THE IDENTIFICATION, ASSESSMENT AND PRIORITISATION OF THREATENING PROCESSES TO THE AQUATIC ENVIRONMENT OF THE LOWER LACHLAN CATCHMENT

REPORT TO THE LACHLAN CATCHMENT MANAGEMENT AUTHORITY

Natural Heritage Trust
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Lachlan CMA CATCHMENT MANAGEMENT AUTHORITY

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

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Cover photo: Lachlan River at Booligal, showing reduced understorey vegetation and bank erosion (Lower Lachlan region, Management Zone 11).

EXECUTIVE SUMMARY

The highly modified nature of inland catchments presents many challenges in the way we protect the environment and manage its natural resources. The majority of waterways have been affected by practices associated with rural and urban development, including the regulation of rivers, the clearing of land and the construction of transport networks.

These practices have lead to a decline in the health of aquatic and riparian habitats in the Lachlan catchment, directly impacting the populations of native fish species and other aquatic biota. There are six key threatening processes as listed under the *Fisheries Management Act* 1994 that occur within the Lachlan catchment, including:

- River regulation;
- The installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams;
- The degradation of native riparian vegetation along NSW water courses;
- The removal of large woody debris;
- Hook and line fishing in areas important to the survival of threatened fish stocks; and
- The introduction of fish to freshwaters in a river catchment outside their natural range.

This project identified these key threatening processes that affect the aquatic environment of the lower Lachlan, assessed their impact within this section of the catchment and presented options for the remediation of affected priority areas. Fieldwork included the assessment of aquatic habitat and instream structures across seven management zones.

Habitat assessment focussed on the four parameters of fish assemblage, aquatic vegetation, riparian vegetation, and large woody debris at 26 sites within the lower Lachlan. For each of these sites a one kilometre reach was established and the habitat parameters were measured and quantified, with an Indexed Frequency Value attributed to each parameter. The assessment of these parameters indicated that the aquatic environment of the lower Lachlan was in an overall poor condition, with fish assemblages dominated by introduced species, and aquatic vegetation and large woody debris providing minimal instream habitat. The riparian vegetation possessed significant stands of native species, however understorey vegetation was in a poor condition.

The assessment of instream structures identified 68 structures across the zones, with 31 acting as barriers to fish passage. Of these barriers, 11 were classified as high priority and required immediate remediation. High priority structures included ten weirs and one culvert, with remediation options such as basic management/maintenance (e.g. removal of sediment and debris blocking inlets), and the modification of structures (e.g. retrofitting low-flow channels, modifying outlet levels, installing fishways) suggested for these sites.

To address the threatening processes and overall poor condition of the aquatic environment in the lower Lachlan it is suggested that remediation actions focus on areas that are currently in reasonable condition, particularly reaches in Zones 8 and 11. Actions suggested for these areas incorporate an integrated restoration approach, focussing on the regeneration of riparian understorey vegetation, reinstatement of woody debris and the remediation of fish passage barriers, with the aim of improving aquatic habitat and native fish populations. Before implementing these suggested actions it is important to review environmental, social, cultural and economic considerations, with the results and process of the current study potentially guiding similar projects that aim to assess and remediate threatening processes in the upper Lachlan catchment.

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1. INTRODUCTION

The following report outlines the results of a project entitled "*The Identification, Assessment and Prioritisation of Threatening Processes to the Aquatic Environment of the Lower Lachlan Catchment*". The project was carried out by the NSW Department of Primary Industries (Fisheries Management) on behalf of the Lachlan Catchment Management Authority (LCMA) and funded by the Natural Heritage Trust Program (Contract No. LA C4 – NHT IPP).

1.1 Project aims and objectives

The project was designed to inform the CMA of key threats facing the aquatic environment of the Lachlan catchment, expanding on findings from previous studies by conducting detailed field work specific to the aquatic habitat of the catchment. The project endeavoured to provide direction for expenditure of funds targeted for aquatic habitat rehabilitation, supporting the Management Targets of the Lachlan Catchment Blueprint (2003). These targets include managing riparian and drainage areas to reduce nutrient and sediment loads entering the system, managing the riparian zone to maintain and increase the extent of native riparian vegetation, and to manage the riparian zone to enhance aquatic diversity and habitat (Lachlan CMB, 2003).

