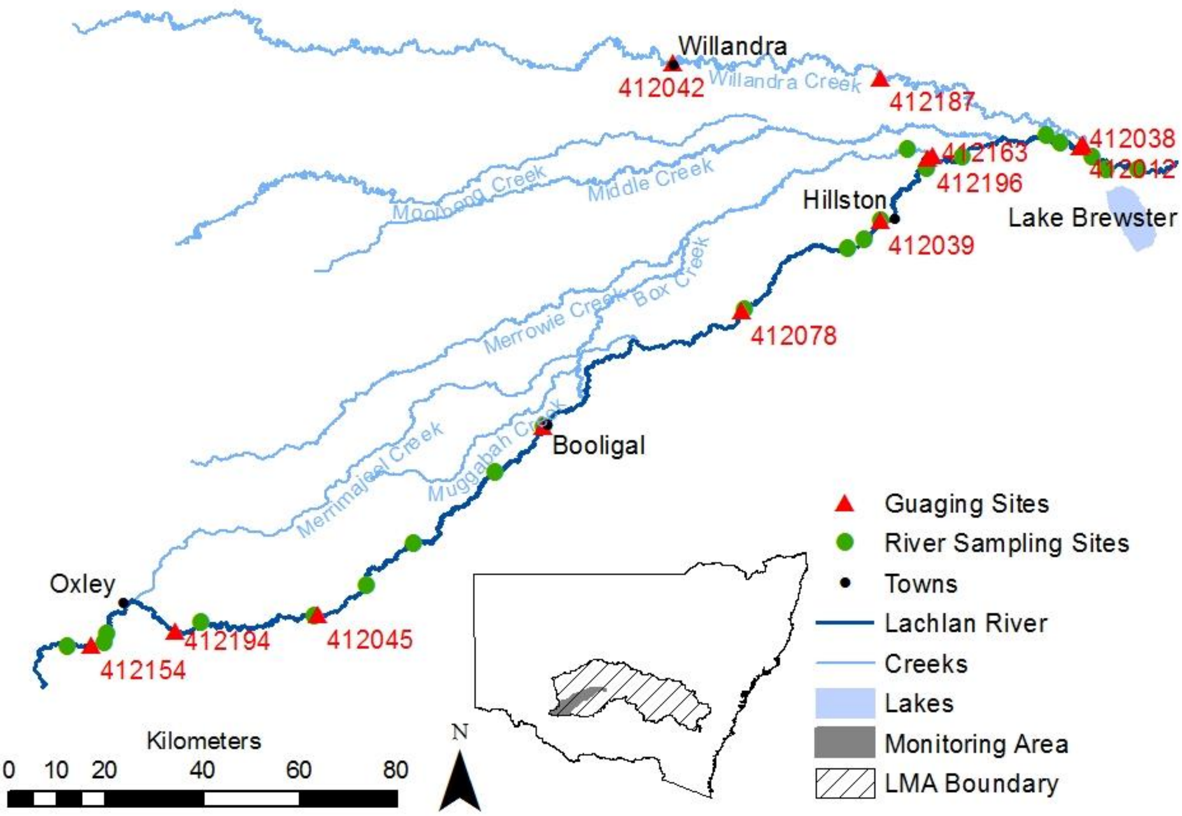

Figure 3. Map of the Lower Lachlan Rivershowing the region that is the focus for the long term intervention monitoring investment from the Commonwealth Environmental Water Office including the location of the gauging stations.

8.7 Establishing sites

8.7.1 Zones and sites

The LTIM project for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy is as follows:

Selected Area → Zone → Site

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

A site is the unit of assessment nested within a zone and for River Hydrology it will be a section of river.

8.7.2 Basin scale site establishment

Basin scale site establishment is based around the Riverine Fish, stream metabolism and water quality protocols. The sample design for the fish protocol involves a minimum of a single zone with 10 sites located within a 100 km stretch of river within the zone.

8.7.3 Area scale site establishment

Selected Area scale site establishment is linked to the area scale evaluation methods for riverine fish, stream metabolism, vegetation condition and diversity, turtles and decapods with sites matched to the sampling locations.

8.8 Monitoring locations

8.8.1 Basin evaluation

For the Lachlan River system, the Zone established for the implementation of Category 1 methods for Riverine fish, stream metabolism and water quality is between Willandra Weir and Hillston.

Assessment of the gauging data (Supplement 8B) indicates that the channel transmits flow in a well behaved and predictable manner. All key hydrologic attributes are propagated along the reach (e.g. baseflow, fresh, bankful flow). This suggests it is possible to model flows in this reach to the required accuracy and no new gauging sites will be established as part of the LTIM project. Water level recorders will be installed at with the dissolved oxygen and temperature data recorders at Willanthry and Lane's Bridge develop a relationship between water levels recorded at the gauging sites and the individual sites.

8.8.2 Selected Area evaluation

Locations will be matched to the sampling locations for riverine fish, stream metabolism, vegetation condition and diversity, microinvertebrates, turtles and decapods. These sites are summarized in Table 3 and shown in Figure 3.

8.9 Timing of monitoring

This protocol aims to capture the influence of Commonwealth environmental water and is designed as continuous monitoring. The use of existing gauge data means that monitoring data are available from prior to the arrival of Commonwealth environmental water and continue for the period over which Commonwealth environmental water influences the hydrology of the river and for the period after the Commonwealth environmental water flows have occurred.

Timing of the releases of Commonwealth environmental water (dependent on conditions) and contract establishment means that the installation of water level recorders is unlikely to commence until after the 2014 environmental water releases.

Table 3. River monitoring sites and the source of hydrological data for use in evaluation

SITE	VEGETATION [1]	RIVERINE FISH	LARVAL FISH	METAB-OLISM	TURTLES AND DECAPODS	HYDROLOGY DATA SOURCE	JUSTIFICATION
Lachlan River @ Benson's Drop		Y			Y	Flow: Lachlan River at Willandra weir (412038) verified using releases from Lake Brewster Water Level: Gauging site data	Gauge close to monitoring site
Lachlan River @ Willanthry		Y		Y	Y	Flow: Modelled flow based on Lachlan River at Willandra weir (412038) and the Willandra Creek at the bridge (412012) Water Level: Water level recorders installed with stream metabolism monitoring equipment.	Supplement 8B
Lachlan River @ Moora Farm		Y			Y	Modelled flow based on Lachlan River at Willandra weir (412038) and the Willandra Creek at the bridge (412012) Water Level: Modelled data based on spot measurements of water level during sampling, gauge data and upstream/downstream water level recorders	Supplement 8B
Lachlan River @ Lane's Bridge		Y	Y	Y	Y	Flow: Modelled flow based on Lachlan River at Willandra weir (412038) and the Willandra Creek at the bridge (412012) Water Level: Water level recorder installed	Supplement 8B
Lachlan River @ Hillston	Y	Y	Y		Y	Flow: Gauge at Hillston (412039) Water Level: Gauging site data	Gauge close to monitoring site
Lachlan River @ Hazelwood	Y					Flow: Modelled data between Hillston and Whealbah Water Level: Modelled data based on	No major distributaries, sufficiently good relationship to create model

SITE	VEGETATION [1]	RIVERINE FISH	LARVAL FISH	METAB-OLISM	TURTLES AND DECAPODS	HYDROLOGY DATA SOURCE	JUSTIFICATION
						observed water level during sampling, gauge data and upstream/downstream water level recorders	
Lachlan River @ Cowl Cowl		Y		Y	Y	Flow: Modelled data between Hillston and Whealbah Water Level: Modelled data based on spot measurements of water level during sampling, gauge data and upstream/downstream water level recorders	No major distributaries, sufficiently good relationship to create model
Lachlan River @ Whealbah		Y	Y	Y	Y	Flow: Gauge at Whealbah (412078) Water Level: Gauging site data	Gauge close to monitoring site
Lachlan River @ Booligal	Y	Y			Y	Flow: Gauge at Booligal (412005) Water Level: Gauging site data	Gauge close to monitoring site
Lachlan River @ Boxyards						Flow: Gauge at Booligal (412005) Water Level: Gauging site data	Gauge close to monitoring site; no major distributaries.
Lachlan River @ Ulonga						Flow: Modelled data between Booligal and Corrong Water Level: Modelled data based on spot measurements of water level during sampling, gauge data and upstream/downstream water level recorders	Gauge close to monitoring site; no major distributaries. Sufficiently good relationship to create model
Lachlan River @ Corrong						Flow: Gauge at Corrong (412045) Water level: gauging site data	Gauge close to monitoring site
Lachlan River @ Braebuck Woolshed						Flow: Gauge at Four mile weir (412194) Water Level: Gauging site data	Gauge close to monitoring site
Lachlan River @ Twitcher's Hut/Geramy	Y					Flow: Modelled data based on data from Gauge at Four mile weir (412194) and Cumbung Swamp end of system	Sufficiently good relationship to create model except in very large flows where return flows from

SITE	VEGETATION [1]	RIVERINE FISH	LARVAL FISH	METAB-OLISM	TURTLES AND DECAPODS	HYDROLOGY DATA SOURCE	JUSTIFICATION
						(412154). Additional data to be provided from water level recorder and linked to cross sections/historical gauging. Water Level: Water level recorder installed with stream metabolism monitoring equipment.	Merrimajeel Creek may be a problem. However, it is unlikely that CEW releases will be sufficient to create return flow conditions.
Lachlan River @ Boyong						Flow: Modelled data based on data from Gauge at Four mile weir (412194) and Cumbung Swamp end of system (412154) Water Level: Modelled data based on spot measurements of water level during sampling, gauge data and upstream water level recorders	Sufficiently good relationship to create model except in very large flows where return flows from Merrimajeel Creek may be a problem
Merrowie Creek						Flow: Gauge at top end of Merrowie Creek downstream of offtake weir (412163) Water level: gauging site data	Gauge close to monitoring site
Other						Flow: TBA, but likely linked to Gauge at top end of Merrowie Creek downstream of offtake weir (412163) Water Level: TBA, but likely linked to Gauge at top end of Merrowie Creek downstream of offtake weir (412163)	

[1] Firm locations not yet provided, these are suggested locations

8.10 Monitoring protocol: Water Height

8.10.1 Equipment

Note that the water level loggers in most instances are to be installed with the dissolved oxygen loggers and the equipment serves multiple purposes.

- Water level logger with an accuracy of no less than 1 cm.
- Tool kit and spare parts for the water level sensor; including spare batteries.
- Metal star pickets/structure sufficiently long to be installed in the deepest part of the stream and star picket driver or mallet.
- PVC pipe to create a stilling well (http://www.onsetcomp.com/water_level_stilling_well.html)
- Means to attach the pipe and water level recorder to star picket or permanent structure.
- GPS.
- Staff gauge.
- Laptop and data cables for connecting to probes / logger.
- Field data sheets.
- Camera.
- Boat (for wide or deep streams).
- Life Jackets.
- Data sheets.
- A copy of this protocol.

Preparation

- Prior to deployment in the field, the probe must be calibrated according to manufacturer's instructions and results of calibration entered into a calibration log.
- Before leaving the office / laboratory the following should be checked for all electronic equipment (sensors, loggers, GPS):
    - Batteries are charged and properly inserted.
    - Previous data downloaded and memory cleared.
    - Check cable and cable connections.
    - Check for any obvious/minor faults on sensors including growth or dirt on the probes.
    - Check contents and condition of probe toolkit.
    - All equipment listed above is present and in functional order.

Site establishment

1. Find the site using the point location established in the Monitoring and Evaluation Plan.
2. Record the following on the field sheet:
    - River name and ANAE StreamID.
    - Date and time.
    - GPS coordinates (latitude and longitude; GDA94).
    - Name(s) of installation team.
3. Identify the deepest point in the stream.
4. Install the star picket/structure at the deepest point in the stream ensuring that it is solidly fixed.
5. Set the water level logger to record at hourly intervals.
6. Deploy water level logger according to manufacturer's instructions.

7. A series of photos of the site and installed structure are to be taken.
8. A cross-section of river depth is to be surveyed with the site survey extending up the banks on either side to encompass the bank full area.

Data collection

- Leave recorders deployed for between four and six weeks.
- At each repeat visit:
  - Download data from water level logger to a laptop following manufacturer's instructions
  - Download barometric pressure data (see Stream Metabolism method)
  - Clean water level recorder and perform routine maintenance if required
- Record any relevant information about the site (changes in site characteristics) since deployment.
- Check water depth manually using a staff gauge.

8.11 Quality Assurance/Quality Control

8.11.1 Flow Data from gauging stations

Quality assurance and quality control protocols implemented by the hydrographic agencies responsible for the gauging stations will be relied up for flow data from existing gauging stations.

8.11.2 Calibration and maintenance of water level recorder

Water level loggers records absolute pressure, which is later converted to water level readings using software which takes into account atmospheric pressure. To compensate for barometric pressure changes, a barometric reference will be used. The barometric reference used for the stream metabolism measurements will be used.

Water level sensors may drift during deployment. To check for sensor drift, a reference level is taken at the beginning and end of the deployment.

Maintenance: The logger requires the following periodic maintenance to ensure optimal operation:

- Protect the logger. This logger can be damaged by shock. Always handle the logger with care. The logger may lose its calibrated accuracy or be damaged if it is dropped. Use proper packaging when transporting or shipping the logger.
- Periodically inspect the logger for biofouling. Biological growth on the face of the pressure sensor will throw off the pressure sensor's accuracy. Organisms that grow inside the sensor nose cone and on the sensor itself can interfere with the sensor's operation and eventually make the sensor unusable. Check the logger when downloading data for biological growth.

8.12 Data analysis and reporting

8.12.1 Daily Mean 'Stage' (Water Height)

From gauging sites: The daily mean 'stage' will be downloaded from the NSW WaterInfo site (http://waterinfo.nsw.gov.au/). This will be the water level in metres above sea level.

From Water level recorders: The water height is measured at 15 minute intervals from the water level recorder and recorded as meters above zero (to 2 decimal places), where zero is the lowest point in the river at the site. Daily mean 'stage' water height is calculated as the mean of the 15 minute data from each day.

- Daily Mean 'Stage' Water Height (m) will be recorded electronically.

8.12.2 Daily mean river discharge

From gauging sites: The daily mean discharge (ML/day) will be downloaded from the NSW WaterInfo site (http://waterinfo.nsw.gov.au/).

Modelled data: The daily mean discharge (ML/day) will be calculated using a Source model (eWater) of flow using gauged flow and diversions (where available) as input data. Flow will be calibrated to downstream gauging sites.

8.12.3 Presence/absence of water at a site

Water height (stage) data will be used to determine the presence/absence of water at a site.

8.12.4 Frequency and duration of watering

The frequency and duration of watering event will be established from the flow records at the sites and linked to flow releases from Lake Brewster.

8.13 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

8.14 Health and safety

For details on health and safety please refer to the Workplace Health and Safety Plan for the Lower Lachlan river system Selected Area (WHS 202.1) in appendix 3.

8.15 References

Supplement 8A: Example Hydrology (River) Stage Height Data Collection Sheet

River name:		StreamID	
Observers:			
Water level logger location (s) (latitude and longitude; GDA94):			
Logging start time:			
Logging stop time:			
Notes:			

Supplement 8B: Assessing existing gauging data for use in evaluating outcomes

The Basin methods state that in many cases river hydrology may be available from local gauging stations or other monitoring projects. Such records should only be used if they are near the selected site (i.e. just upstream or within the zone) and if no tributaries exist between the site and the gauging station. This supplement provides an analysis of the gauging data and the ability to use it to model flow at sites between gauging stations.

Approach

The approach used to assess the suitability of existing gauging data for meeting the needs of the evaluation was to review it against set criteria (see below). Flow data from 2003 – 2014 (present) were analysed.

Criteria for the use of gauging data for both the Selected Area and Basin Evaluation are:

1. Proximity of gauging site to the sampling location
2. Presence absence of tributaries/distributaries between the gauging site and the sampling location
3. The ability to model flows at a site using existing gauging data

For the Selected Area Evaluation, consideration is also given to the hydrological metric used in the evaluation and the degree of accuracy required.

Basin Evaluation of riverine fish, stream metabolism and water quality

The Zone selected for the implementation of the Category 1 Riverine Fish methods is between Willandra Weir and Hillston (Refer Method 3: Riverine Fish). Within this Zone, there are gauging sites on the Lachlan River upstream of Willandra Weir and at Hillston. There are three distributary channels between the gauging sites: Willandra Creek (with a gauge immediately downstream of the fork); Middle Creek (ungauged) and Merrowie Creek (with a gauge immediately downstream of the fork) (Figure 3).

The hydrographs from the gauges at Willandra Weir and Hillston (Figure 4) and correlation of the data (Figure 5) show

- Higher flows at the upstream gauging site (upstream of Willandra Weir) than the downstream gauging site (Hillston). This is because:
    - flows above 2,400 ML/day in the Lachlan River upstream of Willandra Weir result in flows commencing in Willandra Creek
    - irrigation extractions occur in this reach particularly over summer periods (most notable for flows between 2011 and 2014)
    - Losses from the Lachlan River to Middle and Merrowie Creek.
    - Overbank flows during large events which do not return to the main channel.
- There is approximately a 3 day travel time from upstream of Willandra Weir to Hillston
- Correlation of data from the two sites is generally very good (Figure 5) and shows a well behaved relationship with hysteretic flows typical of lowland rivers of very low hydraulic gradient.

- The channel transmits flow in a well behaved and predictable manner. All flow components (base flow, fresh, bankfull and overbank flows) are propagated along the reach

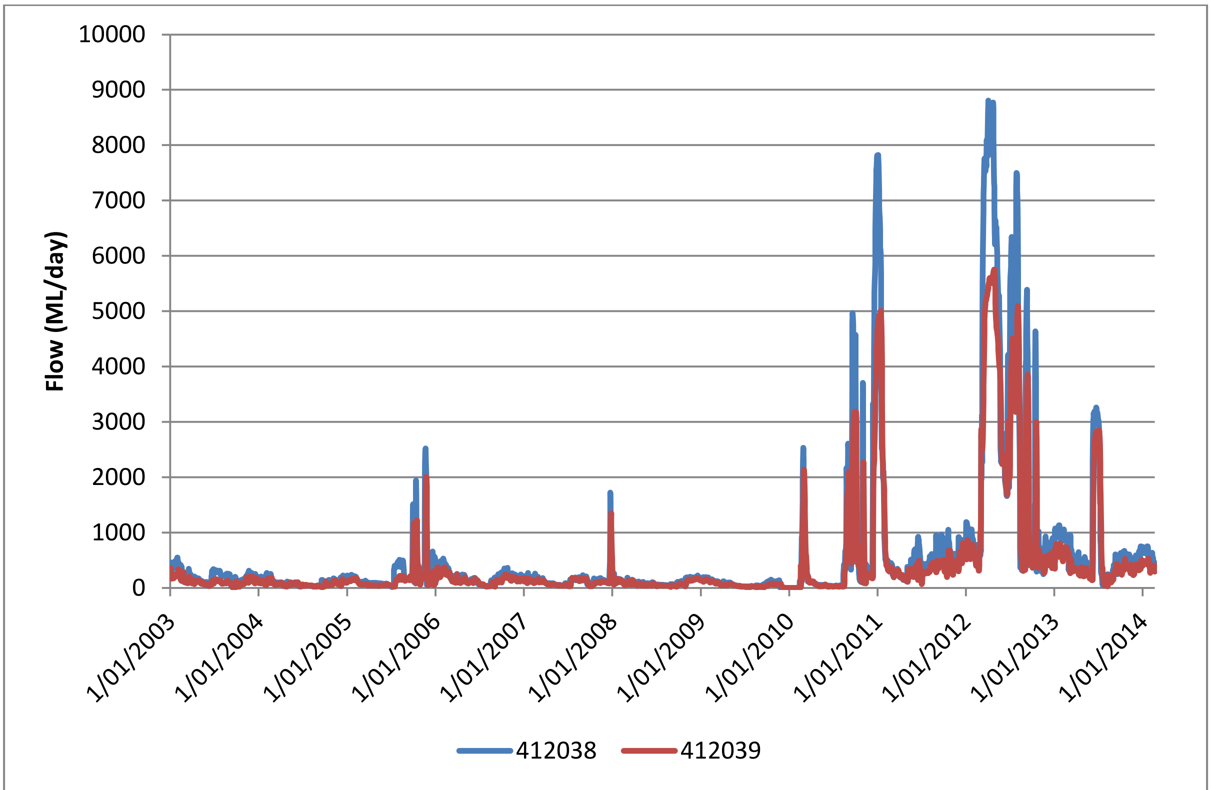

Figure 4. Hydrograph from the Lachlan River at Willandra Weir(412038) and the Lachlan River at Hillston (412039)