The scope of this project was restricted to the lower Lachlan region, which encompasses the area west of Condobolin (Map 1). The aquatic habitat within this region was identified as a priority site by the LCMA, with the methods and findings of this report used as a template to guide similar projects in the upper and mid Lachlan regions.

The primary objectives of the project were to:

- Identify key threats to the aquatic and riparian environments of the lower Lachlan;
- Identify and asses areas of aquatic and riparian habitat degradation in the lower Lachlan;
- Identify and asses instream structures in the lower Lachlan area that may be barriers to fish passage;
- Outline methods for remediating threats and improving management of aquatic habitat in the lower Lachlan; and
- Highlight areas of highest priority for future remediation.

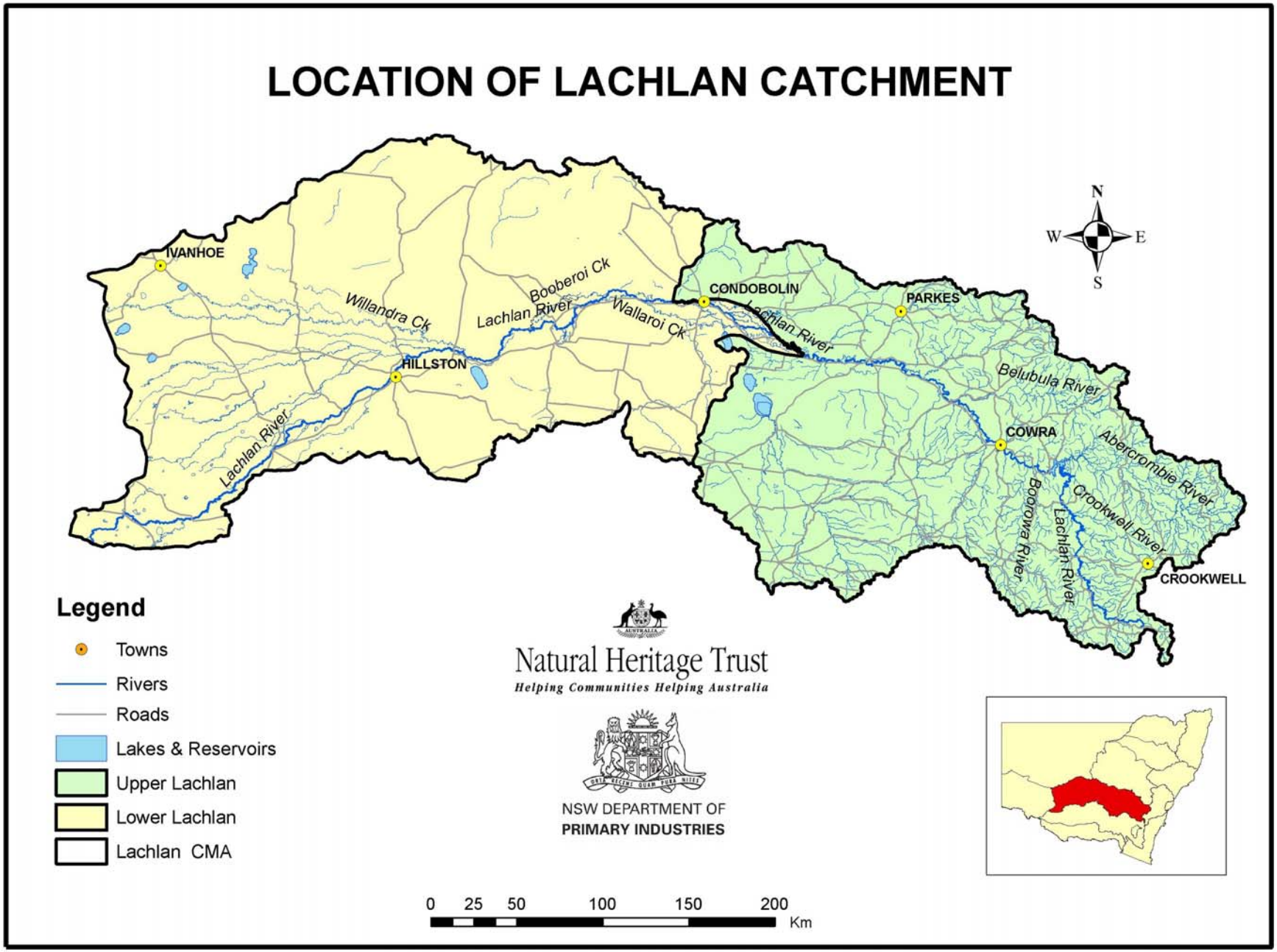
2. BACKGROUND

2.1 Lachlan catchment – Regional setting

The Lachlan catchment is the third largest catchment in the Murray-Darling basin, covering an area of approximately 84,700 km^2 and servicing a population of approximately 100,000 residents. The catchment is located in the south-eastern area of the Murray-Darling basin, rising along the western perimeter of the Great Divide in the east and terminating at the Great Cumbung Swamp on the Riverine Plains in the west (Map 1).