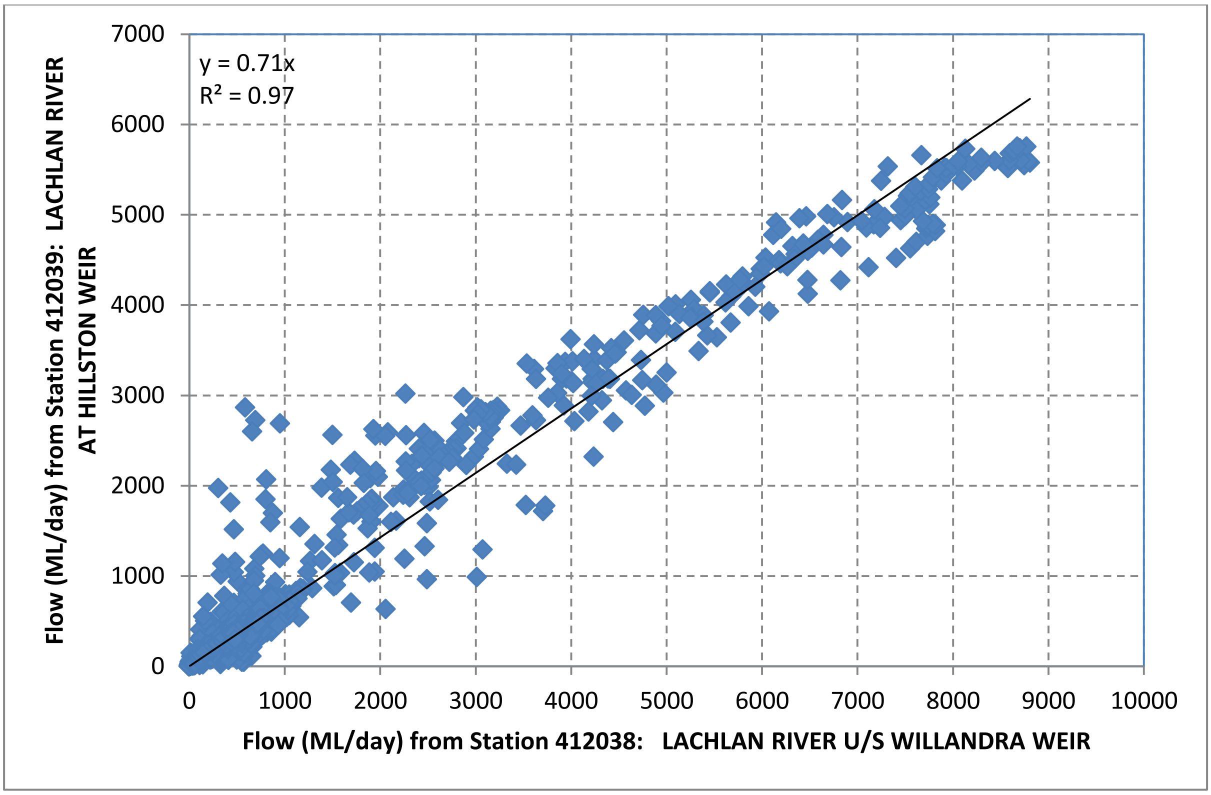

Figure 5. Correlation of flow data from the Lachlan River upstream of Willandra Weir and the Lachlan River at Hillston. A three day lag has been applied to Hillston data to account for approximate travel time.

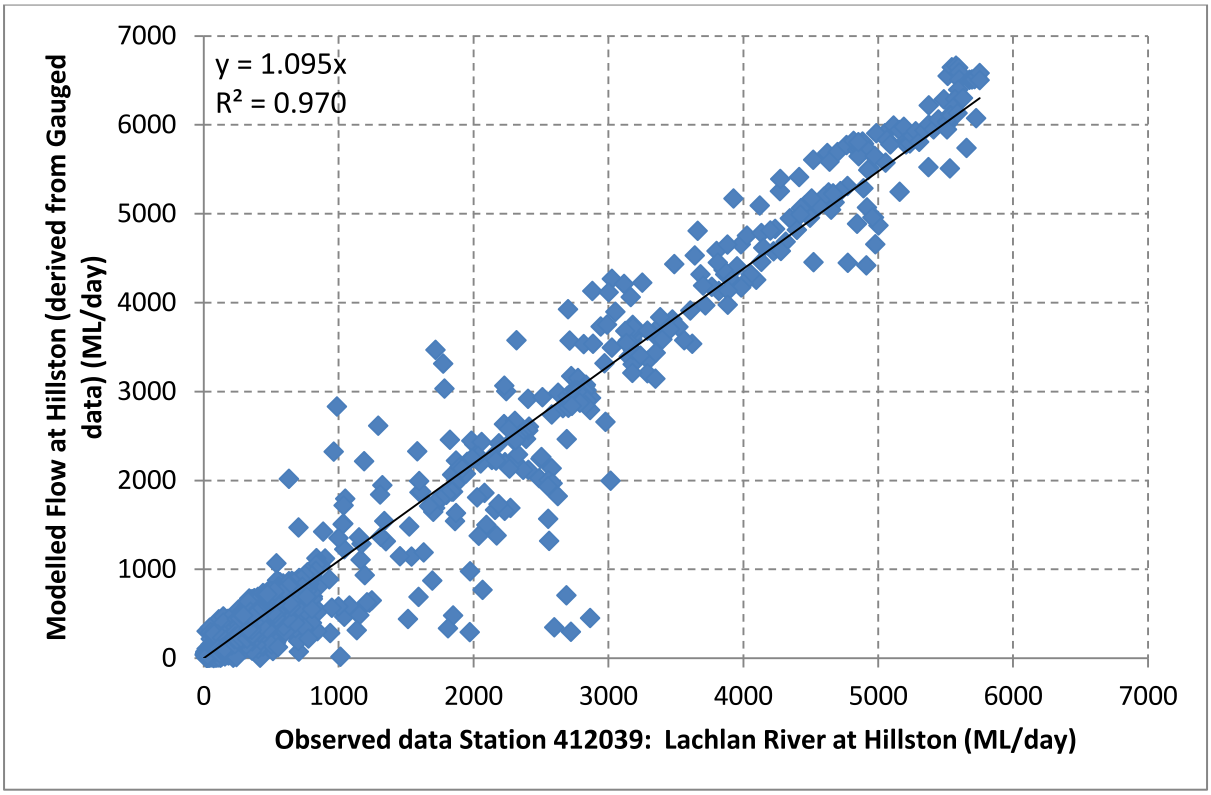

Figure 6. Correlation between modelled and observed flow at Hillston from preliminary modelling. Modelled flow is derived from gauging data and has not been corrected for irrigation demands nor targeted the types of environmental water releases expected.

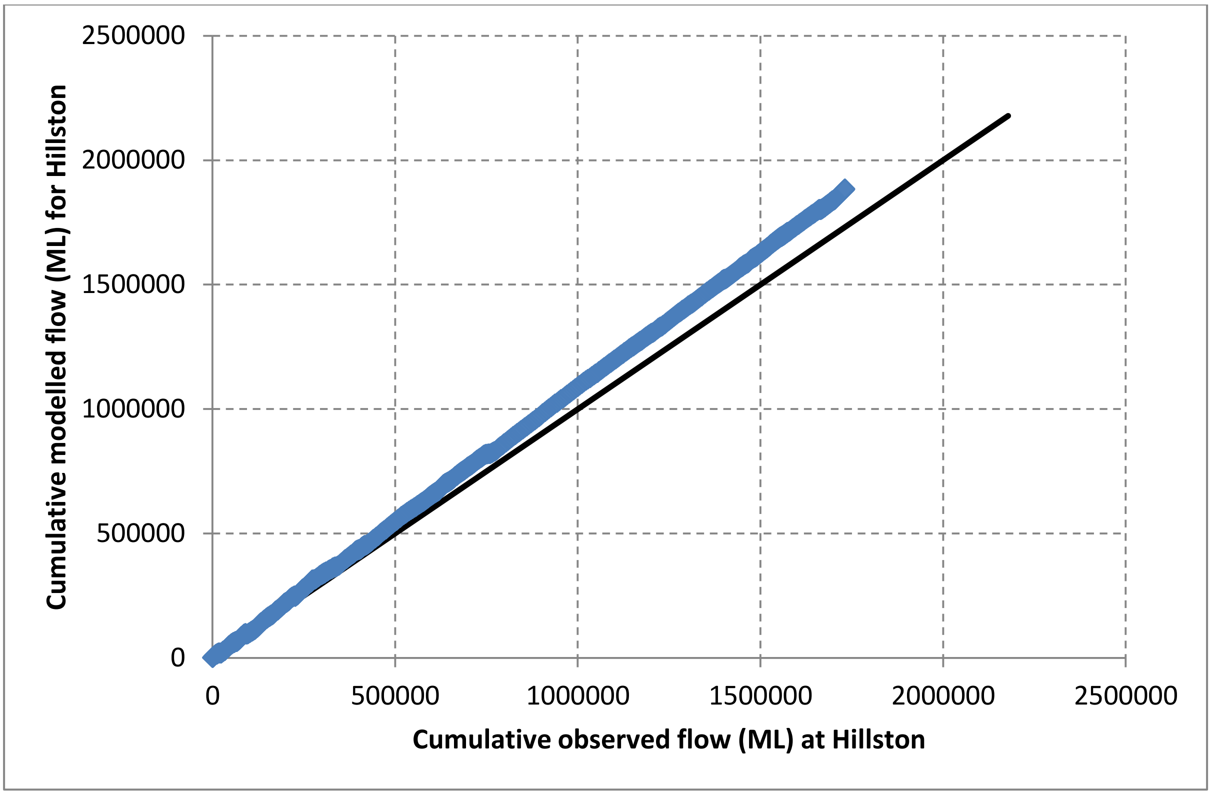

Figure 7. Double mass curve comparing modelled and observed flow for Hillston. Solid black line represents 1:1.

The well behaved nature of the system means that using the upstream gauge and modelling to allow for travel time and diversions will provide more than adequate hydrologic data at downstream sites. Preliminary modelling of flow at Hillston, without including irrigation demands (Figure 6 and Figure 7) suggests that flow can be modelled along this zone to within 10% accuracy.

Area Evaluation of indicators

The sites at which the category 3 riverine indicators will be applied are listed in Table 4. These sites are located either at, or between gauging stations. Key segments of the river are therefore between Hillston and Whealbah, Booligal and Corrong and Four mile weir to Cumbung swamp. These are assessed as follows.

Hillston to Whealbah

The segment of river between Hillston and Whealbah is a single channel without any tributary inputs or distributaries. The hydrographs from the gauges at Hillston and Whealbah (Figure 8) and correlation of the data from the two sites (Figure 9) show:

- Higher flows at the upstream gauging site (Hillston - 412039) than the downstream gauging site (Whealbah - 412078). This is because:
    - irrigation extractions occur in this reach particularly over summer periods (most notable for flows between 2011 and 2014).
    - Overbank flows during large events which do not return to the main channel.
- There is approximately a 3 day travel time from Hillston to Whealbah.
- The channel transmits flow in a well behaved and predictable manner. All flow components (base flow, fresh, bankfull and overbank flows) are propagated along the reach.
- Correlation of data from the two sites is generally good (Figure 9) and shows a well behaved relationship with some evidence of hysteretic flows typical of lowland rivers of very low hydraulic gradient.

The well behaved nature of this segment of river means that using the upstream gauge and modelling to allow for travel time and diversions will provide more than adequate hydrologic data at downstream sites.

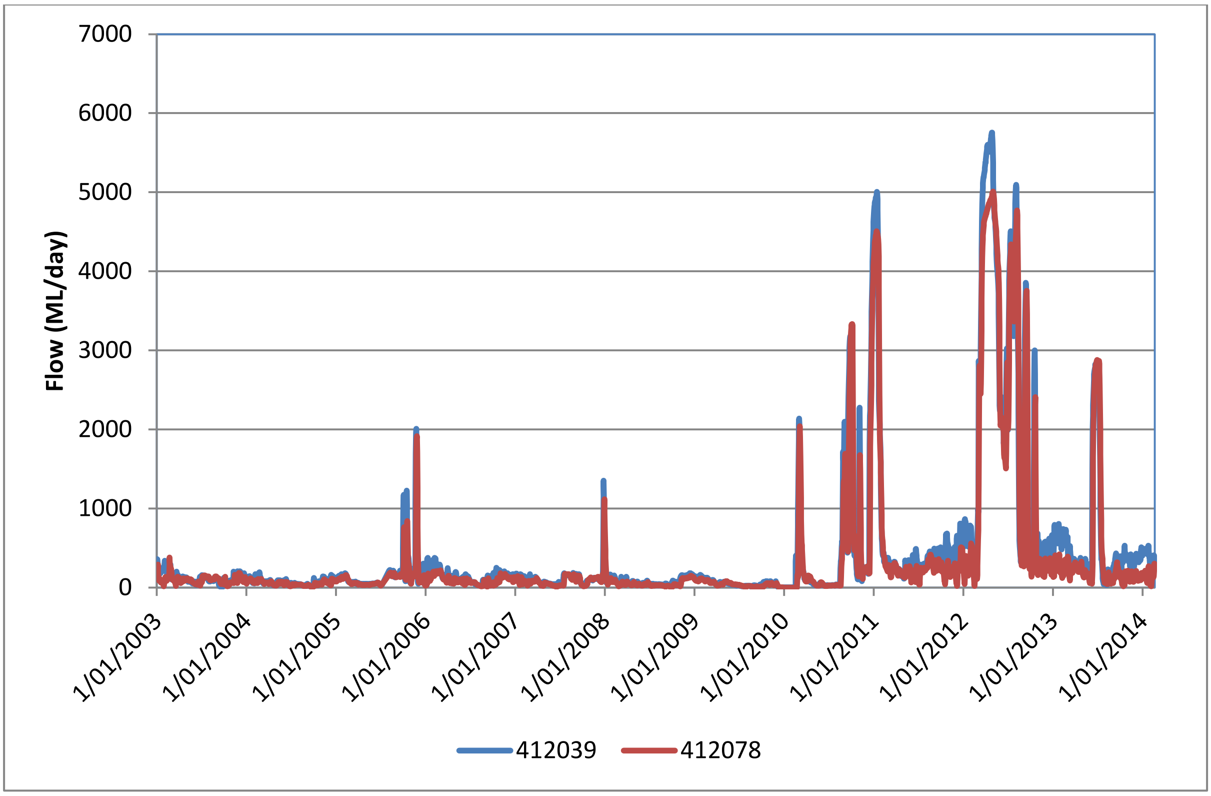

Figure 8. Hydrograph from the Lachlan River at Hillston (412039) and the Lachlan River at Whealbah (412078)

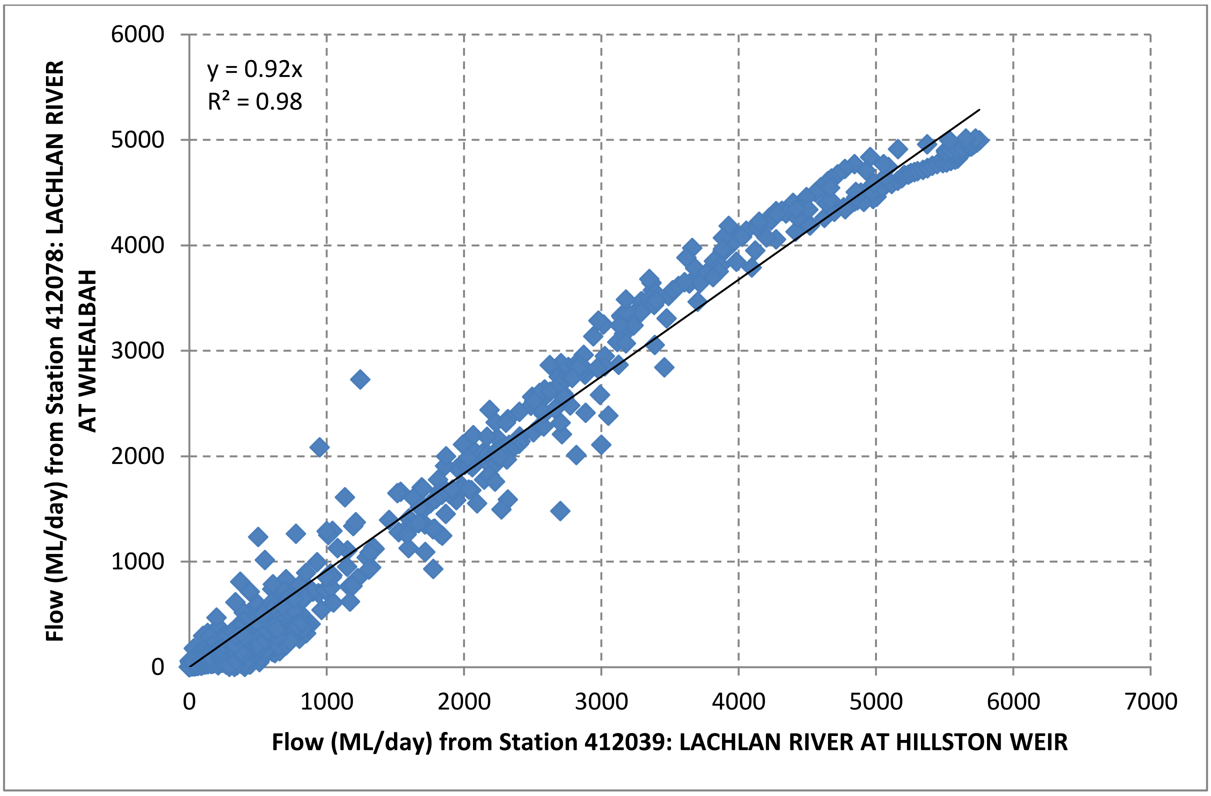

Figure 9. Correlation of flow data from the Lachlan River at Hillston Weir and the Lachlan River at Whealbah. A three day lag has been applied to Hillston data to account for approximate travel time.

8.15.1 Booligal to Corrong

The segment of river between Booligal and Corrong is a complex channel with multiple distributary and interconnecting channels that deliver flow to the complex of wetlands that make up the Lachlan swamp. Historical data from the gauges at Booligal and Corrong have significant periods where the data are classified as being of large uncertainty or the rating table was considered to be unstable. This was particularly noted for the past 10 years of data. For the purposes of this analysis, the past 20 years of data have been used.

In spite of the data limitations, the hydrographs from the gauges at Booligal and Corrong (Figure 10) indicates:

- Generally higher flows at the upstream gauging site (Booligal - 412005) than the downstream gauging site (Corrong - 412045). This is consistent with:
    - Significant losses to the wetland complex in this reach of the river.
    - Overbank flows during large events that do not return to the main channel.
- There is approximately a 10-12 day travel time from Booligal to Corrong.
- The flow components (base flow, fresh, bankfull and overbank flows) are propagated along the reach in spite of the magnitude of flows changing considerably, particularly for flows of more than 1000 ML/day at Booligal.

Correlation of data from the two sites is poor (Figure 11) and shows strongly hysteretic flows which are typical of flood-out reaches of very low gradient lowland rivers.

Using the upstream gauging data and modelling (using Source) to allow for travel time, reach storage, filling of wetland/dead storage and diversions is likely to provide a much better prediction than direct correlation. Categorical data will also be able to be provided to facilitate the evaluation of environmental outcomes. In such a complex system with multiple mobile channels it is unlikely that installing a new gauging site is going to be practical.