The main waterway in the catchment, the Lachlan River, covers a length of approximately 1,450 km, and includes major tributaries such as the Abercrombie, Boorowa, Belubula, Crookwell, Goobang, Bland and Mirool river systems. The upper and middle reaches of these systems are characterised by inflowing water, whilst the lower Lachlan catchment typically services outgoing 'effluent' creeks that are characterised by decreasing flow and channel capacity (Roberts and Sainty, 1996; DLWC, 1998). These systems were important travelling routes for the Wiradjuri Aboriginal people, who used the waterways for food, water and shelter (DLWC, 1998; Lachlan CMB, 2003).

The catchment supports an array of agricultural activities, including the production of wool, livestock, wheat and other cereals that are dependent on the waterways of the catchment especially for irrigation purposes. The infrastructure required to support this landuse, including diversion channels, dams and weirs, has impacted directly on the health and connectivity of the river systems. Flow regulating structures, including the two major water storages of Wyangala and Carcoar Dams, and other regulating weirs such as Booberoi, Lake Brewster



Map 1: Location of the Lachlan catchment.

and Hillston, are used to provide measured water flows. The construction of these, and numerous other weirs, has significantly reduced the frequency of natural flood events, impacting on the condition of aquatic and riparian habitat, as well as producing major instream barriers to fish passage throughout the Lachlan catchment.

The river and its storages are also commonly used to provide drinking water, supply industry and for recreational purposes. The catchment also contains nine highly significant wetlands, including Lake Cowal, the Booligal Wetlands and the Great Cumbung Swamp. These wetlands represent some of the most important aquatic environments in the Murray-Darling basin, displaying great diversity in both their form and biota (Driver *et al*, 2002).

2.2 Lachlan catchment – Aquatic habitat and biodiversity

The Lachlan catchment forms a unique part of the Murray-Darling basin as it only joins the Murrumbidgee River in times of significant flood events. As a result, the Lachlan River is predominantly isolated from other rivers and reflects this isolation in its ecology. The freshwater environment of the Lachlan catchment is comprised of a range of aquatic habitats including swamps, floodplains, wetlands, streams and rivers. Within these broad habitat types, niche habitats such as pools and riffles, gravel beds, snags, aquatic vegetation and riparian vegetation are present, diversifying the habitat available to aquatic species in the Lachlan catchment. This habitat diversity is greater in the upper catchment, with the lower Lachlan having a reduced number of niche habitats (DLWC, 1998).

There is a variety of aquatic and riparian vegetation that is present within the majority of the Lachlan catchment. Aquatic vegetation consists of floating, emergent and submerged plants, with stands of lignum (*Muehlenbeckia florulenta*), ribbon weed (*Vallisneria spp*.), common reed (*Phragmites communis*), and cumbungi (*Typha spp*.) all being present in waterways of the Lachlan (DLWC, 1998). Riparian vegetation of the Lachlan consists of river red gums (*Eucalyptus camaldulensis*), black box (*E. largiflorens*) and river cooba (*Acacia stenophylla*), with stands of these species commonly found along the river and creek banks of the lower Lachlan floodplains (DLWC, 1998). The condition of this habitat varies throughout the catchment, from a reasonable state in the upper and middle sections to a very poor condition in the lower Lachlan (Massey, 1998).

The range of aquatic habitat in the Lachlan supports a diverse assemblage of species, including over 29 freshwater finfish species (see Appendix A and B). Six of these species are introduced, competing with the native fish species, which comprise 23 of the total species in the catchment. The pressures from introduced species, as well as other factors such as reduced water quality, increased fishing pressure, and habitat degradation, have resulted in the population densities of native fish being significantly lower than historical levels (Growns, 2001). Recent studies, which were separately conducted by Growns and NSW Department of Infrastructure, Planning and Natural Resources (DIPNR), now Department of Natural Resources (DNR), in 2001 found an absence of five native species that had previously been recorded in earlier studies by both Llewellyn (1983) and Harris and Gherke (1997). These recent studies of the catchment also found that the native population lacked diversity and abundance, with introduced species having greater abundances throughout the Lachlan (DIPNR, 2001; Growns, 2001; MDBC, 2004).

Within the native species recorded in the Lachlan, seven are listed as threatened in NSW waters. The western populations of the olive perchlet (*Ambassis agassizii*) and the purple spotted gudgeon (*Mogurnda adspersa*), along with the Murray hardyhead species (*Craterocephalus fluviatilis*) are listed as endangered under the *Fisheries Management Act* 1994. Macquarie perch (*Macquaria australasica*), silver perch (*Bidyanus bidyanus*), and the southern pygmy perch (*Nannoperca australis*) are listed as vulnerable under the *Fisheries Management Act* 1994, whilst the Murray cod (*Maccullochella peelii peelii*) species is listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). All of these species have an expected distribution in the Lachlan catchment, with historical records indicating their presence throughout the entire catchment. Pressures such as habitat degradation and the loss of aquatic plants, as well as competition and predation from introduced species have affected these populations.

The region also supports an array of aquatic macroinvertebrates, with 76 families recorded in the catchment, dominated by insects and crustaceans (DLWC, 1998). The macroinvertebrate communities of the catchment vary significantly, with the lower reaches possessing lower species richness than the upper Lachlan (DLWC, 1998). The threatened river snail species *Notopala sublineata*, which is listed as an endangered species in NSW under the *Fisheries Management Act* 1994, has an expected distribution in the Lachlan catchment. This freshwater snail was once widespread in the Murray-Darling basin, with pre 1980 records showing their distribution in the Lachlan catchment, however activities associated with river flow management have rapidly reduced their populations (NSW Fisheries, 2002a).

All these aquatic species are dependent on healthy waterways and access to a range of diverse habitats for their survival. In recognition of this, the aquatic ecological community in the lowland catchment of the Lachlan River has been listed as an Endangered Ecological Community (EEC) under the *Fisheries Management Act* 1994. This includes all native fish and aquatic invertebrates that occur within the natural rivers, creeks, and streams, as well as associated billabongs, lakes, wetlands, effluent streams and floodplains, of the Lachlan catchment below 500 m altitude. The establishment of an EEC in the lower Lachlan recognises the rarity, vulnerability and habitat importance of the region.

2.3 Threatening processes in the Lachlan catchment

Recent ecological assessments have indicated that the aquatic habitat in the Lachlan catchment is highly degraded (Massey, 1998). River regulation and land management practices have lead to a decline in the health of aquatic and riparian habitats, directly impacting the populations of native fish species. There are six key threatening processes as listed under the *Fisheries Management Act* 1994 that occur within the Lachlan catchment. Under this Act, a key threatening process is one that *"adversely affects two or more listed threatened species, populations or ecological communities, or could cause other species, populations or communities to become threatened"*. In the Lachlan catchment this includes:

- River regulation;
- The installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams;
- The degradation of native riparian vegetation along NSW water courses;
- The removal of large woody debris;
- Hook and line fishing in areas important to the survival of threatened fish stocks; and
- The introduction of fish to freshwaters in a river catchment outside their natural range.

2.3.1 River regulation

The regulation of waterways in the Lachlan catchment has been practiced since 1902. The construction of dams and weirs has taken place throughout the entire catchment, including the major storage dams of Wyangala and Carcoar, which have altered approximately 70% of the catchment run-off (DLWC, 1998). The extraction of water from these structures is primarily undertaken for irrigation purposes in the Lachlan catchment, which accounts for approximately 93% of water usage, with the remaining uses including town water supply, stock, domestic and industrial uses (DLWC, 1998). To accommodate for the high level of irrigation in the Lachlan, irrigation channels have been extensively employed, especially in the lower regions of the catchment, significantly impacting on the aquatic health of the environment (S. Morris, pers. comm.). The use of these channels to divert and extract large volumes of water from natural systems can potentially alter variables such as river flow, channel shape and morphology, as well as affect native fish populations by creating instream barriers and extracting larvae and juvenile recruits (Baumgartner, 2005).