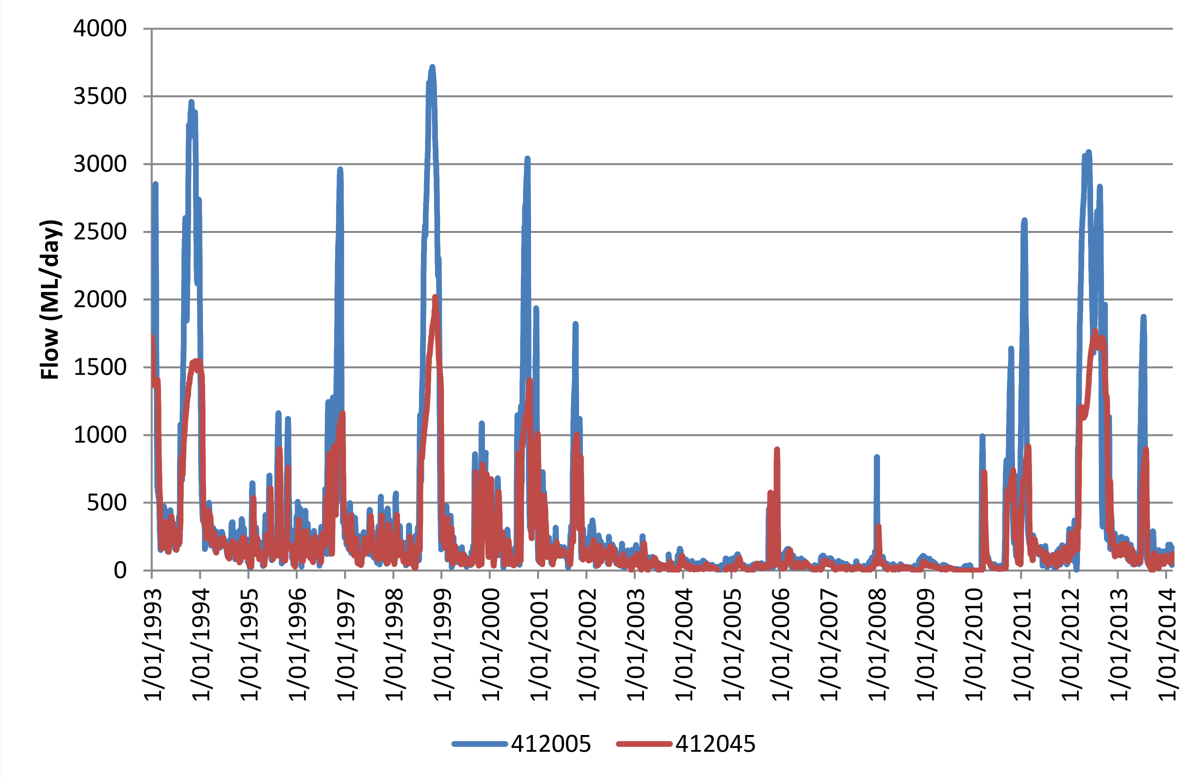

Figure 10. Hydrograph from the Lachlan River at Booligal (412005) and the Lachlan River at Corrong (412045).

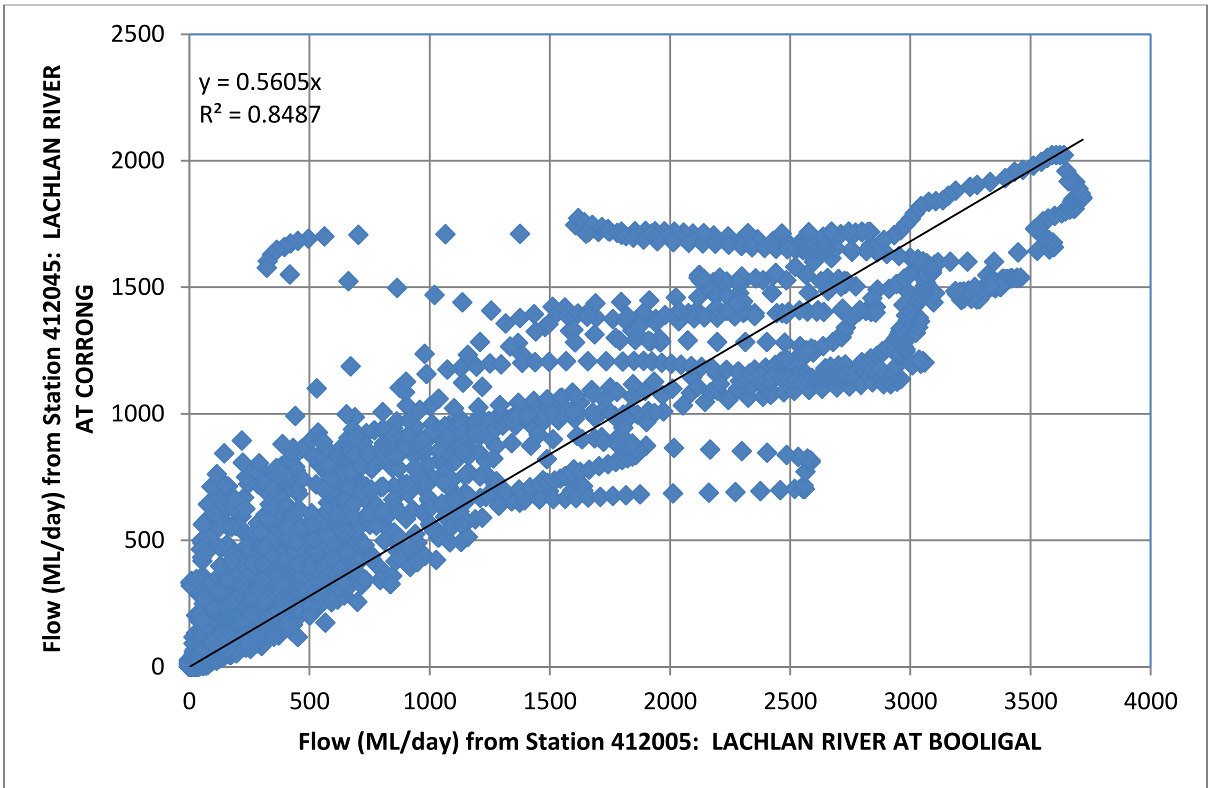

Figure 11. Correlation of flow data from the Lachlan River at Booligal and the Lachlan River at Corrong. A 12 day lag has been applied to the Corrong data to account for approximate travel time.

8.15.2 Corrong to Four mile weir

The segment of river between Corrong and Four Mile Weir is a single channel with no tributaries or distributaries. Data only exist from the gauge at Four Mile Weir from September 2009 until present. The hydrographs from the gauges at Corrong and Four Mile Weir (Figure 12) indicates:

- Generally higher flows at the upstream gauging site (Corrong – 412045) than the downstream gauging site (Four Mile Weir - 412194). This is consistent with:
    - Overbank flows that do not return to the main channel.
    - Overbank flows commencing at quite low flow rates.
- There is approximately a 7 day travel time from Corrong to Four Mile Weir.
- The flow components (base flow, fresh, bankfull and overbank flows) are propagated along the reach in spite of the magnitude of flows changing considerably.

Correlation of data from the two sites is moderate (Figure 13) and shows hysteretic flows which are typical of very low gradient lowland rivers.

Using the upstream gauging data and modelling to allow for travel time and diversions is likely to provide a reasonable estimate of flow of less than 400 ML/day in this section of the reach using a Source model noting limited period of data available for calibration. Categorical data about the flow components will be able to be accurately provided to facilitate the evaluation of environmental outcomes.

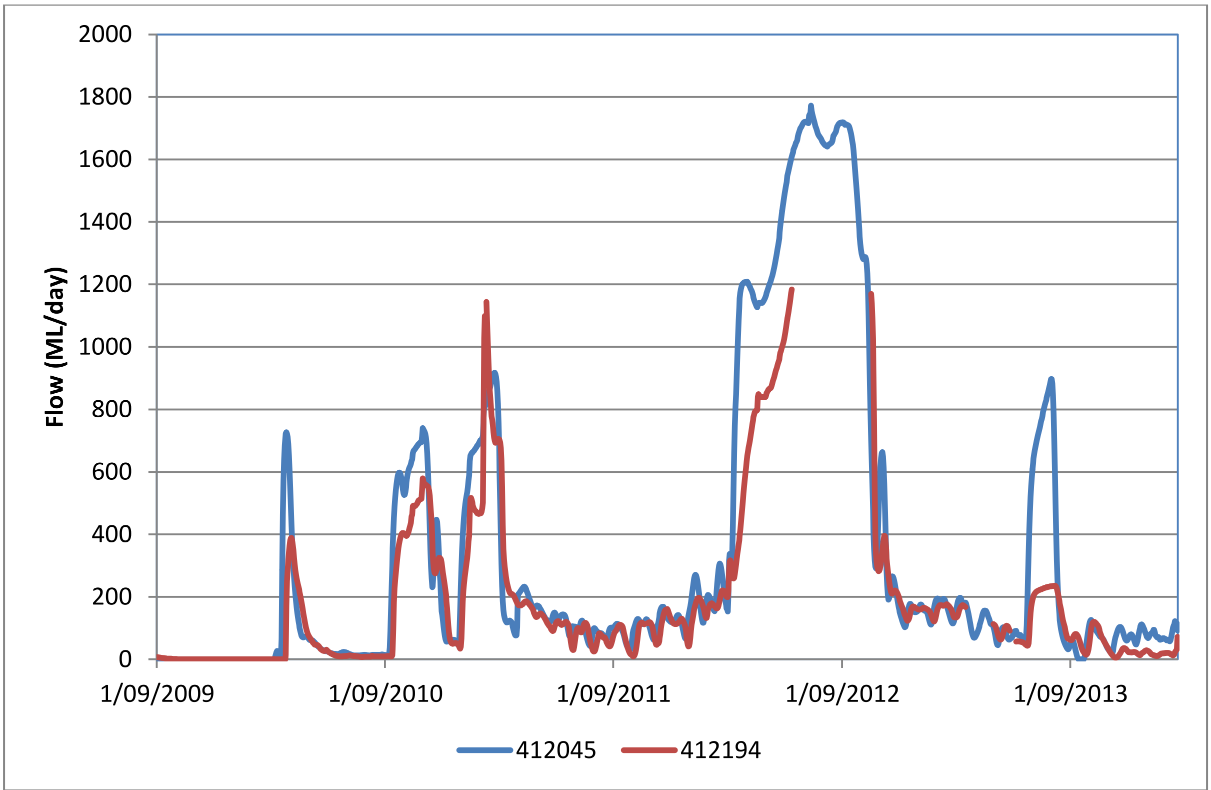

Figure 12: Hydrograph from the Lachlan River at Corrong (412045) and the Lachlan River at Four Mile Weir (412194).

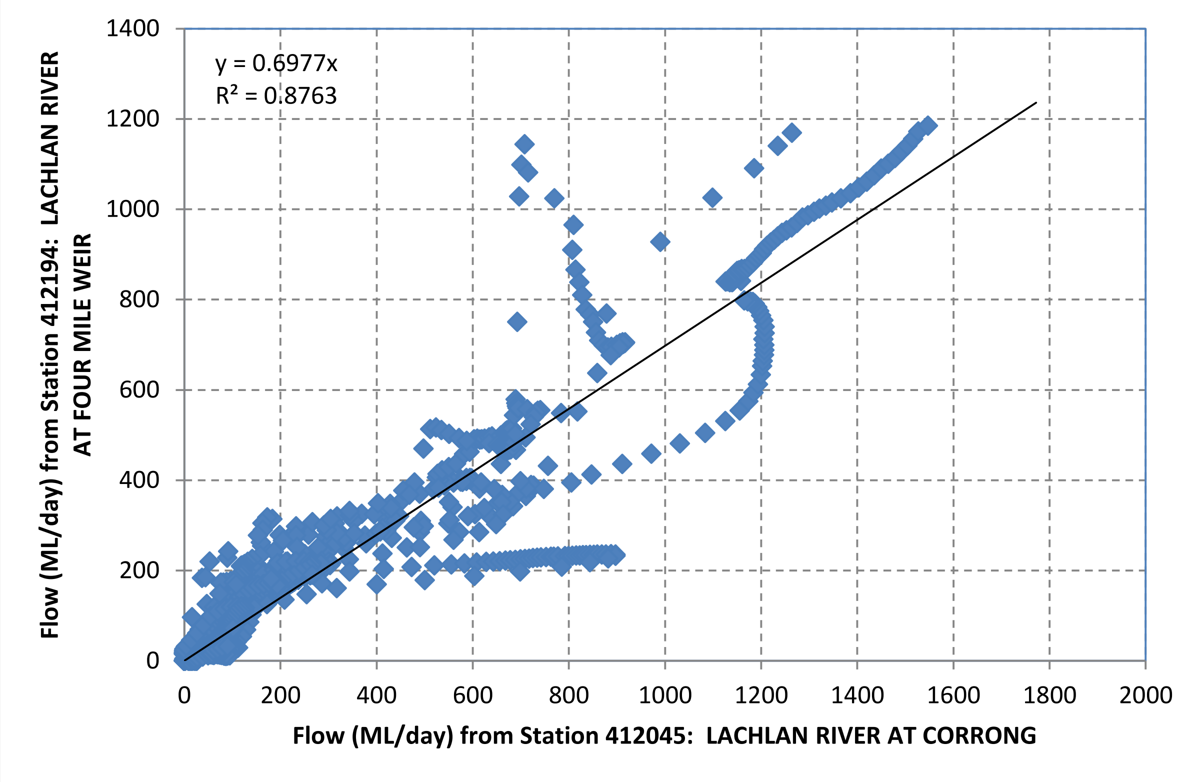

Figure 13. Correlation of flow data from the Lachlan River at Corrong (412045) and the Lachlan River at Four Mile Weir (412194). A 7 day lag has been applied to Corrong data to account for approximate travel time.

8.15.3 Four mile weir to Cumbung End of System

The segment of river between Four Mile Weir and Cumbung End of System comprises a dominant channel with a series of floodplain wetlands terminating in the Great Cumbung Swamp. Merrimajeel Creek rejoins the river between these gauging sites.

Discussions with NOW staff – many years attempting to install gauging in this site and flow gauging is unreliable.

Table 4. Monitoring sites for category 3 indicators and the corresponding upstream and downstream gauging stations.

SITE	VEG[1]	RIVERINE FISH	LARVAL FISH	METAB-OLISM	MICRO-CRUSTACEANS	TURTLES AND DECAPODS	UPSTREAM GAUGING SITE	DOWNSTREAM GAUGING SITE
Lachlan River @ Benson's Drop		Y	Y		Y	Y	Willandra weir (412038) verified using releases from Lake Brewster	
Lachlan River @ Willanthry		Y	Y	Y	Y	Y	Willandra weir (412038) Willandra Creek at the bridge (412012)	Gauge at Hillston (412039)
Lachlan River @ Moora Farm		Y				Y	Willandra weir (412038) and the Willandra Creek at the bridge (412012)	Gauge at Hillston (412039)
Lachlan River @ Lane's Bridge		Y		Y		Y	Willandra weir (412038); Willandra Creek at the bridge (412012)	Gauge at Hillston (412039)
Lachlan River @ Hillston	Y	Y				Y	Gauge at Hillston (412039)	
Lachlan River @ Hazelwood	Y						Gauge at Hillston (412039)	Gauge at Whealbah (412078)
Lachlan River @ Cowl Cowl		Y		Y		Y	Gauge at Hillston (412039)	Gauge at Whealbah (412078)
Lachlan River @ Whealbah		Y	Y	Y	Y	Y	Gauge at Whealbah (412078)	
Lachlan River @ Booligal		Y	Y		Y	Y	Gauge at Booligal (412005)	
Lachlan River @ Boxyards							Gauge at Booligal (412005)	Flow: Gauge at Corrong (412045)
Lachlan River @ Ulonga							Gauge at Booligal (412005)	Flow: Gauge at Corrong (412045)
Lachlan River @ Corrong							Flow: Gauge at Corrong (412045)	
Lachlan River @ Braebuck Woolshed							Four mile weir (412194)	
Lachlan River @ Twitcher's Hut/Geramy	Y						Four mile weir (412194)	Cumbung Swamp end of system (412154).
Lachlan River @ Boyong							Four mile weir (412194)	Cumbung Swamp end of system (412154)

SITE	VEG[1]	RIVERINE FISH	LARVAL FISH	METAB-OLISM	MICRO-CRUSTACEANS	TURTLES AND DECAPODS	UPSTREAM GAUGING SITE	DOWNSTREAM GAUGING SITE
Merrowie Creek							Merrowie Creek downstream of offtake weir (412163)	

1.0 Conclusion

On the basis of these analyses we will develop models of the flow in the Lachlan River between gauging stations. Source (eWater) will be used as the modelling platform. For each segment of the river, the input data will be flow from the upstream gauge/s and diversion data (where available) and the model will be calibrated to flow at the downstream gauge.

9 Hydrology (wetland): Basin and Selected Area methods

9.1 Overview

This protocol describes the methods that will be used for both Basin Evaluation (specified by the CEWO) and the Selected Area Evaluation. While Basin scale methods consider that the hydrological data collected for these methods will inform only the analysis and evaluation of monitoring outcomes for hydrological connectivity, waterbirds and native fish, the M&E Providers for the Lachlan River system Selected Area consider hydrological data essential to the evaluation of outcomes for ***all*** indicators.

9.2 Evaluation questions

9.2.1 Basin Evaluation questions

This protocol does not directly address specific evaluation questions but is important for informing the analysis and evaluation of outcomes for hydrological connectivity, waterbirds and native fish. It indirectly addresses the following Basin Evaluation questions:

- **Long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to hydrological connectivity?
  - What did Commonwealth environmental water contribute to waterbird populations?
  - What did Commonwealth environmental water contribute to native fish species diversity?
  - What did Commonwealth environmental water contribute to fish community resilience?
- **Short-term (one year) questions:**
  - What did Commonwealth environmental water contribute to waterbird breeding?
  - What did Commonwealth environmental water contribute to waterbird chick fledging?
  - What did Commonwealth environmental water contribute to waterbird survival?
  - What did Commonwealth environmental water contribute to native fish reproduction?
  - What did Commonwealth environmental water contribute to native larval fish growth and survival?

The process for evaluating these questions is illustrated in Figure 1, with components covered by this protocol highlighted in blue.

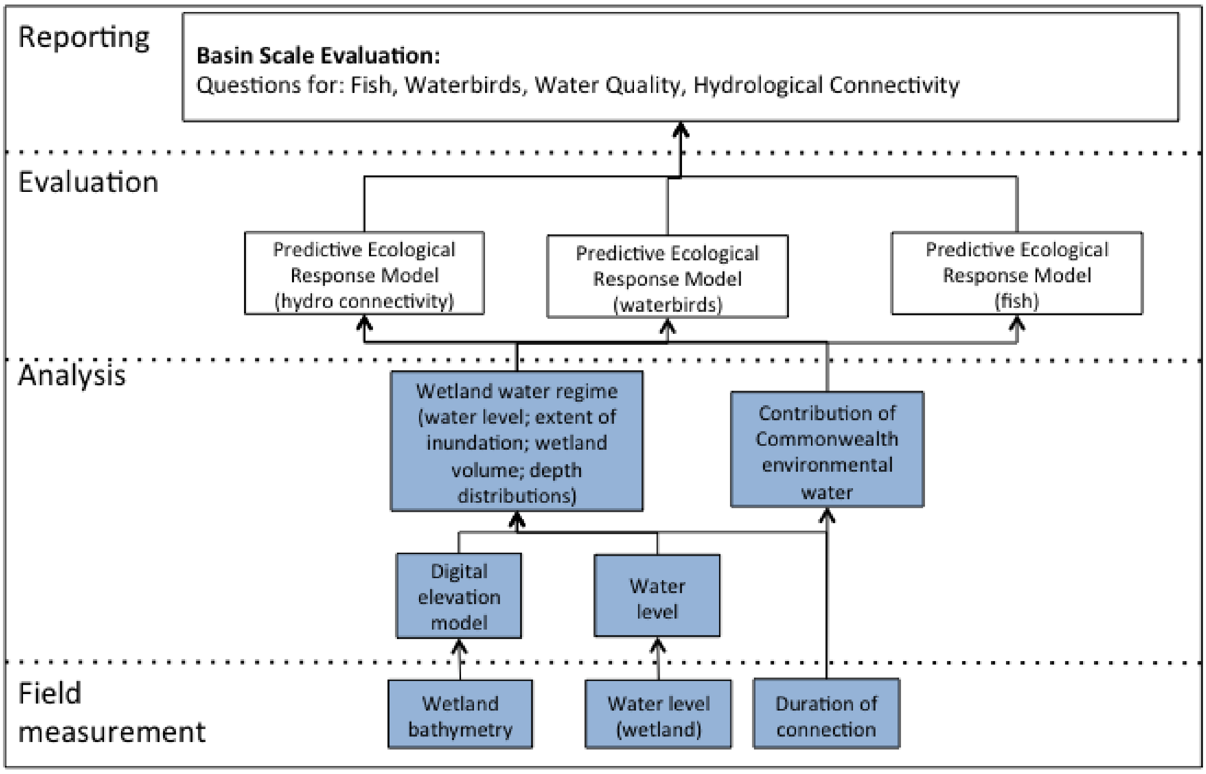

Figure 1: Schematic of key elements of the LTIM Standard Protocol for Basin Evaluation: Hydrology (wetland).