River regulation and water extraction in the Lachlan catchment has had a significant impact on the aquatic habitat and ecology of the region. The Integrated Quantity and Quality Model (IQQM), a method established to estimate historical river flows and determine the impacts of river regulation and water extraction, was applied to the catchment and indicated that:

- there was a reduction in annual flow, particularly in the lower reaches and effluent creeks;

- the frequency of medium-sized floods and freshes had been reduced;
- there were impacts on aquatic fauna and flora, including a reduction in fish migration and breeding events, and the reduction of habitat diversity;
- there was an alteration in the seasonality of flows; and
- water quality had been reduced, with an increase in algal blooms (DLWC, 1998).

Algal blooms occur frequently in the Lachlan River system and are usually associated with the larger water storage reservoirs, including Wyangala Dam, Carcoar Dam, Lake Brewster, Lake Cargelligo and Booligal Weir (DLWC, 1998). These environments predominantly provide stable conditions of low salinity levels, appropriate nutrient levels and high temperatures over long periods, resulting in the occurrence of algal blooms (DIPNR, 2004c). Such occurrences have the potential to increase the biological oxygen demand of a waterway, compete with aquatic macrophytes for light, and disrupt the nutrient cycling of a system (DIPNR, 2004c). Algal blooms may also produce contact irritants or harmful toxins that can have a significant impact on the water use of humans and animals (DIPNR, 2004c).

Another significant impact associated with dam and weir construction is the occurrence of cold water pollution. This form of pollution is generally the result of stored water being released from deep layers within a reservoir, which often have lower water temperatures than the natural waterway. Cold water pollution can have significant direct and indirect impacts on all biological processes, affecting the survival of native fish and other aquatic fauna (Todd *et al*, 2005). The release of cold water indirectly impacts native fish populations by reducing the availability of food and providing conditions more favourable to introduced species, whilst directly reducing spawning cues and success, as well as the survival of larvae (Todd *et al*, 2005). In the Lachlan catchment, it has been identified that cold water pollution is occurring below Wyangala and Carcoar dams, with significant reductions in water temperature associated with these structures (Lugg, 1999). The larger of these two dams, Wyangala, has been identified as potentially causing severe cold water pollution in the catchment, impacting on the aquatic flora and fauna of the Lachlan (Preece, 2004).

2.3.2 Barriers to fish passage

Impeding fish passage through the construction of dams, weirs and waterway crossings can negatively impact native fish by creating physical, hydrological or behavioural barriers that:

- interrupt spawning or seasonal migrations;
- restrict access to preferred habitat and available food resources;
- reduce genetic flow between populations;
- increase susceptibility to predation and disease through accumulations below barriers;
- fragment previously continuous communities; and
- disrupt downstream movement of adults and impede fish larval drift through the creation of still water environments (Fairfull and Witheridge, 2003).

The impact of instream structures on fish passage will vary depending on a) the design of the structure b) the nature of flow, debris and sediment movement in the waterway, and c) the swimming capabilities of fish (dependent on species and age) present in the waterway.

In general, bridges and arch structures have the least impact on fish passage as they normally involve limited disturbance to the stream flow or the aquatic habitat of a waterway (Fairfull and Witheridge, 2003). Fish are able to swim under most bridge types during a range of hydrological conditions without encountering any form of blockage.

Culverts are waterway crossings with round or box-shaped cells designed to convey flow underneath the roadway. Some culverts can become a hydrological barrier during both freshes and low flows, especially if there is excessive variation in water level across the outlet (causing a waterfall effect). In addition to this, culverts can restrict fish movement due to a lack of lighting, excessive flow velocities and due to debris blocking the opening.

Low-level crossings such as causeways and fords, which are formed directly on the channel bed, are generally constructed at or near bed-level. Both types of crossings can drown out

reasonably frequently, however at low flows they may act as a barrier by providing inadequate flow depth and a fall in water level at the structure crest can cause a waterfall effect.

Instream structures that span the whole channel, including regulating structures such as weirs, levees and floodgates can impede natural flows and act as physical and hydrological barriers to fish movement. Such structures can isolate upstream and downstream habitats, as well as seasonal or ephemeral habitats on floodplains and wetlands (Thorncraft and Harris, 2000; Fairfull and Witheridge, 2003).

The Lachlan catchment possesses a range of these instream structures that perform different services. This includes infrastructure such as diversion channels, dams and weirs that support the agricultural landuse, and both public and private transport networks that service the urban and rural centres of the region. These structures have impacted directly on the condition of the aquatic environment in the catchment, affecting the ecology of this system.

2.3.3 Degradation of riparian zone

Riparian zones form an integral part of the aquatic landscape, and include land immediately adjacent to waterways, areas surrounding lakes, and wetlands on floodplains that interact with rivers during times of flood (Lovett and Huggan, 1998). Riparian zones perform important functions that benefit the aquatic environment, including supplying food and habitat for aquatic biota, buffering waterways against nutrient and sediment runoff, and protecting the stability of stream banks (Robins, 2003). These landforms have the potential to directly impact the condition of the aquatic environment by affecting channel morphology, bank stability, and water properties, with a negative impact predominantly resulting in:

- a reduction in food and habitat;
- a reduction in water quality through the presence of algae and loss of shade;
- an alteration in the light and temperature of streams;
- the promotion of weed invasion by species such as Lippia (*Phyla canescens*) and willow (*Salix spp*.); and
- a reduction in bank stability that can lead to erosion (Massey, 1998).

The clearing of riparian vegetation has occurred extensively throughout the Lachlan catchment, mainly for agricultural purposes. This has left the current state of this habitat in a very poor condition with only a few undisturbed native stands remaining (Massey, 1998). The majority of streams in the Lachlan have been cleared on both sides, with the native vegetation replaced by exotic species such as willow and Blackberry (*Rubus fruticosus*).

Degradation of this riparian zone can also lead to the formation of stream-bank erosion, which often occurs when vegetation is cleared, weakening the ability of waterway banks to resist the forces of erosion (Price and Lovett, 2002). Erosion processes that have occurred in the Lachlan include riverbank scouring, undercutting and slumping, the incision of stream beds, and gully erosion. This has increased the sediment load of the waterways in the Lachlan catchment, reducing the water clarity of the Lachlan River and its associated tributaries (Driver *et al*, 2002). Erosion has also lead to changes in the shape of the river by making it wider and shallower in some parts and deeper and narrower in others (Driver *et al*, 2002).

2.3.4 Degradation of instream habitat

Instream habitat includes the presence of woody debris, macrophytes, and algae within a system. This material plays an essential role in providing important habitat and shelter for fish and other aquatic biota from strong currents and predators, as well as substrate for fish to lay eggs. Aquatic vegetation also plays a vital role in improving water quality by providing nutrient sinks and sources that filter nutrients and stabilise sediments (Smith and Pollard, 1999).

The degradation of instream habitat has predominantly occurred through the removal of woody debris and the removal of instream vegetation, as well as other factors associated with river regulation, stock access and stream bed instability. The presence of woody debris in waterways of the Lachlan has suffered a reduction in recent times due to removals associated with improving water passage to downstream users, as well as the clearing of native riparian

vegetation (Massey, 1998; Smith and Pollard, 1999). This has the potential to reduce the population of native fish by limiting the sites available for shelter and breeding, as well as reducing the diversity of aquatic habitat in the Lachlan catchment (Massey, 1998).

Aquatic vegetation of the Lachlan catchment has also experienced extensive degradation, with the majority of vegetation generally being in a very poor condition (Massey, 1998). This has predominantly been caused by the direct removal of aquatic plants through activities associated with agricultural practices and aggregate extraction. This activity is undertaken in the Lachlan catchment at seven locations, with a total of 59,500 m^3 extracted during the 1995–1996 period (DLWC, 1998). Aggregate extraction from within waterway channels has the potential to accelerate erosion of the river channel, as well as cause direct disturbance to aquatic habitat (DLWC, 1998). This direct disturbance can lead to a reduction in habitat and food for aquatic and terrestrial wildlife, a decline in the abundance and distribution of fish species, an alteration of species composition of instream plants, and an overall reduction in the health of the aquatic environment (Morris *et al*, 2001).

2.3.5 Direct impacts to native fish

Numerous pressures are placed on the native finfish species of the Lachlan catchment, resulting in significantly lower population densities than historical levels (Growns, 2001). These pressures include the key threatening processes of increased hook and line fishing, especially in important fish habitat areas, and the introduction of fish to waters within the catchment, including fish stocking programs and the establishment of introduced species.