9.2.2 Selected Area evaluation questions

This protocol does not directly address specific evaluation questions but is important for informing the analysis and evaluation of monitoring outcomes for ***all*** of indicators. The wetland indicators for the Lachlan River system Selected Area that will use hydrological data and the relevant hydrological measures are shown in

Table 1. As such the protocol indirectly addresses the following Area scale evaluation questions:

- **Long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to sustainable ecosystem diversity?
  - Were ecosystems to which Commonwealth environmental water was allocated sustained?
  - Was water delivered to a representative suite of ecosystem types?
  - What did Commonwealth environmental water contribute to vegetation extent?
  - What did Commonwealth environmental water contribute to microcrustacean community composition?
  - What did Commonwealth environmental water contribute to native fish populations?
  - What did Commonwealth environmental water contribute to native fish species diversity?
  - What did Commonwealth environmental water contribute to fish community resilience?
  - What did Commonwealth environmental water contribute to native fish survival?
  - What did Commonwealth environmental water contribute to waterbird populations?
  - What did Commonwealth environmental water contribute to waterbird species diversity?
  - What did Commonwealth environmental water contribute to sediment transport?
  - What did Commonwealth environmental water contribute to biotic dispersal?
  - What did Commonwealth environmental water contribute to populations of long-lived organisms?

- **Short-term (one year) questions:**
  - What did Commonwealth environmental water contribute to microcrustacean contribution to the abundance of native larval fish?
  - What did Commonwealth environmental water contribute to microcrustacean contribution to the growth of native larval fish?
  - What did Commonwealth environmental water contribute to microcrustacean contribution to the survival of native larval fish?
  - What did Commonwealth environmental water contribute to connectivity of microcrustacean communities between river and wetlands?
  - What did Commonwealth environmental water contribute to native fish reproduction?
  - What did Commonwealth environmental water contribute to native larval fish growth and survival?
  - What did Commonwealth environmental water contribute to other vertebrate reproduction and recruitment?
  - What did Commonwealth environmental water contribute to other vertebrate survival?

- **Short-term (one-year) and long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to the condition of floodplain and riparian trees?
  - What did Commonwealth environmental water contribute to vegetation community diversity?
  - What did Commonwealth environmental water contribute to vegetation species diversity?
  - What did Commonwealth environmental water contribute to microcrustacean productivity?

- What did Commonwealth environmental water contribute to resilience of microcrustacean egg banks?
- What did Commonwealth environmental water contribute to waterbird breeding?
- What did Commonwealth environmental water contribute to waterbird chick fledging?
- What did Commonwealth environmental water contribute to waterbird survival?
- What did Commonwealth environmental water contribute to other vertebrate reproduction and recruitment?
- What did Commonwealth environmental water contribute to other vertebrate survival?
- What did Commonwealth environmental water contribute to hydrological connectivity?
- What did Commonwealth environmental water contribute to refuges?
- What did Commonwealth environmental water contribute to recovery?
- What did Commonwealth environmental water contribute to fish community resilience?

Table 1. Lachlan River system Selected Area indicators and the hydrological metrics used in the evaluation

INDICATOR	USE IN EVALUATION	HYDROLOGY ATTRIBUTES USED IN EVALUATION
Ecosystem Type (Cat 1)	Basin Scale: Validation of hydrological regime	Permanent or temporary surface water (from long term records)
Tree stand condition (Cat 1)	Basin Scale: Predictive Ecological response model	unspecified
Vegetation Diversity and condition (Cat 3)	Area Scale: Change in vegetation metrics in relation to watering	presence/absence of water; water depth, duration of watering, frequency of watering
Fish (Wetland) (Cat 1)	Basin Scale: Predictive Ecological Response model	unspecified
Fish (Wetland) (Cat 3)	Area Scale: Change in fish metrics in relation to wetland hydrology attributes	flood pulse duration and magnitude, dry spell duration total flow volume categorical flow component (base flow, freshes, bankfull and overbank)
Fish (larvae) (Cat 1)	Basin Scale Predictive Ecological Response Model	unspecified
Fish (larvae) (Cat 3)	Area Scale: Assessing larval fish metrics against hydrological attributes	watering event extent - timing, duration, water depth
Microinvertebrates (Cat 3)	Area Scale: Relationships between the key microcrustacean variables and density and growth of larval fish, flow, river height, time since last inundation, time dry and other covariates will be examined using Bayesian statistics to test a conceptual model of expected relationships.	flow, water depth, time since last inundation, time dry
Turtles and Decapods (Cat 3)	Area Scale: Change in turtle and decapod numbers in relation to wetland hydrology attributes	flood pulse duration and magnitude, dry spell duration and total flow volume categorical flow component categories (base flow, freshes, bankfull and overbank)

9.3 Relevant ecosystem types

Wetlands.

9.4 Relevant flow types

Bankfull, overbank and overbank (infrastructure assisted).

9.5 Overview and context

9.5.1 Basin scale

At the Basin scale, hydrology (wetland) is an event based monitoring protocol designed to capture aspects of a wetland's water regime that influence behaviour and condition of waterbirds and native fish. In particular, this protocol aims to quantify the effect of Commonwealth environmental water on aspects of wetland hydrology that are most important for waterbirds and native fish. This protocol is based on a combination of field measures and hydrological modelling and comprises:

- Wetland bathymetry (digital elevation model).
- *In situ* water level loggers.
- River inflows and outflows.

9.5.2 Area scale

At the area scale, hydrology (wetland) is a continuous monitoring protocol designed to capture aspects of a wetlands water regime that will be used to evaluate the effect of Commonwealth environmental water. This protocol is based identifying the attributes that will be used in the evaluation for each of the indicators within the Lachlan River System Selected Area and uses a combination of existing gauge data, field measures and hydrological modelling.

Key hydrological attributes of wetland required to inform the evaluation are:

- Presence/absence of water at a site
- Frequency and duration of watering
- Water depth
- Connection

The protocol therefore comprises:

- Wetland bathymetry (digital elevation model)
- *In situ* water level loggers
- Fixed point cameras
- River inflows and outflows

9.6 Complementary monitoring and data

While in many Selected Areas water level recorders and / or wetland bathymetry are available from other studies or monitoring projects, wetland bathymetry to the accuracy specified by the M&E Advisers for Basin Evaluation is not available in the lower Lachlan system, nor are there operational water level recorders in the wetlands.

Historical monitoring programs have relied on basic bathymetric data (wetland extent and spot measurements of depth) and known depth-area relationships from which volume can be reasonably estimated. These data will be drawn upon for Area Evaluation.

The project will also rely on the systematic mapping of inundation extent being undertaken for the Lower Lachlan River System Selected Area by NSW OEH. These data will be used to establish inundation extent and the dates of wetland connection. The current extent of the inundation mapping is expected to be extended as part of the LTIM Project to encompass the entire area of the Lower Lachlan River System Selected Area and this method relies on those data becoming available.

9.7 Establishing sites

9.7.1 Overview

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy for stream metabolism is as follows:

Selected Area → Zone → Site

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

A site is the unit of assessment nested within a zone and in this instance will be a wetland or complex of wetlands.

9.7.2 Basin scale site establishment

Wetland hydrology is required to inform the Basin-scale quantitative evaluation of fish and waterbird responses to Commonwealth environmental water (see LTIM Standard Protocol: Fish (Wetland); LTIM Standard Protocol: Waterbird breeding and LTIM Standard Protocol: Waterbird diversity). The sample design for the fish (wetland) protocol involves a minimum of a single zone with three wetland sites; protocols for waterbirds are more flexible. Wetland hydrology will be undertaken at all sites at which fish and / or waterbirds are monitored.

9.7.3 Area scale site establishment

Wetland hydrology is also required to inform Area-scale evaluation of all wetland based indicator responses to Commonwealth environmental water (see other methods for the Lachlan River system). Area scale site establishment is therefore linked to the sites used for wetland fish, waterbird breeding and diversity, vegetation condition and diversity, microinvertebrates, turtles and decapods monitoring.

9.8 Monitoring locations

9.8.1 Locations: Basin scale evaluation

For the Lachlan River system, the Zone established for the implementation of Category 1 methods for wetland and larval fish monitoring is Zone 1 with the three wetlands selected for monitoring being Moon moon swamp, Booligal swamp and Murrumbidgil Swamp. The only wetland to be targeted for waterbird breeding events is Booligal swamp.

9.8.2 Locations: Area scale evaluation

Locations will be matched to the sampling locations for Category 3 methods for wetland fish, waterbird diversity, vegetation condition and diversity, microinvertebrates, turtles and decapods. These sites are summarized in Table 2 and shown in Figure 2.

Table 2. Wetland monitoring sites and the source of hydrological data for use in evaluation

SITE	VEGETATION [1]	WETLAND FISH	LARVAL FISH	WATER-BIRDS	MICRO-CRUSTACEANS	TURTLES AND DECAPODS	HYDROLOGY DATA SOURCE
Gum swamp							Inundation mapping NSW OEH
Hillston-Hunthawang River/Billabong							Inundation mapping NSW OEH
Hazelwood Billabong	Y						Inundation mapping NSW OEH
Whealbah Billabong	Y						Time lapse camera to identify connection
Moon Moon swamp	Y			Diversity			DEM established using UAV acquired data and a single water depth logger in the deepest point of the open swamp area
Thompsons Billabong							Inundation mapping NSW OEH
Upper Lachlan Swamp							Inundation mapping NSW OEH
Lower Lachlan swamp							Inundation mapping NSW OEH
Peppermint swamp							Inundation mapping NSW OEH
Lake Waljeers							Inundation mapping NSW OEH
Lake Bullogal	Y						Inundation mapping NSW OEH
Ryan's Lake							Inundation mapping NSW OEH
Erin's Billabong	Y						Inundation mapping NSW OEH
Lake Ita	Y						Inundation mapping NSW OEH
Baconian Swamp							Inundation mapping NSW OEH
Great Cumbung Swamp							Inundation mapping NSW OEH
Lignum Lake	Y			Diversity			known depth-area relationships One water depth logger at deepest point Time lapse camera to identify connection
Marrool Lake	Y			Diversity			known depth-area relationships

SITE	VEGETATION [1]	WETLAND FISH	LARVAL FISH	WATER-BIRDS	MICRO-CRUSTACEANS	TURTLES AND DECAPODS	HYDROLOGY DATA SOURCE
							One water depth logger at deepest point Time lapse camera to identify connection
Spells Paddock				Diversity			Wetland extent and depth measurements One water depth logger at deepest point Time lapse camera to identify connection
Charlie's Lake							Inundation mapping NSW OEH
Clear Lake							Inundation mapping NSW OEH
Lake Tarwong							Inundation mapping NSW OEH
Cuba Dam	Y						Inundation mapping NSW OEH
Tom's Lake							Inundation mapping NSW OEH
Upper Gum Swamp							Inundation mapping NSW OEH
Booligal Swamp	Y			Breeding Diversity			DEM established using UAV acquired data and 3 water depth loggers distributed throughout swamp
Murrumbidgil Swamp				Diversity			DEM established using UAV acquired data and 3 water depth loggers throughout swamp
Lake Merrimajeel	Y						Inundation mapping NSW OEH
Lower Gum Swamp	Y						Inundation mapping NSW OEH

[1] Firm locations not yet provided, these are suggested locations.

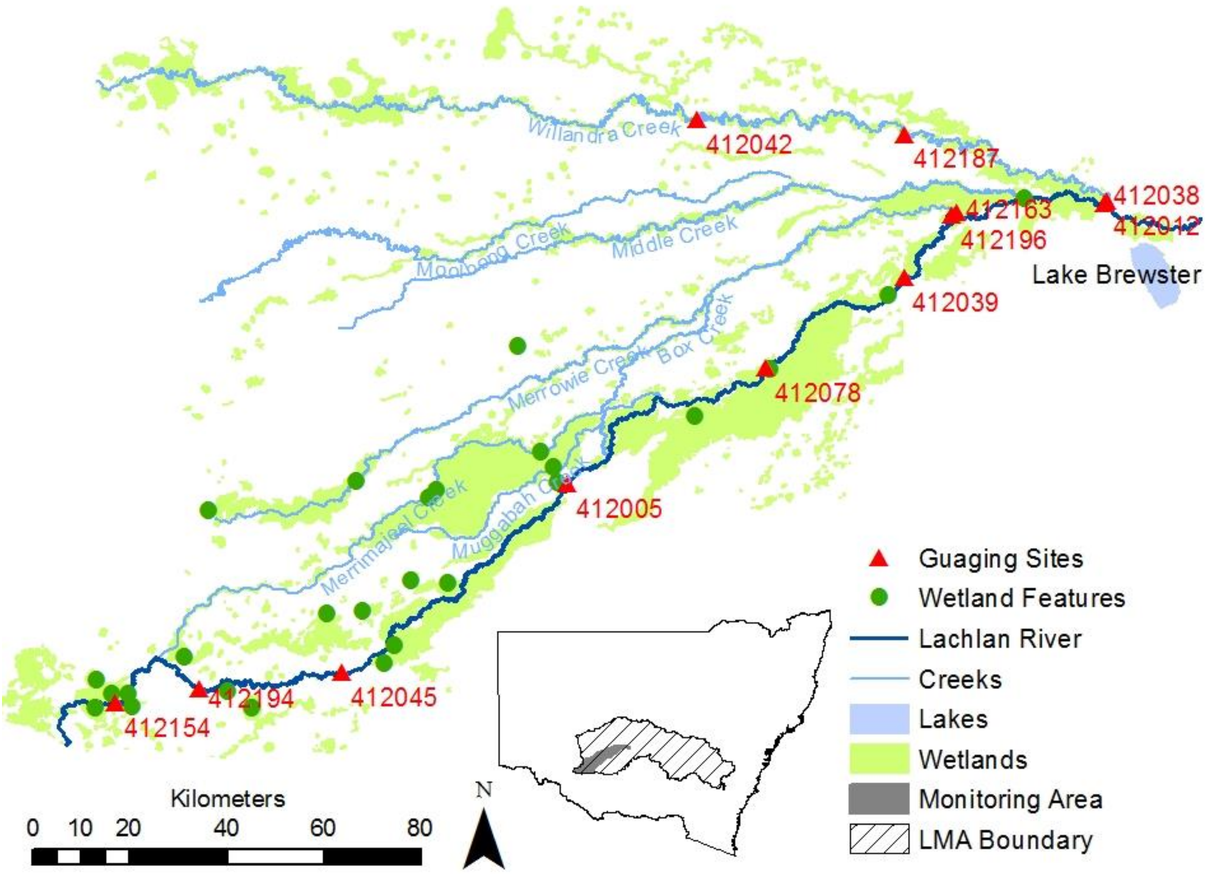

Figure 2. Map showing wetland site locations for all sites monitored within wetland in the Lower Lachlan River System Selected Area.

9.9 Timing of monitoring

This protocol aims to capture the wetland hydrology of sites that are monitored for biotic responses as part of the LTIM Project. Monitoring must therefore commence at the time the biological monitoring commences, or the time that Commonwealth environmental water is delivered to the site, whichever is the earlier. Monitoring of wetland hydrology must continue for the duration of biological monitoring or the influence of Commonwealth environmental water on the site, whichever is the later.

Timing of the releases of Commonwealth environmental water (June to August each year) and contract establishment means that the installation of water level recorders is unlikely to commence until after the 2014 environmental water releases.

9.10 Wetland bathymetry: Basin Evaluation

Wetland bathymetry is required to develop a digital elevation model (DEM) of sufficient resolution to calculate measures such as extent and duration of inundation and water depth distributions. As existing data are not sufficient to establish a DEM for the three wetlands used for Basin Evaluation survey will be used to collect bathymetric information.

The three wetlands of interest are large (Booligal Swamp = approximately 800 ha; Murrumbidgil Swamp = approximately 200 ha and Moon-moon swamp: 330 ha), with complex bathymetry and at times impenetrable vegetation. Over such sized wetlands, traditional ground based survey is time consuming and costly; LIDAR data collection used a fixed wing aircraft is also costly. The most cost effective option for establishing wetland bathymetry is to use Unmanned Aerial Vehicles (UAV's) mounted with Near Infrared (NIR) and true colour (RGB) cameras to produce high resolution images and accurate geo-reference Digital Surface Models (DSM).

Details of the data capture and output is included as Supplement 9B, and it is noted that the following specifications have been established:

- Elevation and grid size accuracy to 0.05 m.
- DEM will be referenced to m AHD.
- The lowest point(s) of the wetland will be determined using a suitable software package.

Wetland maximum extent will be estimated as the boundary between the wetland and the surrounding terrestrial land (i.e. the level or sill where further inundation would result in water spilling out of the wetland onto the surrounding land) is not clear.

9.11 *In-situ* logging: Basin and Area Evaluation

Water level loggers are deployed in the deepest part/s of the wetland and set to record water level daily. Loggers are deployed for the entire period that Commonwealth environmental water is influencing the wetland water regime. A number of the wetlands being monitored for the basin scale evaluation have complex bathymetry and therefore require multiple water depth loggers (these are noted in Table 2).

9.11.1 Equipment

- Water level logger with an accuracy of no less than 1 cm.
- Tool kit and spare parts for the water level sensor; including spare batteries.
- Metal star pickets/structure for holding the logger and star picket driver or mallet.
- PVC pipe to create a stilling well (http://www.onsetcomp.com/water_level_stilling_well.html)
- Means to attach probe to star picket or permanent structure.
- GPS.
- Field data sheets.
- Laptop and data cables for connecting to probes / logger.

9.11.2 Protocol

Preparation

- Prior to deployment in the field, the probe must be calibrated according to manufacturer's instructions and results of calibration entered into a calibration log. Note that it is expected that the loggers used will not require calibration.
- Before leaving the office / laboratory the following should be checked for all electronic equipment (sensors, loggers, GPS):

- Batteries are charged and properly inserted.
- Previous data downloaded and memory cleared.
- Check cable and cable connections.
- Check for any obvious/minor faults on sensors including growth or dirt on the probes.
- Check contents and condition of probe toolkit.
- All equipment listed above is present and in functional order.

Field method

- Record the following on the field sheet:
  - Wetland name and ANAE WetlandID.
  - Date and time.
  - GPS coordinates (latitude and longitude; GDA94).
  - Name(s) of survey team.

- Select appropriate place for deployment of water quality logger noting:
  - Water level logger should be deployed in a position where it can capture the full range of water depths (i.e. at the deepest section of the wetland).
  - If the wetland has a complex bathymetry that results in isolated wetland cells at lower water levels, more than one logger may be required.
  - Sensors can be deployed on suitable existing structures such as water level gauging posts or on star pickets securely embedded in the wetland substrate.

- Deploy loggers according to manufacturer's instructions.
- Leave loggers deployed for a period of time sufficient to capture the temporal extent of the influence of CEW.
- Retrieve loggers and record date and time on field sheet.
- Record any relevant information, such as changes in site characteristics since deployment.
- Upload data onto laptop following manufacturer's instructions.
- If loggers are to be immediately re-deployed perform routine maintenance / cleaning as necessary.

9.12 Connection: Fixed time lapse cameras

Time lapse cameras are deployed so that they capture the onset of flow into the wetland and to record whole of system responses to watering. Cameras are deployed for the entire period that Commonwealth environmental water is influencing the wetland water regime.

9.12.1 Equipment

- Time lapse cameras that can be programmed according to daylight hours.
- Tool kit and spare parts; including spare batteries.
- Means to attach camera to permanent structure or tree.
- GPS.
- Field data sheets.
- Laptop and data cables for connecting to camera.

9.12.2 *Protocol*

Preparation

- Prior to deployment in the field, the camera must be set to take photos at the same time each data accounting for changes in day length.
- Before leaving the office / laboratory the following should be checked for all electronic equipment (sensors, loggers, GPS):
    - Batteries are charged and properly inserted.
    - Previous data downloaded and memory cleared.
    - Check cable and cable connections.
    - Check for any obvious/minor faults including growth or dirt on the lens.
    - Check contents and condition of toolkit.
    - All equipment listed above is present and in functional order.

Field method

- Record the following on the field sheet:
    - Wetland name and ANAE WetlandID.
    - Date and time.
    - GPS coordinates (latitude and longitude; GDA94).
    - Name(s) of survey team.

- Select appropriate place for deployment of camera noting:
    - Field of view must encompass the wetland sill/point at which water enters from the stream network.
    - Field of view should also capture areas likely to have visual response to watering.

- Deploy camera according to manufacturer's instructions.
- Leave camera deployed for a period of time sufficient to capture the temporal extent of the influence of CEW.
- Retrieve cameras and record date and time on field sheet.
- Record any relevant information, such as changes in site characteristics since deployment.
- Upload data onto laptop following manufacturer's instructions.
- If cameras are to be immediately re-deployed perform routine maintenance / cleaning as necessary.

9.13 Duration of connection

The duration for which wetland(s) are connected to adjoining river systems will be determined from reviewing the time lapse photographs to identify the start date of connection and data on which connection ceases. This will be reported in terms of days, including start and finish dates.

9.14 Quality Assurance/Quality Control

9.14.1 *Precision and accuracy of bathymetric measures and derived DEM*

The DSM and DEM will be produced to an accuracy of 4 cm per pixel with vertical resolution of less than 10 cm (Supplement 9B).

9.14.2 Mapping of inundation extent

Spot measurements of water depth during field visits and notes on the extent of inundation will be used to verify the NSW OEH mapping of inundation extent and wetland connection.

9.14.3 Calibration and maintenance of water level recorder

Water level loggers record absolute pressure, which is later converted to water level readings using software which takes into account atmospheric pressure. To compensate for barometric pressure changes, a barometric reference will be used. The barometric reference used for the Stream metabolism measurements will be used.

Water level sensors may drift during deployment. To check for sensor drift, a reference level is taken at the beginning and end of the deployment.

Maintenance: The logger requires the following periodic maintenance to ensure optimal operation:

- Protect the logger. This logger can be damaged by shock. Always handle the logger with care. The logger may lose its calibrated accuracy or be damaged if it is dropped. Use proper packaging when transporting or shipping the logger.
- Periodically inspect the logger for biofouling. Biological growth on the face of the pressure sensor will throw off the pressure sensor’s accuracy. Organisms that grow inside the sensor nose cone and on the sensor itself can interfere with the sensor’s operation and eventually make the sensor unusable. Check the logger periodically for biological growth.

9.14.4 Maintenance of Time Lapse Cameras

Time lapse cameras require the following periodic maintenance to ensure optimal imagery is obtained:

Protect the camera: The camera is robust but should be handled with care to ensure it is not damaged. Strong cabling is required to affix the camera to trees and locks are recommended.

Inspections: Periodic inspections of the camera for spider webs or growths that may impact the quality of the photographs.

9.15 Data analysis and reporting

For Basin and Area Evaluation, CatchmentSIM will be used with the water level data and the DEM to calculate the following wetland water regime parameters:

- Duration of connection (days).
- Daily water level (cm).
- Daily extent of inundation (m^2).
- Daily wetland volume (m^3).
- Wetland depth distributions (calculated a percentage of total wetland area) in the following categories:
    - Dry.
    - 1-20 cm.
    - 20-40 cm.

- 40-60 cm.
- 60-80 cm.
- 80-100 cm.
- > 100 cm.

For area scale evaluation, review of the time lapse imagery will be used to determine duration of connection (days). In addition, the water level data and bathymetry will be used to calculate the following wetland water regime parameters:

- Duration of connection (days).
- Daily water level (cm).
- Daily extent of inundation (m^2).
- Daily wetland volume (m^3).

9.15.1 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard. The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (wetland).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

9.16 Health and safety

For details on health and safety please refer to the Workplace Health and Safety Plan for the Lower Lachlan river system Selected Area (WHS 202.1) in Appendix 3 to the M&E Plan.

Supplement 9A: Example Hydrology (wetland) Data Collection Sheet

Wetlandid:		Wetland name:	
Observers:			
Water level logger location (s) (latitude and longitude; GDA94):			
Logging start time:			
Logging stop time:			
Notes:			

Supplement 9B: Wetland Bathymetry using Unmanned Aerial Vehicles

Australian UAV (http://www.auav.com.au/) have provided an acceptable quotation to develop a DEM for the three wetlands of the lower Lachlan River System.

Australian UAV operates two class leading fixed wing eBee aircraft, a Cinestar 8 octocopter and a Phantom quadcopter. For this data capture the Sensefly eBee (www.sensefly.com) is recommended as the best available aircraft due to its ability to carry both Near Infrared (NIR) and true colour (RGB) cameras, produce high resolution images and highly accurate geo-referenced Digital Surface Models (DSMs).

The project areas will be flown with a NIR camera at 120m Above Ground Level (AGL) giving an average resolution of approximately 4cm/pixel. NIR imagery will enable easier removal of vegetation from the DSM.

To achieve an accuracy in the x, y and z planes of 40mm, 40mm and 50mm it is necessary to place Ground Control Points (GCPs) in a 250 to 300m grid across the site. GCPs will consist of a white 1m by 1m cross painted onto the ground and 'surveyed in' using an RTK GPS unit to determine the x, y, z coordinates at each location.

Data are supplied as an .ecw image file and a GeoTIFF. The Digital Surface Model data is supplied in an ASCII point format and DSM model grid. Contours can be generated if required. The vegetation will be removed from the DSM to produce Digital Elevation Model (DEM). The DEM produced consists of a surface generated by averaging elevations between points remaining after vegetation removal and therefore is an approximation of the land form found beneath the canopy of the plants removed.

Safety and Quality Assurance

Australian UAV maintains a comprehensive quality assurance process that has been specifically designed to cater for large area data capture, processing and management. Integrated with this is our safety management system that incorporates aircraft operation, site personnel safety and reporting. All our staff are trained 4WD recovery, construction site safety, first aid, remote area working and aircraft handling.

Australian UAV is unique in that the company owned and operated by professional waterway scientists and engineers, each with more than 16 years of experience. This experience is important in projects such as this as we understand the required outputs and are therefore able to optimise the data capture to provide the most suitable aerial image tailored to your requirements.

10 Turtles and decapods methods

10.1 Overview

These methods describe a customised monitoring strategy to be employed for the following evaluations:

- Area (Category 3) Evaluation of the response of freshwater turtles to Commonwealth environmental water delivery (Zone 1).
- Area (Category 3) Evaluation of the response of freshwater decapods to Commonwealth environmental water (Zone 1).

The evaluation will be opportunistic and limited in scale of interpretation as the sampling can occur for little additional cost in association with the Basin-Scale riverine fish sampling.

10.2 Selected Area Evaluation questions

Freshwater turtles

- **Short-term (one-year) and long-term (five year) question:**
  - What did Commonwealth environmental water contribute to freshwater turtle (other vertebrate) abundance and diversity?

Decapods (Freshwater crayfish and shrimp)

- **Short-term (one-year) and long-term (five year) question:**
  - What did Commonwealth environmental water contribute to freshwater decapod abundance and diversity?

The process for evaluating these questions is illustrated in Figure 1, with components covered by this protocol highlighted in blue.

10.3 Relevant ecosystem types

Rivers & wetlands are the ecosystems relevant to turtles and decapods. This protocol refers only to monitoring rivers.

10.4 Relevant flow types

All flow types are relevant to turtles and decapods.

The area scale (landscape) assessment will not allow an assessment of the outcome of any specific fresh, bankfull or overbank flow event, but represents the overall response of turtle and decapod populations to the combination of natural and managed hydrological conditions experienced across a single zone of the target area over a 5 year period (i.e. Is the population within the selected area improving?).

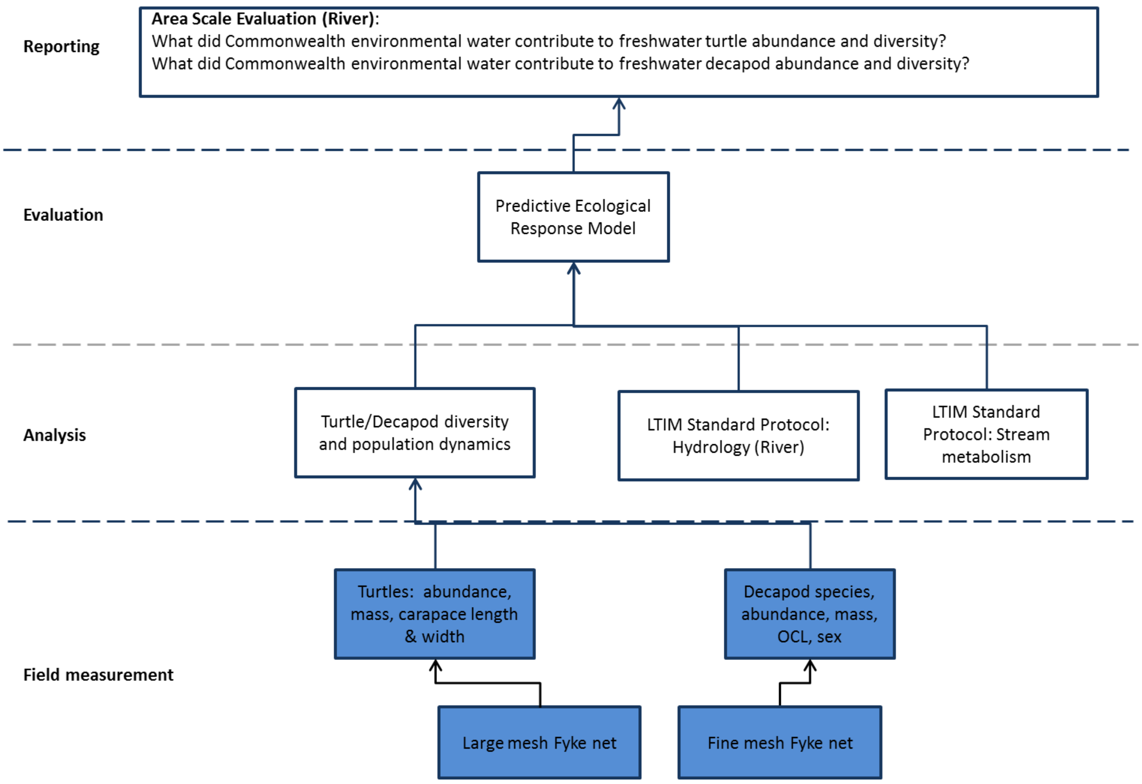

Figure 1: Schematic of key elements of the Lower Lachlan LTIM Protocol: Turtle and Decapod Sampling

10.5 Overview and context

Turtles and yabbies (decapods) form a part of the social fabric of country life – with most people having fond memories of watching turtles and catching yabbies from local wetlands and creeks. Turtles and yabbies also play a significant role in indigenous culture. Downstream of the Lower Lachlan Swamps where the fish populations are dominated by invasive species (e.g. Growns 2001; Price 2009), yabbies can be abundant, and turtles are widespread. Thus turtles and decapods are an important ecosystem attribute of the region.

While riverine turtles rely on stream and riparian zones to complete their life cycles, relatively little is known about the relationship between flow and freshwater turtles (Bodie, 2001). Seasonal patterns of reproduction may be linked to flow (eg Cann 1998) and movement patterns have been observed to be strongly directed by flow with issues noted during fishway development. Changes in aspects of the natural flow regime that alter available physical habitats are of concern (e.g. Tucker et al., 2001), and impounding rivers has been demonstrated to alter dietary composition in a number of species (Tucker et al., 2012).

Aspects of decapod life-history are strongly linked with flow. At a whole of system scale, flow controls the physical habitat available to aquatic organisms in lotic systems and can structure crayfish distributions (e.g. Johnston and Robson, 2009).Floods drive large-scale dispersal and subsequent colonisation of new habitats for freshwater crayfish (Nguyen et al., 2004). Flow also determines the distribution of slackwater microhabitats which are important for decapods. For example, freshwater shrimp utilise slackwater habitats during early life stages in lowland rivers, whereas faster water is used as a dispersal mechanism during ontogeny (Price and Humphries, 2010).

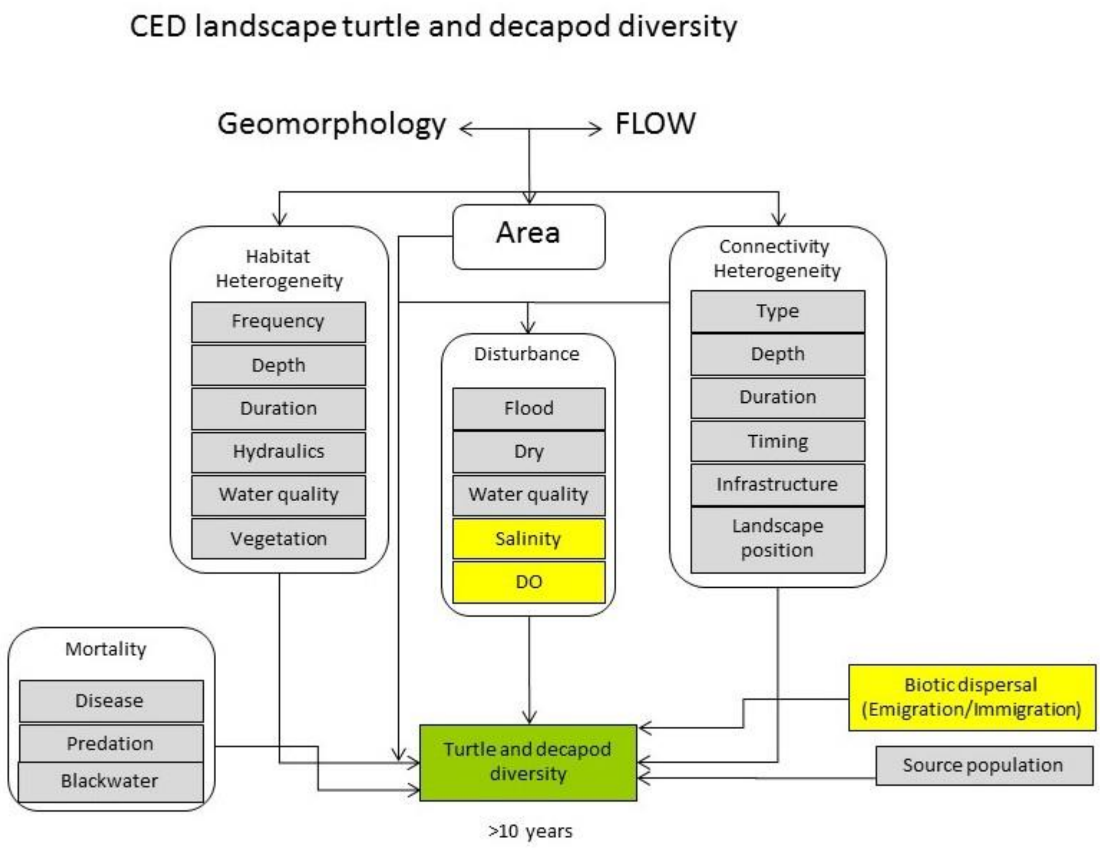

Figure 2. Revised landscape turtle and decapod diversity CED. Yellow boxes indicate other CEDs.

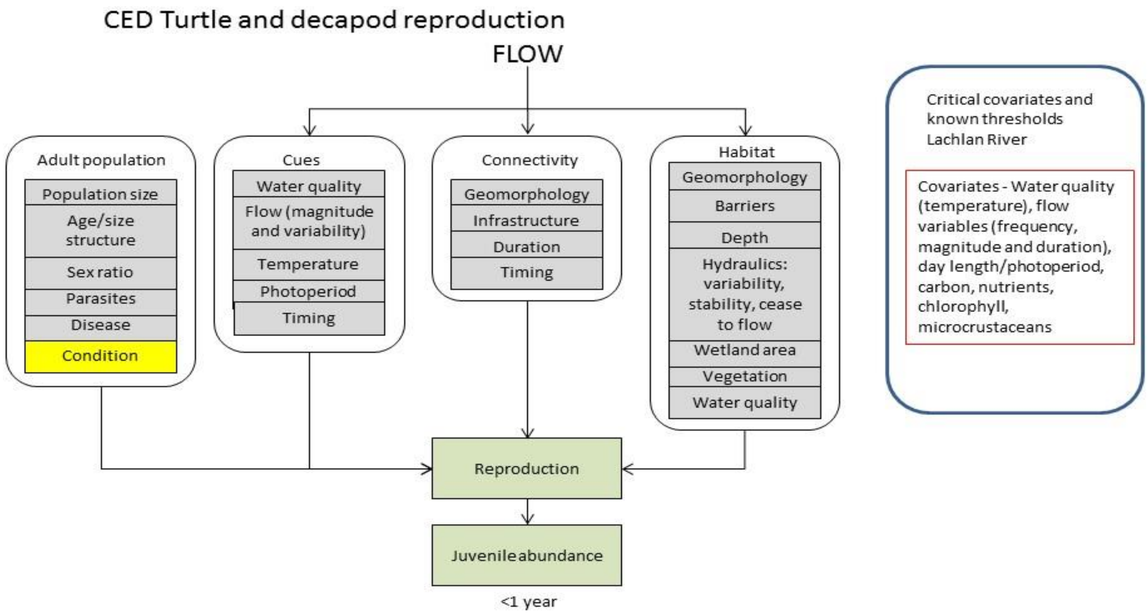

Figure 3. Revised turtle and decapod reproduction CED. Yellow boxes indicate other CEDs.

10.6 Complementary monitoring and data

We are aware of two other projects which plan to collect fish data from within the study area over the study period. The Invasive Animals CRC plans to continue to collect data from the seven sites established by Gilligan *et al*. (2010) between 2015 and 2017 as part of its carp biocontrol M&E program. This project adheres to SRA sampling protocols. The second is a Murray-Darling Basin scale fish assemblage condition monitoring program which will sample within the Lachlan catchment from 2015-2019. Sampling will be undertaken from November to April each year using standardised SRA protocols (MDBA 2012), including targeted sampling of decapods using opera house nets. Turtles will only be recorded as by-catch.

10.7 Monitoring locations

The lower Lachlan selected area can be partitioned into five spatially, geomorphologically and hydrologically distinct river channel zones at a broad landscape scale (Figure 3);

Zone 1	Lachlan River channel between Brewster Weir and Booligal.
Zone 2	Lachlan River channel between Booligal and Corrong.
Zone 3	Lachlan River channel between Corrong and its terminus in the Great Cumbung Swamp
Zone 4	Merrowie Creek
Zone 5	Torringanny, Box, Merrimajeel and Muggabah Creek system.

Sampling of turtles and decapods will be undertaken within Zone 1 in conjunction with fish sampling when time and resources permit. This zone is situated in the upper reaches of the selected area and this zone will receive Commonwealth environmental water during every year of the LTIM Project.

It is unknown whether turtles and decapod assemblages differ between the remaining zones and Zone 1, but as monitoring is complimentary to that of riverine fish, these other zones will not be monitored as part of the LTIM Project.

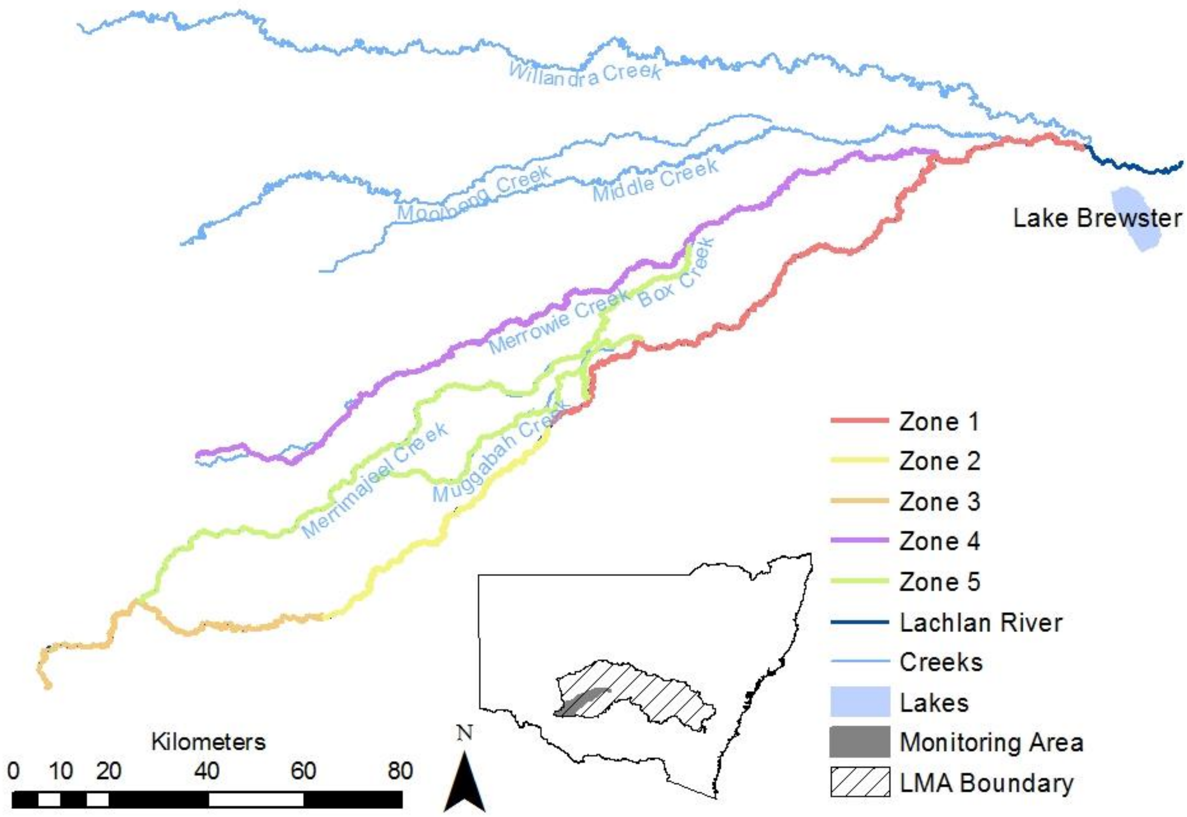

Figure 3 Map showing extent of Lachlan River Selected Area, Basin-scale sampling reach (Zone 1) and additional sampling zones.