Fishing pressure in the Lachlan catchment encompasses activities associated with commercial and recreational fishing, including illegal activities that occur within these sectors. Commercial fishing in the Lachlan was a major industry by the end of the 19th Century, contributing significantly to the decline of native fish species, including the Murray cod (Roberts and Sainty, 1996). In 1998 it was determined that this activity was a major threat to native fish stocks in NSW, resulting in the commercial fishing of native fishes being banned in the Lachlan catchment. Recreational fishing has also had an impact on the aquatic resources of the Lachlan catchment, although not as severe as commercial activities, with anecdotal evidence indicating that there has been a major decline in numbers of native fishes that were previously popular for sport-fishing (Roberts and Sainty, 1996). Species no longer readily available include Murray cod, catfish (*Tandanus tandanus*), Macquarie perch and golden perch (*Macquaria ambigua*). Associated with these two fishing sectors is the occurrence of illegal fishing activities, which includes the use of cross lines, fish traps, gill nets, and an excess number of setlines (Loring, 1995). Illegal fishing has the potential to impact on aquatic resources by reducing the number of native freshwater fishes and also reducing numbers of other wildlife including turtles, platypus, water rats and birds (NSW Fisheries, 2002b).

As a result of the pressures that commercial and recreational fishing has placed on native fish populations, the practice of introducing fish species into the systems of the Lachlan catchment has taken place. This has involved the managed stocking of both native and introduced species, as well as the accidental stocking of introduced species, both of which have the potential to adversely impact native fish populations (NSW DPI, 2005). In the Lachlan catchment, fish stocking has focussed on the native silver perch, golden perch, Murray cod and trout cod (*Maccullochella macquariensis*) species, as well as the introduced brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) species. This has been done to replenish depleted native fish populations, as well as to enhance recreational fisheries in the region. Anecdotal evidence suggests that in areas where native fish are stocked there is an increase in the abundance of the species, however it is difficult to determine if stocked fish are maintaining viable populations within the waterway and significantly adding to the population over time (S. Thurstan pers. comm.).

The stocking of introduced fishes into the drainage systems of the Lachlan has the potential to impact native fish populations through predation, competition for food and space, introduction of diseases, habitat disturbance and reduction of genetic integrity through hybridisation. Introduced species are classified as species that have been either accidentally or deliberately transported from overseas countries into Australian waters and established wild populations. This has been achieved predominantly due to the ability of introduced

species to adapt and tolerate a large variety of aquatic conditions and habitats, including degraded environments. The introduced species present in the Lachlan catchment, as well as their habitat and impact details, are listed in Table 1.

Table 1: The habitat and impact of introduced fish species in the Lachlan catchment (source: Faragher and Lintermans, 1997).

Species	Habitat	Impact
Brown Trout	Found in cooler waters of upper mountain and slope areas.	Direct predation on aquatic invertebrates and riparian fauna, as well as the native mountain galaxiid (*Galaxias olidus*). Also in competition with mountain galaxiid, with impact linked to a decline in the native species.
Carp	Widely spread, with optimum habitat being in slow-flowing waters at low altitudes. Often found in turbid water of poor quality, resulting in high densities.	Significant environmental damage, causing high levels of turbidity and loss of aquatic vegetation. In direct competition with native species for habitat and food, often out competing native fish as a result of larger abundances.
Gambusia	Inhabit freshwaters at low elevations, withstanding environmental conditions such as high temperatures and low oxygen levels.	Direct competition with native species for resources has led to a decline in populations, especially the purple spotted gudgeon and pygmy perch. Also an aggressive predator, preying on a wide variety of aquatic and terrestrial species and fin-nipping other fishes, leading to secondary infections.
Goldfish	Inhabit slow-flowing waters, withstanding environmental conditions such as high temperatures and low oxygen levels.	Known vector of the Goldfish Ulcer Disease (GUD), which has the potential to infect other fish species, especially hatchery-reared fish.
Rainbow Trout	Found in cooler waters of upper mountain and slope areas.	Direct predation on aquatic invertebrates, being in competition with the mountain galaxiid. May transmit the Epizootic Haematopoietic Necrosis (EHN) virus to native fish.
Redfin Perch	Occur in still or slow-flowing waters, especially where aquatic vegetation is abundant.	Direct predation on aquatic invertebrates, being in competition for resources with native species. May transmit the EHN virus to native fish, with the Macquarie perch, silver perch and mountain galaxiid being highly susceptible.