There is little historical data available on decapod and turtles assemblages within the focal reach. The sites required for freshwater turtle and decapods monitoring will be matched to those of the Riverine fish sampling (refer Riverine Fish sampling protocols). Zone 1, where the monitoring for freshwater turtles and decapods will take place, extends for approximately 100km from Brewster Weir to the township of Hillston (see Figure 1 in the M&E Plan); however sampling sites will be located below Willandra Weir, which is approximately 20 km downstream Lake Brewster. The 100 km reach specified is the maximum distance within which the 10 riverine fish monitoring sites can be selected (Figure 3) (Hale *et al.* 2013).

10.8 Monitoring timing

Annual sampling for Area-scale assessment of turtles and decapods will be undertaken as part of the fish sampling between March and May each year, as specified by the standard methods (Hale *et al.* 2013).

10.9 Monitoring protocol

10.9.1 Equipment

- 12 x fine meshed fyke nets (10 plus two spares) per site, with anchors and stakes
- Electrofishing and boating personal protective equipment

- GPS
- GPS coordinates of site structure (passive sample waypoints and electrofishing units)
- Passive sample waypoints determined using random number generator (sample locations within sites)
- Data sheets
- Hanging scales with bag for large turtles (1 - 50 kg capacity with 10 g accuracy) and bench scales with tray for smaller turtles (0-1000 g capacity to 0.1 g accuracy)
- Water quality meter (pH, DO, Temperature, Conductivity, Turbidity)
- Ethics and sampling permits

Additional sampling equipment to Cat 1 requirements (see Section 1.8.2);

- 3 x coarse meshed fyke nets (two plus one spare) per site, with anchors and stakes
- 12 x collapsible shrimp traps (ten plus two spares) per site
- 7 x opera house traps (five plus two spares) per site

10.9.2 Protocol

Area-scale annual assessment (Zone 1)

Annual sampling for basin-scale analysis within zone 1 will follow the standard methods for riverine fish as specified by Hale *et al.* (2013). The inclusion of turtles and decapods the following additional protocols and augmentations at each site have been proposed;

1. Length data from all turtle species is recorded for all operations of every gear type (with sub-sampling of 10 individuals per species /net or trap).
2. The individual weight of measured individual turtles to be recorded.
3. Two replicate coarse-meshed fyke nets will be set as per the protocols for small-mesh fyke nets to target turtles
4. Ten unbaited collapsible shrimp traps will be set for the duration of the electrofishing operations (minimum of 1.5 hours) to maintain consistency with SRA protocol.
5. Data will be recorded from any turtles collected within the fyke nets to generate data suitable for assessing the response of turtles to environmental flows. Taxa, abundance, carapace length (mm), carapace width (mm), weight (grams) of turtles will be recorded (with subsampling of 10 individuals per net).
6. Five replicate baited opera house traps will be set as per the unbaited shrimp traps to generate CPUE data on decapod crustaceans. Length (occipital-carapace length (mm)) and weight (to 0.1 g) of *Cherax sp.* (yabbies) will be recorded (with subsampling of 10 individuals per trap). Decapods from the families *Paratya* and *Paleamonidae* (shrimps) will not be measured and only enumerated per species / net.

The inclusion of additional gear types (fykes and traps) will add some time on-site for technicians in terms of setting, retrieving and processing, and consequently the additional data collected and subsequent analyses will depend on the resources available.

10.10 Quality Assurance/Quality Control

QA/QC activities specific to this protocol include:

- NSW DPI staff are permitted to sample fish in NSW waters under a NSW Section 37 permit.
- NSW DPI will apply to undertake research on fish under a research authority granted by the NSW Fisheries Animals Care & Ethics Committee.
- Fyke nets, shrimp traps and opera house traps are checked for holes or damage prior to every field trip and during each trip, and damaged nets either repaired or replaced.
- Scales are calibrated following manufacturers specifications prior to every field trip.
- Data will be transferred from field data sheets into intermediate tables within a Microsoft Access database (I&I NSW Freshwater Fish Research Database - FFRD) and the original datasheets stored in fire-proof safes. Data in intermediate tables will be processed through a series of 50 range-checks to identify any outliers and inconsistencies in data recording. All potential errors are referred to the senior operator responsible for data collection at that site for confirmation and/or correction. The corrected intermediate tables are then appended into the FFRD for storage. A level 3 data audit is also undertaken by the supervising scientist after each year's sampling in order to ensure compliance with sampling protocols.

10.11 Data analysis and reporting

10.11.1 Generation of metrics and indicators

Freshwater Turtles

Relative abundance

Raw catch and effort data for each sampling operation (net/trap set) will be recorded. Processed data for turtle abundances will be reported as standardised catch-per-unit-effort (CPUE) per net hour.

Population structure data

Morphometric measurements recorded for turtles will be analysed and size distribution information used to indicate whether turtles have recruited.

Freshwater decapods

Relative abundance

Raw catch and effort data for each sampling operation (net/trap set) will be recorded. Processed data for decapod abundances will be reported as standardised catch-per-unit-effort (CPUE) per net hour.

Population structure data

Annual change in length (Occipital Carapace Length) frequency distributions of *Cherax* populations only will be investigated in order to assess response to the provision of environmental water.

10.11.2 Data analyses

Selected Area

Freshwater turtles

- **Short-term (one-year) and long-term (five year) question:**
    - What did Commonwealth environmental water contribute to freshwater turtle abundance and diversity?

Long term changes in CPUE and diversity of turtles will be analysed using non-parametric PERMANOVA (Primer 6).

Decapods (Freshwater crayfish and shrimp)

- **Short-term (one-year) and long-term (five year) question:**
    - What did Commonwealth environmental water contribute to freshwater decapod abundance and diversity?

Long term changes in CPUE and diversity of decapods will be analysed using non-parametric PERMANOVA (Primer 6).

10.12 Data management

Following confirmation of the identity of those species where voucher specimens were collected, data will be transferred from field data sheets into intermediate tables within a Microsoft Access database (the I&I NSW Freshwater Fish Research Database - FFRD). Data in intermediate tables will be processed through a series of 50 range-checks to identify any outliers and inconsistencies in data recording. All potential errors are referred to the senior operator responsible for data collection at that site for confirmation and/or correction. The corrected intermediate tables are then appended into the FFRD for storage. A level 3 data audit is also undertaken by the supervising scientist after each year's sampling in order to ensure compliance with sampling protocols.

The original datasheets will be scanned and copies of the data stored at the University of Canberra. The original data sheets will be stored in fire-proof filing cabinets at the Narrandera Fisheries Centre.

10.13 Health and safety

For details on health and safety please refer to the Workplace Health and Safety Plan for the Lower Lachlan river system Selected Area (WHS 202.1) in appendix 3.

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Commonwealth Environmental Water Office
Long Term Intervention Monitoring Project
Lachlan River System

Appendix 2
Communication and Engagement

February 2015

UNIVERSITY OF CANBERRA

Contents

1 Appendix 2: Communication and Engagement

This Appendix provides details regarding:

- Lachlan LTIM Reference Group
- Landowner relationship.
- Stakeholder needs analysis and reasons for engagement.
- Stakeholder expectations and risk management.

2 Lachlan LTIM Reference Group

2.1.1 Purpose

The Lachlan LTIM Reference Group will provide a forum for the exchange of information and intelligence that supports the implementation of the LTIM Project, through effective coordination of environmental watering, and monitoring and evaluation.

2.1.2 Authority

The Lachlan LTIM Reference Group will be organised, operated and Chaired by Dr Fiona Dyer, University of Canberra, under these Terms of Reference approved by the CEWO.

The Lachlan LTIM Reference Group has no executive powers, supervisory functions or decision-making authority in relation to the LTIM Project. It is an operational group tasked with a general support and advisory role.

2.1.3 Objectives:

The Lachlan LTIM Reference Group will facilitate:

- Effective coordination between environmental water delivery partners and other relevant monitoring and evaluation projects and groups, including relevant advisory bodies, such as the Lachlan Riverine Working Group
- Communication to environmental water managers of any information that would improve environmental water management
- Exchange of information and intelligence relevant to improving the implementation of the LTIM Project, as well as improve the efficacy of environmental watering activities to support adaptive management on both a short-term (preliminary observations during watering events) and longer-term (evaluation outcomes)
- The identification, communication and management of any issues, risks or opportunities relevant to the LTIM Project.

2.1.4 Membership

The Lachlan LTIM Reference Group includes agencies involves in the successful delivery of the Lachlan LTIM Project. This includes: organisations directly and indirectly responsible for delivering LTIM Project deliverables; representatives from organisations involved in environmental water planning and delivery.

The Reference Group comprises the members listed in Table 1 who have been nominated by the project lead and agreed to by the CEWO.

Table 1. Lachlan LTIM Reference Group membership (as at April 2014)

NAME/POSITION	AGENCY
Fiona Dyer (Chair)	Institute for Applied Ecology, University of Canberra - Lachlan LTIM Project (lead organisation)
Ben Broadhurst	Institute for Applied Ecology, University of Canberra - Lachlan LTIM Project (lead organisation)
Monitoring and Evaluation Representative	Monitoring and Evaluation, Commonwealth Environmental Water Office
Water Delivery Representative	Environmental Water Delivery, Commonwealth Environmental Water Office
M&E Advisers Representative	Monitoring and Evaluation Advisor, Murray Darling Freshwater Research Centre
Lachlan Environmental Water delivery officer	Environmental Water Delivery, NSW Office of Environment and Heritage
Organisation representative	NSW Office of Water
Organisation representative	Lachlan Catchment Management Authority
Organisation representative	NSW Fisheries, conservation branch

2.1.5 Terms of Reference

The Lachlan LTIM Reference Group will be responsible for supporting strategic direction of the LTIM Project and exchanging information and intelligence to support the LTIM Project and adaptive management. It will:

- Actively support and promote the LTIM Project within partner organisations.
- Review (where appropriate) key project documentation, including evaluation reports.
- Exchange operational intelligence relevant to the LTIM Project, including intelligence on upcoming watering or monitoring activities.

- Exchange intelligence relevant to adaptive management of environmental water, including operational observations, monitoring outcomes and evaluation outcomes.
- Consider stakeholder expectations (where appropriate) of the LTIM Project.
- Exchange intelligence on any risks, actual or perceived, to the LTIM Project.
- Communicate key messages of the LTIM Project to organisations involved in environmental water planning and delivery.
- Document key discussion points and outcomes of Lachlan LTIM Reference Group meetings and distribute these to members (including the CEWO) in the form of minutes.

2.1.6 Operations

The Reference Group will operate in alignment with the following requirements:

Meetings

Working Group meetings will be held at least twice during Stage 1 (2013-14) and quarterly (or as required) from 2014-15. Meetings will be held primarily as teleconferences with an annual face to face meeting.

Should a member be unable to attend a meeting, a suitable alternate may attend provided prior notification is given to the chair.

Minutes and Agendas

Staff from the Institute for Applied Ecology, University of Canberra will prepare and distribute meeting agendas and minutes. Agendas and minutes from the previous meeting will be distributed no later than five days prior to the meeting. Meeting minutes and action items will be distributed within two weeks of the meeting. Immediate actions may be circulated earlier.

Agenda items

Table 2 lists the standard agenda items for the Reference Group. Members can submit additional items to be included on agenda at the discretion of the Chair.

Table 2: Reference group standard agenda items

ITEM	RESPONSIBILITY
Review and accept minutes from last meeting	M&E Provider [Chair]
Update on action items from last meeting	Chair and members
Update on planned watering activities	Delivery partners, environmental water planning organisations
Update on planned monitoring activities	M&E Provider lead
Update on monitoring observations and evaluation outcomes to support adaptive management	M&E Provider lead
Update on community engagement	M&E Provider lead
Other business	All
Confirmation of next meeting	M&E Provider [Chair]

Where practical, meeting papers will be distributed no later than [five days] prior to the meeting, and will include:

- Agenda.
- Previous meeting minutes.
- Any papers for consideration.

Grievances:

Grievances identified within the Reference Group will be mediated by the Chair. Where a grievance is deemed significant, a member or members of the Reference Group may be removed, at the discretion of the CEWO.

3 Landowner Relationship

Key members of the Lachlan M&E Provider Team either currently or have in the past worked extensively in the monitoring zones, and hence, have existing good relationships and access arrangements with many of the potential affected landholders. In particular, OEH Senior Environmental Water Manager (Paul Packard) has been conducting long-term routine communication activities and risk management/mitigation as standard operating procedure for all past environmental flow actions and has nurtured good relationships with many potentially affected landholders to the point that they willing to contribute their own resources (e.g. time and equipment) or change practices to facilitate environmental water delivery. Likewise, other Lachlan M&E Provider Team researchers also have good relationships and contact networks either built up over many years (10 years plus) for past programmes, or existing protocols and access arrangements in place for present monitoring sites (e.g. NSW DPI Fisheries and NSW Office of Water IMEF). Initial contact with potential affected landholders will be through introductions and build on such arrangements and relationships. Due diligence and care will be taken to prevent any risk to those existing relationships and the valuable investment and resource they represent to agencies and personnel outside the LTIM Project (e.g. a point which will be emphasised during LAP induction mentioned below).

Prior to onset of field monitoring (after 30 June 2014) and for the life of project activities, Central Tablelands LLS will provide a dedicated staff person, Senior Lands Services Officer High Conservation Value Aquatic Ecosystems (HCVAE; and LRWG Executive Officer) as a consistent single point of contact for all project activities. The Senior Lands Services Officer (HCVAE) and M&E Provider Leader (with assistance from Lachlan M&E Provider Team) will conduct face-to-face interviews with each affected landholder after 17 April 2014 and before monitoring schedule starts (30 June 2014). All landholder access requirements from such interviews will be formalised in a document called Land Access Protocol (LAP), with a copy provided to landholder and all field monitoring staff. All field staff will be inducted in relevant LAPs by Senior Lands Services Officer (HCVAE) with assistance from Paul Packard, with inbuilt opportunity for feedback from all users as well as landholders to be incorporated into each LAP.

There is scope to also expand the LAP to capture landholder observations (e.g. local rainfall, regeneration line along riparian corridors, river levels, time of recession, seed set etc). Rainfall, in particular, is systematically recorded by landholders and is a popular topic of conversation that 'breaks the ice'. Given the large distances between monitoring sites and Bureau of Meteorology (BoM) weather stations, rainfall is one form of anecdotal/observation data worth capturing routinely at every site visit. This will be formalised during LAP induction given that each landholder will have their own set of requirements and limits to participation (i.e. some will be happy to provide rainfall on the spot after each event via email or during face-to-face/telephone conversations whereas others will not want to be tied into a regular obligation).

OEH Senior Environmental Water Manager (Paul Packard) will also provide introductions, project oversight and be a critical source of insight for specifics to each property and landholder's situation, especially during the (M&E Plan) development stage and during the negotiation of LAPs. In recognition of the potential for access conditions and land management practices to change over 5-years, the Senior Lands Services Officer (HCVAE) will monitor LAPs and provide frequent opportunity to review and update with participating affected landholders.

All Land Access Protocols (LAPs) will be scanned and emailed to the Communication Theme leader and the Project Manager within 5-days of completion of field monitoring trip, all follow-up actions implemented, a copy placed on file for auditing purposes, with routine checks (phone calls) also conducted by Senior Lands Services Officer (HCVAE) to landholders ensure they are satisfied with level and method of engagement. Senior Lands Services Officer (HCVAE) will also keep a Stakeholder Log, including follow-up actions, and provide that to auditors along with copies of LAPs.

4 Stakeholder needs analysis and reasons for engagement

Table 3 provides details regarding stakeholder needs, reasons for engagement, what success would look like, and links to CEWO 5 high-level objectives.

Table 3 Stakeholder needs analysis including reasons for engagement (e.g. why engage and related outputs), what success would look like, and links to the CEWO 5 high-level objectives.

WHY ENGAGE?	MAIN STAKEHOLDER GROUP(S)	RELATED OUPUTS	MAIN OUTCOMES: What success looks like!	HIGH-LEVEL OBJECTIVE(S)
Seeking local knowledge and input to inform initial project development	• Affected landholders • Stakeholder groups • CEWO and Lachlan LTIM Reference Group, and delivery partners	• M&E Plan development (especially site selection and logistics (i.e. best access points) • M&E Plan 5-year implementation and review • Selected Area schedule of monitoring • Area evaluation reports • Information transfer	• M&E Plan contains the best possible suite of sites and schedule of monitoring to meet Evaluation questions and Standard method requirements; with robust scenarios and mechanisms for rapid adjustments once in-field monitoring starts and Commonwealth environmental water is delivered • LTIM Project fully costed and deliverable, opportunities for efficiencies created	2. and 5.
Obtaining buy-in from stakeholders (including willingness to participate and contribute)	All stakeholder group categories including CEWO and Lachlan LTIM Reference Group, and delivery partners	• M&E Plan • Area evaluation reports • Quarterly Project Progress Reports • Media products and communication activities	• M&E Plan implemented and/or current hypothetical's/unknowns (i.e. specifics of Commonwealth environmental water action) modified in response to conditions as they unfold in real time (i.e. event-based monitoring) based on local, real-time information/data and/or observations; the 'quality' of which is improved by input from stakeholders with local expertise/experience unique to the Lachlan • Ongoing access to monitoring sites • Affected landholders/managers willingly contribute time and resources to both real-time management of environmental flows or events (bird breeding event) and field monitoring including observational reporting and operational assistance • Affected landholders and stakeholder groups provide input into progress reports • Stakeholders participate in engagement activities and contribute to outputs and outcomes (i.e. provide quotes or photos and endorse case studies, reports etc.) • All stakeholders provide considered, critical and productive feedback on the management of Commonwealth environmental water	2., 4. and 5.

WHY ENGAGE?	MAIN STAKEHOLDER GROUP(S)	RELATED OUPUTS	MAIN OUTCOMES: What success looks like!	HIGH-LEVEL OBJECTIVE(S)
Early warning of problems, or affirmation that relevant issues/objectives are being addressed and effectively/appropriately communicated	• CEWO and Lachlan LTIM Reference Group, and delivery partners • M&E Provider Leader • Stakeholder groups	• M&E Plan • Area evaluation reports • Quarterly Project Progress Reports • Media products and communication activities	• M&E Provider Leader ensures effective and timely communication pathways and protocols are established between themselves, and all Theme leaders and staff, who inform the M&E Provider Leader immediately of any proposed substantial changes to M&E Plan and or Selected Area schedule of monitoring, or any potential 'problems' that may arise (e.g. change sites due to lack of environmental water delivery)– any substantial changes discussed with CEWO, Lachlan LTIM Reference Group and M&E Advisors, and a collaborative solution is found and relayed back to relevant M&E Provider staff. • If the complexity of the system is such that predetermined solutions in M&E Plan are not proving effective, there is capacity and goodwill to allow emergent solutions to be considered and communicated. • Outputs and outcomes are processed and analysed, and feedback provided from M&E Advisors and CEWO to M&E Provider in a timely and informative manner that allows adjustments to be made without unnecessary time lags.	**5**
To ensure stakeholders contribute to knowledge and understanding, development of solutions and improve the ultimate delivery of the project	• Affected landholders • Stakeholder groups	• M&E Plan • Operational information (observed) • Monitoring data • Area evaluation reports • Relationship with Delivery Partners to support evaluation	• Implementation and review/revision of M&E Plan is supported by stakeholder contributions and insights where appropriate • Information is exchanged on project activities (monitoring undertaken, observations, evaluation) to allow for adaptive management in the delivery of environmental water over time • Operational information (observed) is shared in a timely and cooperative manner • Monitoring data is enriched by relevant contextual information provided by stakeholders	**1.– 5.**
Better decision-making based on local knowledge from those impacted by decisions	• Affected landholders • Stakeholder groups	• Operational information (observed) • Monitoring data • Area evaluation reports • Progress reports • Relationship with Delivery Partners	• Environmental water decision-making processes become more inclusive and reflective of 'localism' • Local knowledge is reflected/referenced in LTIM Project outputs where permissible	1., 2., and 4

WHY ENGAGE?	MAIN STAKEHOLDER GROUP(S)	RELATED OUPUTS	MAIN OUTCOMES: What success looks like!	HIGH-LEVEL OBJECTIVE(S)
A mechanism for shared responsibility and problem solving; better risk management	• Affected landholders • Stakeholder groups • CEWO and Lachlan LTIM Reference Group, and delivery partners	• Operational information (observed) • Monitoring data • Area evaluation reports • Progress reports • Relationship with Delivery Partners	• Risks are mitigated and operational constraints resolved by collaborative problem solving	2., 4., and 5.
Opportunities to develop long-term and trusting relationships	• Affected landholders • Stakeholder groups	• Operational information (observed) • Monitoring data • Area evaluation reports • Progress reports • Relationship with Delivery Partners	• LTIM Project results in a large number of collaborative products (i.e. peer reviewed publications, co-supervision of postgraduate research, inter-agency or whole-of-government decision-making and reports) • Relationships continue to grow outside the scope and duration (5 years) and additional monitoring is funded	1. and 4.
Demonstrate that Commonwealth environmental water is being managed well	All stakeholder group categories	• Basin evaluation reports • Mass media in general	• Ecological outcomes from the use of environmental water are supported by robust (including potential peer-reviewed publications) data collection, analysis, results and interpretation • Monitoring informs 'science underpinning the Basin Plan' and Basin Evaluation questions; as well as local planning mechanisms (e.g. Annual Watering Plans) with demonstrable improvements in understanding in core areas (i.e. cause and effect diagrams) or where knowledge gaps previously identified • By monitoring multiple indicators at the same sites related to the same environmental water event, improve understanding of whole-of-ecosystem relationships, and potentially demonstrate multiple benefits and efficient as well as effective management	**1.– 5.**
Assist managers of Commonwealth environmental water learn from experience and improve the delivery of water over time (adaptively manage)	• Stakeholder groups		• Environmental water managers report feedback or provide examples of how the LTIM Project has improved the state of knowledge in key areas which affect (and hence also improve) the delivery of environmental water over time • Documented links between data/knowledge provided by LTIM Project and 'ability' (i.e. reduction in risk, approvals) to 'mature' in decision making and adaptively manage a broader range of watering events and objectives (e.g. e-flow to benefit native fish or primary production)	4

4.1 Stakeholder expectations and risk management

Table 4 provides an analysis of stakeholder expectations and associated risks, including mitigation measures. Table 5 provides a detailed schedule of proposed engagement activities matched to stakeholder expectations and level of engagement.

Table 4 Analysis of stakeholder expectations and associated risks, including risk mitigation measures.

STAKEHOLDER CATEGORY	ENGAGEMENT TYPE AND PURPOSE	EXPECTATIONS	RISKS	RISK MITIGATION and GENERAL PROTOCOLS	NEGOTIABLE FACTORS	NON-NEGOTIABLE
Affected landholders	Permission and ongoing access to monitoring sites	• No interruption to agricultural enterprise operations, nil impact/damage on property • Conditions of access adhered to at all times • Treated respectfully at all times, any concerns or questions noted and appropriate action taken – all requests receive a reply	• Landholder complaint of improper conduct e.g. gate left open, fence damaged - requires explanation and grievance management or withdraws access permission – flow on effects to other affected landholders and project goodwill from participating landholders collapses • Land sale resulting in new owner that removes access rights	• Written Land Access Protocol (LAP) and initial meetings where discuss all options and need for flexibility – obtain consensus on negotiable and non-negotiable factors with contingencies build in or alternatives negotiated where possible • Monitoring field staff trained in LAP • LAP/Code of Conduct regularly audited to ensure being followed, reviewed and updated • LAP has safe-guards build in and connects with C&E Plan grievance framework • Refer to past stakeholder information; Build on existing good client relationships with landholders and maintain regular phone or face-to-face contact • Renegotiate LAP with new owner	• Depending on method may be possible to be flexible with exact dates which may change at short-notice due to weather conditions or shift in agricultural/production needs of landholder • Some conditions or restrictions to access	• Monitoring sites or access area location and timing for some methods (and potential access points) • Standard methods and indicators • Environmental water delivery (e.g. target, delivery rate and amounts, purpose etc) • Flexibility required for event-based monitoring

STAKEHOLDER CATEGORY	ENGAGEMENT TYPE AND PURPOSE	EXPECTATIONS	RISKS	RISK MITIGATION and GENERAL PROTOCOLS	NEGOTIABLE FACTORS	NON-NEGOTIABLE
Affected landholders	Two-way communication (information/opinions/observations) about monitoring activities/methods/results undertaken on property	• Receives timely and considered feedback on results etc • Opinions on results, local-knowledge are noted and reflected in the LTIP Project outputs/reports etc • Valued participant with all LTIM Project staff taking active steps to listen to their views and where appropriate, relay these back to CEWO	• Goodwill dissipates if follow-up actions not taken •Landholder dissatisfied with level of involvement/participation ad withdraws from project	• Establish during LAP consultation (i) landholders purpose or reason for participating (ii) any past adverse experience/sensitivity to be aware (iii) level of involvement desire/expect and if non-negotiable factors, find other means for meaningful involvement (iv) be clear on limits to control over data/information and input to outputs or products, and don't provide any 'raw' or unpublished LTIM Project material • Ascertain landholder's interest is (i.e. fish, frogs, river red gum etc) and provide personalised end-of-year summary of outcomes and/or photos, species list etc • Where appropriate landholder contribution acknowledged • Implement protocols for informal conversations, and guidelines for communicating consistent key messages	• In broad descriptive terms, the information provided to landholder and method of delivery (i.e. if wants face-to-face visit etc) • Landholders may be able to see input/opinions reflected in some alternative form or products e.g. incorporation of ancillary data like rainfall or land management info; then landholder formally informed (in writing where necessary); case studies by other agencies such as LLS	• End use of data e.g. to answer Evaluation questions, especially Basin-scale standard methods • Mass media products and statement of opinion in public forums (i.e. media though CEWO, discourage radio/newspaper interviews etc)
All stakeholders	Effective and quality communications and engagement activities	• Accurate, timely and up-to-date communication products free of error	• Conversely, informal communications mis-represented and 'mis-nomas' or concerns regarding results or objectives spread through local community • Inconsistent or conflicting messages in the public arena	• Centralised communication arrangements and Figure 5 networks. • No media without express permission from Director, Monitoring and Evaluation Section within CEWO • Plan and allow adequate time to obtain most relevant, up-to-date information/analysis from authorative sources; factor in Quality Assurance • Use Standard Terms and		

STAKEHOLDER CATEGORY	ENGAGEMENT TYPE AND PURPOSE	EXPECTATIONS	RISKS	RISK MITIGATION and GENERAL PROTOCOLS	NEGOTIABLE FACTORS	NON-NEGOTIABLE
				Style Guide used by Commonwealth Government • Use templates where possible • LMRO develop a set of consistent key messages or responses to FAQ in conjunction with CEWO and Delivery Partners		
Stakeholder groups	Seek information on water system outlooks and river management, and potential re-adjustment of M&E Plan over time	• Focused/strategic provision of information, and considered 'intelligent' requests for information with clear time frames and actions required	Stakeholder groups withdraw or dis-engage because (i) demand on time and resources too great and (ii) fail to provide critical information immediately while 'dilute' the key messages with low priority information/requests • Potential governance issues or complaints if LTIM Project is perceived as having undue influence over environmental water planning (i.e. where and when to deliver flows) in order to meet/justify LTIM Project objectives and investment	• Lachlan M&E Provider staff who also stakeholder reps directly negotiate and then review and adjust level of engagement (e.g. LTIM Project a standing item on quarterly meeting Agenda) • Lachlan LTIM Reference Group (Select Area Working Group) to monitor relationships and expectations with Delivery Partners and environmental water advisory group (EWAG; i.e. LRWG)		• M&E Advisors and Providers have ultimate decision on site selection and methods, and Selected Methods non-negotiable • Project focus is contribution of Commonwealth environmental water
Affected communities	Inform and obtain buy-in or appreciation for objectives Acceptance of the underlying science of Basin Plan implementation i.e. cause-and-effect diagrams	• Regular, transparent and relevant provision of information, with opportunity to engage directly with LTIM project staff and CEWO • Locally relevant results/outcomes/outputs and value for money • To be provided with objective, accurate and consistent information at all stages of the project • To be provided with opportunities to provide feedback on analysis, alternatives and/or outcomes, and to voice any concerns and	• LTIM project as a platform for more general lobbying/criticism of broader government policy and reform • Unable to detect or communicate effectively project benefits, achievements and value of investment (i.e. waste of taxpayer money) • Failure to obtain buy-in from community who publically question the value of the LTIM Project, and the science underpinning use of CEWO environmental water – seen as having the evaluation outcomes imposed upon the	• Centralise contact with affected communities (i.e. Central Tablelands LLS) and adhere to protocols, involve CEWO area leader • Utilise local networks and tailor message to the audience - find out first what they want to know and if have any historical concerns or interests; be aware of other related local issues • Target activities to interested or open-minded community groups/forums and avoid 'contentious forums' • If possible, piggy back on	• Potential to modify community engagement activities as long as within budget and scope • While can't change standard methods should be able to explain what they are, and logic and rationale	• LTIM Project scope and M&E Plan and schedule of monitoring activities • Evaluation questions and high-level objectives • Sites to receive delivery of environmental water • Schedule or engagement activities and associated budget • Commercial-in-confidence information • Existing C&E pathways only and no public meetings at this stage

STAKEHOLDER CATEGORY	ENGAGEMENT TYPE AND PURPOSE	EXPECTATIONS	RISKS	RISK MITIGATION and GENERAL PROTOCOLS	NEGOTIABLE FACTORS	NON-NEGOTIABLE
		needs • To have local knowledge and views be considered input into selection of assumptions and models underlying interpretation of data	community and not reflecting local views on 'how the lower Lachlan system works', and contribution of CEWO environmental water to ecological outcomes relative to local rainfall, land use, channel constraints, planned environmental water etc	events or projects of high interest general relevant (e.g. feral animal information, weed control etc)		

Table 5 Detailed Schedule of proposed Engagement activities matched to stakeholder expectations and level of engagement.

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	ENGAGEMENT TYPE	LINK TO Table 1. OBJECTIVE	PURPOSE	METHOD(s)	RESPONSIBILITY	TIMING
(1)	**Initial landholder meetings**	**Affected landholders**	**Inform/Involve/Consult:** Provide accurate and timely information about the project, its impacts, and any other aspects that may have an effect on them (early disclosure)	1. and 2.	Initial phone call to obtain landholder to participate in project; then develop Land Access Protocols	• Phone call to arrange face-to-face meeting to record access conditions/considerations • Face-to- face meeting • Documentation and approval of Land Access Protocol • Provide copy to affected landholder	M&E Provider Leader and Central Tablelands LLS Snr Land Services Officer (HCVAE)	ASAP after 17 April 2014 and by 30 June 2014

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	ENGAGEMENT TYPE	LINK TO Table 1. OBJECTIVE	PURPOSE	METHOD(s)	RESPONSIBILITY	TIMING
(2)	**Land Access Protocol**	**Affected landholders**	**Inform/Involve/Consult:** Monitoring staff to implement Land Access Protocol (LAP)	1., 2., 3., 4., 5., and 7.	Adhere to, and refine Land Access Protocol as required	• Telephone or face-to-face briefing/meeting and induction of all field monitoring staff in relevant LAP •Follow the sequence of actions listed in each LAP	M&E Provider Leader and Central Tablelands LLS ; and every Theme leader (and monitoring staff) on an ongoing basis	• Between 17 April and 30 June 2014 field monitoring staff to be 'trained' in relevant LAP • All staff to implement Pre, during and post each monitoring trip
(3)	**Oversight of landholder protocols and relationships**	**Affected landholders**	**Involve/Consult:** Risk Management and as part of Review/Evaluation of C&E Plan	1., 2., 3., 4., 5., and 7.	Quality Assurance: ensure Land Access Protocols are being followed and obtain feedback from affected landholders	• Phone interviews (opportunistic face-to-face or if requested) • Post/email copy of Area evaluation report and brief summary report specific to property or areas of interest (i.e. fish, birds)	M&E Provider Leader and Central Tablelands LLS Snr Land Services Officer (HCVAE)	Annually to coincide with Annual Area evaluation report: around November each year
(4)	**Grievance**	**Affected landholders**	Contact initiated by affected landholder: e.g. Grievance Management	3. and 6.	Landholder relations: responding to requests or potential grievance issues	• Initially telephone or email, then face-to-face mediation	CEWO area leader , M&E Provider Leader, and Central Tablelands LLS Snr Land Services Officer (HCVAE)	Contingency
(5)	**M&E Provider informal contact with landholders**	**Affected landholders**	**Involve/Consult:** M&E Provider Theme leaders may request input, records or have a question for landholder	1., 4., 5. and 7.	Affected landholders periodically contacted for additional contextual information (e.g. local rainfall, condition of delivery channel, land management information etc.)	• Phone and face-to-face interviews • Emails and circulars • Where possible through existing pathways such as OEH/CEWO environmental water event monitoring, LRWG, Lachlan CSC meetings etc	M&E Provider Leader in conjunction with Theme leaders and Central Tablelands LLS Snr Land Services Officer (HCVAE)	As required, more likely event-based and in conjunction with Monthly and/or Quarterly progress reports to CEWO

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	ENGAGEMENT TYPE	LINK TO Table 1. OBJECTIVE	PURPOSE	METHOD(s)	RESPONSIBILITY	TIMING
(6)	**Opportunistic presentations as existing community events**	**Affected communities**	**Inform:** Raise public awareness and appreciation/acceptance for LTIM Project objectives	2. and 8.	Improve awareness and knowledge on the role of CEWO and purchases environmental water. Provide balanced, objective, accurate and consistent information to assist local communities to understand the five high-level objectives	• Provision of Key Messages and approved communication material (e.g. Fact Sheet, item in newsletters) at Local Land Services stalls at local community events (e.g. Henty Field Days) • Potential presentation at partnerships forums or Local Land Services events, for example, Science Forum	CEWO area leader , M&E Provider Leader, and Central Tablelands LLS Snr Land Services Officer (HCVAE)	• If LLS or partners have stalls at appropriate venues (e.g. Henty Field Days, local shows e.g. Booligal and Hillston shows) or other Local Land Services awareness raising events e.g. Carp a Thons, community forums. Presentations to occur if appropriate Central Tablelands LLS staff already attending LLS-run event.
(7)	**Media and internal communication products (i.e. Fact Sheet)**	**All stakeholders especially non-targeted general public and affected communities and landholders**	**Inform:** Raise public awareness and appreciation/acceptance for LTIM Project objectives	2. and 8.	As above	• Media releases, newspaper editorials (local and regional/state), local ABC radio, Fact Sheets and case studies, newsletters (including E-newsletters), Lachlan Environmental Water Management Plan website (www.lrwg.com.au) and social media • Utilise Western/Riverina Local Land Services (LLS) networks and planned project activities e.g. distribute newsletters, website, fact sheets, field days, forums	CEWO area leader , M&E Provider Leader, and Central Tablelands LLS Snr Land Services Officer (HCVAE)	Event and outcome based, opportunistically as they arise with existing networks, such as: • 4 times a year for quarterly LRWG internal newsletter via Lachlan CSC and LVW, LRWG landholder email distribution lists and connections with Water Trust Districts. • Regularly or as 'good news stories' or outcomes of watering events become apparent – posted on Lachlan LTIM Project page on LEWMP website.

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	ENGAGEMENT TYPE	LINK TO Table 1. OBJECTIVE	PURPOSE	METHOD(s)	RESPONSIBILITY	TIMING
(8)	**LRWG initial consultation**	**LRWG**	**Involve/Inform/Consult:**	All objectives	Initial discussions with LRWG and obtain feedback on C&E Plan, and how they would like to be engaged in future	LRWG Quarterly meeting: The LTIM Project agreed as standing Agenda Item at each meeting	Central Tablelands LLS Snr Land Services Officer (HCVAE) and Lachlan LTIM Reference Group	Wednesday 26 February 2014 with outcomes reported back to M&E Provider Leader and CEWO area leader, and used to inform the final M&E Plan due 17 April 2014
(9)	**Ongoing communication with LRWG**	**LRWG**	**Involve/Consult:** Information exchange and collaborative problem solving	All objectives	• To obtain ongoing feedback/input from stakeholders on analysis, alternatives and/or outcomes • To work directly with stakeholders throughout the process to ensure respective concerns and needs are consistently understood and considered, and to share key learnings and improve management of environmental water	• Inform via LRWG Executive Officer (emails, meeting briefings, newsletter etc) • Involve/ Consult via attending LRWG meetings and briefing papers • Personal discussion with key staff, and other planning meetings	• Central Tablelands LLS Snr Land Services Officer (HCVAE) and Lachlan LTIM Reference Group	As required, however, where possible updates (i.e. Quarterly progress reports and draft Annual Area evaluation reports) should coincide with LRWG quarterly meetings • M&E Provider Leader may attend planning session for Lachlan Valley Annual Watering Plan (~ Feb/March each year)
(10)	**Existing stakeholder group pathway**	**Lachlan Customer Service Committee (CSC)**	**Involve/Consult:** Information exchange		• To obtain feedback from stakeholders on analysis, alternatives and/or outcomes	• Inform via CSC State Water Corporation administrator, Sri Sritharan, who is also LRWG representative • LRWG newsletter and CSC briefing papers; potential to present at CSC meeting by request or invitation	As above	As required via above protocols
(11)	**Existing stakeholder group pathway**	**Lachlan Valley Water (LVW) and Water Trust Districts**	**Involve/Consult:** Information exchange		As above	• Inform via LRWG representatives such as LVW Executive Officer Mary Ewing; Water Trust Districts via LRWG reps Gordon Turner and OEH Paul Packard who already	**As above**	As above

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	ENGAGEMENT TYPE	LINK TO Table 1. OBJECTIVE	PURPOSE	METHOD(s)	RESPONSIBILITY	TIMING
						attends meetings etc • LRWG newsletter and briefing papers as requested		
(12)	**Existing stakeholder group pathway**	**Local government**	**Inform:** Raise public awareness and appreciation/acceptance for LTIM Project objectives	7., 8., and 9.	To utilise distribution/communication networks	• Inform via Local Land Services Local Government Officers and associated reference/advisory groups	Central Tablelands LLS Snr Land Services Officer (HCVAE) and Lachlan LTIM Reference Group	When required (pre or post watering events)
(13)	**Collaborate with other research/ monitoring or water resource projects**	**Research institutes**	**Inform:** Potential to collaborate and expand monitoring activities	7., 8. and 10.	To build on existing projects and where possible utilise equipment and students for field monitoring	• Inform and establish collaborative/information sharing relationships via existing LTIM Project team networks	• M&E Provider Leader to liaise with relevant Lachlan LTIM Project staff to obtain a list of relevant projects, contact details, and access to available information	Prior to 30 June 2014 and ongoing
(14)	**MDBA-related policy/ legislation requirements**	**Other relevant government sections or departments (e.g. MDBA related obligations)**	**Involve/Consult:** Information exchange to improve Basin-scale knowledge and management	10	To ensure LTIM Project outputs and outcomes for meeting high-level objective are consistent with future legislative and policy requirements	• Via LRWG and Lachlan LTIM Project team existing agency networks	• M&E Provider Leader to liaise with relevant Lachlan LTIM Project staff to obtain a list of relevant projects, contact details, and access to available information	As required

ACTIVITY NO.	SUMMARY TITLE	STAKEHOLDER	ENGAGEMENT TYPE	LINK TO Table 1. OBJECTIVE	PURPOSE	METHOD(s)	RESPONSIBILITY	TIMING
(15)	**Case studies**	**Affected landholders**	**Inform/Involve/Consult:**	All objectives	To ensure goodwill does not dissipate and landholders are not dissatisfied with level of involvement/participation and withdraw from project. To works towards improved decision-making based on local knowledge from those impacted by decisions	Via specific interviews with select affected landholders, and utilising all project information available from M&E Provider Team (i.e. LAPs, annual C&E Plan evaluation, Stakeholder log, emails and feedback surveys, review of LAPs etc)	M&E Provider Leader and Central Tablelands Snr Lands Services Officer (HCVAE) to liaise with relevant Lachlan LTIM Project staff	As requested or expedited by affected landholder; Year 4 or 5 of LTIM Project

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INSTITUTE FOR APPLIED ECOLOGY

Commonwealth Environmental Water Office Long Term Intervention Monitoring Project Lachlan River System

Appendix 3

Workplace Health and Safety Management Plan

February 2015

UNIVERSITY OF CANBERRA

Workplace Health and Safety Management Plan

WHS202.2 February 2015

Organisation Details	
Business/Trading name	**Institute for Applied Ecology, University of Canberra**
ACN/ABN	633 873 422
Contract Job Number	RM2011000201
Authorising Person	Professor Ross Thompson
Address	Institute for Applied Ecology, University of Canberra, Bruce, ACT. 2601
Phone	02 6201 2452
Fax	02 6201 5305
Mobile	0429 949 121
Email	fiona.dyer@canberra.edu.au

Document history and status

Version	Date Issued	Reviewed by	Approved by	Revision Type
WHS 202.1	30 October 2014	Erin Murrihy	Fiona Dyer	External
WHS 202.2	20 February 2015	Guy Jones/Ebony Coote	Fiona Dyer	Internal

Distribution of copies

Version	Type	Issued to
WHS 202.1	Electronic	Commonwealth Environmental Water Office
WHS 202.2	Electronic	Commonwealth Environmental Water Office

Contents

1 Project details and introduction

The following table sets out a brief description of the work to be carried out by University of Canberra and project team institutions during the course of the Lachlan river system Selected Area Long-Term Intervention Monitoring (LTIM) Project managed by Fiona Dyer.

Date	Description of Works	No of Employees (inc subcontractors)
July 2014 – July 2018	Fish monitoring (including riverine, wetland and larval fish, microcrustaceans, turtles and decapods) Frogs and tadpole monitoring Waterbird monitoring (breeding and diversity) Water quality monitoring (including stream metabolism) Hydrology (riverine and wetland) Vegetation monitoring (tree stand condition and vegetation diversity)	Total = 13 – 16 (including project leads, researchers and technical assistants)

The table below identifies the designated person with ultimate responsibility for the management of workplace, health safety and environment for the Long Term Intervention Monitoring Project: Lachlan river system Selected Area.

Name	Contact Details
Fiona Dyer	fiona.dyer@canberra.edu.au 02 6201 2452 Mob: 0429 949 121

The project team institutions intended to be used on this site are:

Business	Contact Details
New South Wales DPI Fisheries	Jason Thiem
	jason.thiem@dpi.nsw.gov.au
	Mob: 0408 327 528
University of New South Wales	Kate Brandis
	kate.brandis@unsw.edu.au
	Mob: 0431 242 396
New South Wales Office of Water	Patrick Driver
	Patrick.Driver@water.nsw.gov.au
	Mob: 0427 406 949
Local Land Services	Joanne Lenehan
	joanne.lenehan@lls.nsw.gov.au
	Mob: 0409 496 908
Charles Sturt University	Andrew Hall
	ahall@csu.edu.au
	Mob: 0423 459 987
	Kim Jenkins
	kim.jenkins@unsw.edu.au
	Mob: 0409 748 373

University of Canberra will ensure that the above mentioned project team institutions will provide SWMS for their specialised work, and that University of Canberra shall review the SWMS, and keep up to date copies with the WHS files of the project. If they are an employer, University of Canberra will also ensure that evidence relating to a current workers compensation policy is provided.

Name of authorising person: *Ross Thompson*

(Acting Director Institute for Applied Ecology and Chair of Water Science, University of Canberra)

Signature:

Date:

2 Document Control

University of Canberra

- Maintains an up to date version of this WHS Management Plan.
- Retains all obsolete pages of the Plan for a minimum of 7 years to demonstrate a record of WHS management practices.
- Provides a copy of the current version of the WHS Management Plan to Commonwealth Environmental Water Office, including all relevant SWMS.
- Reviews the Plan on a 6-monthly basis.
- Ensures all amendments to the Plan are recorded in the Register of Amendments.

Register of Amendments					
Date	**Page/Form No.**	**Version No.**	**Description of Amendments**	**Prepared by**	**Approved by**
19/2/2015	3	WHS202.1	Update of contact names	FD	RT

Distribution Register			
Version No.	**Date of Issue**	**Name of Recipient**	**Position / Organisation**
WHS-202.1	30 Oct 2014	Commonwealth Environmental Water Office area leader	Monitoring and Evaluation Section Commonwealth Environmental Water Office
WHS-202.2	20 Feb 2015	Commonwealth Environmental Water Office area leader	Monitoring and Evaluation Section Commonwealth Environmental Water Office

3 Objectives and targets

University of Canberra has established the following objectives and targets to support and maintain the effectiveness of the WHS Management Plan.

Planning
Objective:
Employees are provided with regular and up-to-date information on WHS for the duration of the contracted/agreed works.
Target:
Review the content of the WHS Management Plan 6-monthly intervals to maintain the currency of information provided to Commonwealth Environmental Water Office.

Risk Management
Objective:
Employees are familiar with hazards and risks associated with the contracted/agreed works that are assessed as a medium to high risk.
Target:
Risk Assessment(s) or the equivalent list cover, as a minimum, those hazards and risks associated with the contracted/agreed works that are assessed as a medium to high risk.

Consultation
Objective:
Employees are regularly consulted on matters that affect WHS.
Target:
Regular email and phone contact between project team institution leads.

Training
Objective: Employees are provided with training to enable work practices to be undertaken that are safe and minimise risk to the environment. **Target:** All employees involved with the contracted/agreed work have undertaken as a minimum the three levels of induction training, i.e. general industry (safety awareness) training, site specific training and work activity training as noted in the Risk Assessment(s) specific to the contracted/agreed works.

4 WHS Policy

The University of Canberra Health and Safety Policy defines the principles of the health and safety commitment of the University of Canberra and its approach to the continuous improvement and compliance of health and safety in the workplace. This policy document is available at: https://www.canberra.edu.au/myuc-s/business-units/vpo/hr/safety-wellbeing-equity-diversity/health-and-safety-management.

5 Hazard identification, risk assessment and control

University of Canberra will not commence work unless:

- University of Canberra and the project team institutions have undertaken an assessment of the risks associated with the work activities and prepared a written Risk Assessment; and
- University of Canberra or project team institutions (as appropriate) have provided relevant induction training to all employees.

Risk assessments for each monitoring task will be prepared, maintained and updated by the responsible project team institution (outlined in section 7 below). The University of Canberra will maintain and update a compiled / overarching risk assessment.

Project team institution leads will identify the potential hazards of the proposed work activities, assess the risks involved and develops controls measures to eliminate, or minimise, the risks. The risk management process is carried out in consultation with employees. University of Canberra is responsible for maintenance, oversight and enforcement of this process and roles.

5.1 Identifying Hazards

University of Canberra in consultation with project team institution leads will breakdown specific work activities into job steps to assist in identifying all potential hazards.

The risk management process includes:

1. Identification of a hazard
2. Identification of the associated risk
3. Assessment of the risk which includes:
    - The likelihood
    - The consequence
    - Assigning a priority for rectification
4. Control the risk using a hierarchy of control measures consisting of (in order of preference):
    - Elimination
    - Substitution
    - Isolation
    - Engineering controls
    - Administrative controls (SOPs, training)
    - Personal Protective Equipment
5. Documentation of the process
6. Monitoring and review of the process.
7.

These work activities are detailed in a task specific Risk Assessment. The Risk Assessment is a list of job steps and other work related practices. For each of the work activities and associated job steps identified in the Risk Assessment, University of Canberra in consultation with project team institution leads has identified potential hazards and their risks.

To assist in identifying hazards and risks, University of Canberra in consultation with project team institution leads has considered the use of resources such as codes and standards, industry publications (i.e. safety alerts; hazard profiles for specific trade groups), workplace experience and consultation (i.e. Toolbox Talks).

5.2 Assess Risks

University of Canberra in consultation with project team institution leads has identified a risk class/ranking for potential workplace hazards by referring to the categories ranging from high to low in a Risk Matrix.

6 Personal Protective Equipment (PPE)

University of Canberra and project team institutions maintain all PPE supplied to employees where such PPE is specified as a control measure in the Risk Assessment. University of Canberra and project team institutions will ensure all items of PPE are manufactured, used and maintained in accordance with the relevant Standard. Proof of Standard compliance will be provided, e.g. labelling. Each employee will be instructed and trained in the correct use of the PPE issued.

7 Roles and Responsibilities

University of Canberra and project team institutions will provide the following key trained and competent personnel:

Employee Name	Position	Contact Details
Fiona Dyer	Project lead; hydrology lead; Water Quality lead	fiona.dyer@canberra.edu.au ph: 02 6201 2452 mob: 0429 949 121
Ben Broadhurst	Project delivery; larval fish	ben.broadhurst@canberra.edu.au ph: 02 6206 8608 mob: 0423 363 636
Dean Gilligan	Riverine and wetland fish	jason.thiem@dpi.nsw.gov.au ph: 02 6958 8219 mob: 0408 327 528
Ross Thompson	Stream Metabolism	ross.thompson@canberra.edu.au ph: 02 6201 5041
Patrick Driver	Tree stand condition; Vegetation diversity	Patrick.Driver@water.nsw.gov.au mob: 0427 406 949
Kate Brandis	Waterbirds (breeding; diversity)	kate.brandis@unsw.edu.au Mob: 0431 242 396
Kim Jenkins	Microcrustaceans	kim.jenkins@unsw.edu.au Mob: 0409 748 373
Andrew Hall	Frogs and tadpoles	ahall@csu.edu.au mob: 0423 459 987

8 Training and Competencies

Having regard to the hazards and risks associated with the work activity, University of Canberra and project team institutions will assure that all employees are trained and competent to perform all tasks in a way that is safe and does not adversely impact on themselves, others or the environment. Institutional requirements on training to be provided will be outlined in SWMS, however, some generic training that will be undertaken is outlined in the table below.

Training required for field based work

Training details	Indicator	Date of Completion	Staff required to undertake
Senior first aid	All (field based work)	End July 2014	All*
Electrofishing principals	Fish (riverine & wetland)	End July 2014	Field trip leaders - Martin Asmus; Ben Broadhurst
Current drivers licence	All	End July 2014	All those who will drive a vehicle
4wd training	All (field based work)	End July 2014	All**
Boat licence	Fish (Larval, riverine & wetlands); frogs & tadpoles	End July 2014	All persons operating a boat

* At least one member of a field party must have current senior first aid qualifications.

** Drivers of 4wd vehicles must have 4wd operational training.

9 Consultation

University of Canberra and project team institutions promote the active participation of all team members in WHS decisions. Team members will be consulted and given opportunity, encouragement and training to be proactively involved in WHS matters affecting the LTIM Project and their work activities. Consultation will occur in reference to, but not limited to, the following subjects / topics:

- hazard identification and risk assessment processes;
- control measures for the management of hazards and risks; and
- WHS performance measures.

10 Hazardous substances/dangerous goods on site

University of Canberra and project team institutions will provide a current (within 5 years of the date of issue) MSDS to the principal Contractor (Commonwealth Environmental Water Office) for all products and substances to be used for the work activity. Products identified for the project so far are listed in the Hazardous substances / dangerous good register (below). Specifically these are:

- Petroleum (used to power outboard motors and generators)
- Diesel (used to power 4WD vehicles)
- Ethanol (used to store fish samples)
- Two-stroke outboard oil (for outboard motors)

Before a product or substance is used for the work activity, University of Canberra and project team institutions will review the Material Safety Data Sheet (MSDS) to determine if the product or substance is classified as hazardous. All employees involved in the use of products classified as hazardous, are provided with information and training to allow safe completion of the required task. As a minimum standard, all safety and environmental precautions for use listed on the MSDS are followed when using the substance and are included in the Risk assessment. No products or substances, including chemicals or fibrous materials, are brought to the workplace without a current MSDS. All products and substances to be brought to the workplace are to be documented on a hazardous substance/dangerous goods register (below).

Hazardous substance / dangerous goods register

Product Name	Application	Quantity	Product labelled		MSDS	
Unleaded petrol	**Power boat; generator**	**20-25L**	Yes **X**	No ☐	Yes **X**	No ☐
Diesel	**4WD**	**<150L**	Yes **X**	No ☐	Yes **X**	No ☐
100% Ethanol	**Preserving fish samples**	**<10L**	Yes **X**	No ☐	Yes **X**	No ☐
Outboard 2 stroke oil	**For 2-stroke engines**	**<2L**	Yes **X**	No ☐	Yes **X**	No ☐
			Yes ☐	No ☐	Yes ☐	No ☐
			Yes ☐	No ☐	Yes ☐	No ☐
			Yes ☐	No ☐	Yes ☐	No ☐

University of Canberra and project team institutions consider the following when selecting chemicals and substances for use on site:

- Flammability and exclusivity;
- Toxicity (short and long term);
- Carcinogenic classification if relevant;
- Chemical action and instability;
- Corrosive properties;
- Safe use and engineering controls;
- Environmental hazards; and
- Storage requirements.

All storage and use of hazardous substances and dangerous goods is in accordance with the MSDS and legislative requirements. All hazardous substances and dangerous goods are stored in their original containers with the label intact at all times. Hazardous substances and dangerous goods of any quantity are not stored in amenities, containers (unless properly constructed for the purpose), sheds or offices.

11 Electrical equipment on site

University of Canberra and project team institutions will ensure that the use of electrical wiring, equipment, portable tools and extension leads is in accordance with applicable codes and standards. University of Canberra and project team institutions will ensure that all electrical equipment brought on site is listed on the Electrical Equipment Register below. The register is completed prior to commencement of the works and maintained for the duration of the works on site. All electrical equipment including leads, portable power tools, junction boxes and earth leakage, or residual current, devices is inspected and tested by a suitably qualified person and labelled with a tag of currency before being used on site.

Electrical equipment register

Equipment Description	Plant / Serial No.	Date of Inspection/ Test	Date of next Inspection/Test
University of Canberra - SmithRoot backpack electrofisher	F00213	September 2013	September 2014
University of Canberra - SmithRoot boat mounted electrofisher	29821	November 2013	November 2014
NSW DPI: Electrofishing vessel "AC/DC", 7.5GPP	305470	27/05/2013	May-June 2015
NSW DPI: Electrofishing vessel "Fish Magnet", 7.5GPP	AU-WWA135510 DF7	12/02/2014	12/02/2015
NSW DPI: Electrofishing vessel "ASP", 2.5GPP	AVWWA-128683	Dec-2012	Apr- May 2014
NSW DPI: Backpack Electrofisher, Smith-Root LR 24	SRI07229	12/02/2014	12/02/2015

12 Hazard and Incident Reporting and Investigation

12.1 Hazards

University of Canberra and project team institutions require all team members to report hazards immediately to the Project supervisor (Fiona Dyer – University of Canberra). Where the hazard cannot be corrected immediately, University of Canberra and project team institutions will record the details of the hazard in the Hazard Register. University of Canberra and project team institutions will investigate all reported hazards and implements control measures to eliminate and/or minimise the likelihood of an incident or injury. University of Canberra and project team institutions will regularly review and evaluate the effectiveness of control measures until the hazard is addressed and/or all risks have been mitigated or reduced. University of Canberra will issue a copy of any completed Hazard Report form to the Commonwealth Environmental Water Office, as required.

12.2 Incidents

All injuries to, or disease in any person that is caused as a result of operations that arose from any undertaking of the University of Canberra and project team institutions, including traveling between a person's residence and work must be reported. This includes:

- Any workplace incident
- Any workplace incident where the safety of a person (including an employee, student, contractor or visitor) was placed at risk
- The occurrence of any injury (psychological or physical)
- Hazards or near misses (i.e. events which have the potential to cause any of the above outcomes).

12.3 Incident Investigations

University of Canberra will complete an Incident Investigation Report in the event of any injury involving medical attention or off site treatment or in the event of any incidents involving a near miss, property/plant damage or injury to the public or the environment.

The Commonwealth Environmental Water Office will be informed immediately in the event of the above. Following discussions with the Commonwealth Environmental Water Office, a decision will be made as to who will conduct the incident investigation. The Commonwealth Environmental Water Office will be provided with a copy of the completed Incident Investigation Report.

12.4 Notifiable Incidents

University of Canberra and project team institutions will report all notifiable incidents to the relevant Authority.

Where such an incident has occurred, University of Canberra and project team institutions will consider whether the site needs to be preserved for investigation by the relevant Authority.

12.5 Record Keeping

University of Canberra will keep records of incidents and injuries in accordance with statutory requirements.

Reference Documents (provided in full at the end of this document)

Document #	Document Name:
3133	Health and Safety Policy
n/a	**University of Canberra:** Job Safety Analysis: Larval fish sampling
n/a	**University of Canberra:** Safety Management Plan for Water Quality, Hydrology and Stream Metabolism Sampling
n/a	**University of New South Wales:** - Centre for Ecosystem Science, School of BEES, UNSW - Risk Assessment for Fieldwork in wetland and waterbird ecology.
HS017	**University of New South Wales:** HS Risk management form - Aerial Survey of Waterbirds
HS307	**University of New South Wales:** HS307 Hazard & Incident Reporting Procedure
n/a	**Charles Sturt University:** Faculty of Science Research Fieldwork Risk Assessment: Frog and Tadpole surveys
n/a	**NSW Office of Water:** Office of Environment and Heritage Job Safety Analysis - Vegetation Field Survey
n/a	**NSW DPI Fisheries:** Document - Health, safety and environment systems overview
n/a	**NSW DPI Fisheries:** SWMS - Driving a motor vehicle

n/a	**NSW DPI Fisheries:** SWMS - Operation of a 4WD vehicle
n/a	**NSW DPI Fisheries:** SWMS - Refuelling vehicles and watercraft
n/a	**NSW DPI Fisheries:** SWMS - Launch and retrieval of watercraft
n/a	**NSW DPI Fisheries:** SWMS - Use of watercraft less than six metres
n/a	**NSW DPI Fisheries:** SWMS - Towing a trailer
n/a	**NSW DPI Fisheries:** SWMS - Manual Handling
n/a	**NSW DPI Fisheries:** SWMS - Field Work
n/a	**NSW DPI Fisheries:** SWMS - Working Outdoors
n/a	**NSW DPI Fisheries:** SWMS - Backpack Electrofishing
n/a	**NSW DPI Fisheries:** SWMS - Boat Electrofishing
n/a	**NSW DPI Fisheries:** SWMS - Operating of fish netting equipment
n/a	**NSW DPI Fisheries:** SWMS - Safe handling of fish
n/a	**NSW DPI Fisheries:** SWMS - Lab work – sorting and ageing fish
n/a	**NSW DPI Fisheries:** SWMS - Use of chemicals

n/a	**NSW DPI Fisheries:** SWMS - Use of office equipment
n/a	**NSW DPI Fisheries:** T&I Work health and safety Policy
n/a	**NSW DPI Fisheries:** T&I WHS framework_ Standard-1-Leadership-and-Accountability
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Standard-2-Legal-Requirements
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Standard-3-Strategy,-Objective-and-Targets
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Standard-4-Risk-Management
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Standard-5-Communication,-Consultation-and-Engagement
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Standard-6-Incident-Management
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Safety-Standard-11-Document-Control-and-Records-Management
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Standard-12-Health-and-Wellbeing
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Standard-13-Monitoring,-Audit-and-Reporting
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Standard-14-Preventive-and-Corrective-Actions
n/a	**NSW DPI Fisheries:** T&I WHS Framework_Standard-15-Measurement,-Verification-and-Review
n/a	**NSW DPI Fisheries:**

	Critical-Risk-Control-Driving
n/a	**NSW DPI Fisheries:** Critical-Risk-Control-Fatigue
n/a	**NSW DPI Fisheries:** Critical-Risk-Control-Working-on-watercraft
n/a	**NSW DPI Fisheries:** Fisheries NSW Risk Register 2013-14
n/a	**NSW DPI Fisheries:** NSW DPI Aquatic Fieldwork Hygiene SOP
n/a	**NSW DPI Fisheries:** NSW DPI Electrofishing Procedure
n/a	**NSW DPI Fisheries:** NSW DPI Electrofishing Training Schedule
n/a	**NSW DPI Fisheries:** NSW T&I Safe Operation of Watercraft Policy
n/a	**NSW DPI Fisheries:** NSW T&I Safety and wellbeing strategy summary
n/a	MSDS Diesel
n/a	MSDS Ethanol 100%
n/a	MSDS Outboard oil
n/a	MSDS Petroleum

Note: NSW DPI (Freshwater Ecosystems Unit) are currently in the process of reviewing their Safe Work Method Statements. Revised SWMS will be available by July 2014 and distributed upon request.