2.3.6 Water pollution

The threatening process of water pollution occurs throughout the Lachlan catchment, and may involve either point source pollution, diffuse pollution or a combination of the two. Point source pollution occurs due to localised discharges from sewage treatment plants, drains or a spill, with the impact commonly occurring immediately below the discharge point (DLWC, 1998). Impacts associated with this type of pollution include eutrophication, which may lead to the formation of algal blooms, and a decline in the health of native aquatic organisms. To minimise these impacts, pollution discharges are regulated throughout the catchment, however unregulated accidental spills still occur, significantly contributing to water pollution in the Lachlan (DLWC, 1998).

Diffuse pollution results from run-off from the surrounding catchment and has the potential to have a significant impact on the aquatic environment (DLWC, 1998). This form of pollution predominantly involves agricultural pesticides and fertilisers, which are used extensively throughout the Lachlan to control plant and insect pests. Many of the chemicals used for this purpose are essentially toxic and do not distinguish between pest and non-pest species, increasing their potential impact on biota that is associated with the aquatic environment (Lloyd-Jones, 1999; Lloyd-Jones and Raisin, 2003). The impact of diffuse pollution on aquatic ecosystems depends upon a number of factors, including the type of chemical used, the volume and frequency of its use, and the life-cycle stage of the impacted organism, with such pollution having the potential to cause mass fish kills and waterbird mortalities (Lloyd-Jones, 1999; Morris *et al*, 2001).

3. PROJECT METHODS

3.1 Previous investigations in the Lachlan catchment

Several studies have previously been undertaken by natural resource management agencies within the Lachlan catchment, addressing aquatic habitat health, fish passage and aquatic ecology issues. These studies were reviewed as part of the current project to identify knowledge gaps relating to aquatic habitat and fish passage in the Lachlan catchment.

Massey (1998) assessed the health of the riverine environment in the Lachlan catchment, studying some of the key physical and biological attributes of the major streams, including overall aquatic habitat, riparian vegetation, and aquatic vegetation condition (Table 2). The review assessed these attributes based on the diversity of habitat available and the percentage cover of vegetation present.

Table 2: Summary of the assessment of aquatic habitat in the Lachlan (source: Massey, 1998).

Riverine Attribute	Condition (%)				
	Very good	Good	Moderate	Poor	Very poor
Overall aquatic habitat	1	26	40	23	10
Riparian vegetation	4	5	13	19	59
Aquatic vegetation	0	1	8	15	76

From the study it was concluded that the overall aquatic environment of the Lachlan was in a moderate to poor condition, with only 1% classified as being in a very good condition (Massey, 1998). Riparian vegetation was found to be in a poor condition, dominated by exotic species, whilst the majority of aquatic vegetation was diminished and classified as being in a very poor condition (Massey, 1998).

The status of native fish and their habitat was assessed in the Lachlan catchment during a study conducted by Growns (2001). The study focussed on the fish species present in the main Lachlan River channel and its associated effluent creeks, as well as the riparian and aquatic vegetation available in these systems. During the study 13 species were recorded out of approximately 5,000 fish sampled, with the greater abundance of alien species suggesting that the native fish community of the Lachlan was in a poor condition (Growns, 2001). The habitat assessment found that riparian vegetation mainly consisted of native trees, however aquatic vegetation was found to be in low abundances at the majority of sites. There were few significant relationships found between the abundance of fish species and the habitat components recorded during the study (Growns, 2001).

In 2002, NSW Fisheries (now incorporated in NSW DPI) completed a statewide review of weir structures identified in the Department of Land and Water Conservation (DLWC) Weirs Inventory. This initial weir review focused on licensed structures that were accessed through the DLWC's Licensing Administration database System (LAS). A total of 225 weir licences were registered in the Lachlan catchment, with 120 weirs existing on named watercourses and only 45 of these structures found and inspected during the review (NSW Fisheries, 2002c). Following the Initial Weir Review, a Detailed Weir Review was conducted (see Appendix C), which identified 20 structures that required structural or operational modifications, 12 of which occurred in the lower Lachlan (Table 3).

Table 3: Weirs identified for fish passage remediation actions in the lower Lachlan catchment (source: NSW DPI, 2006a).

Barrier Name	Waterway	Ownership	Proposed Action
Booberoi Weir	Lachlan River	State Water	Recommended for a vertical slot fishway
Booligal Weir	Lachlan River	State Water	Recommended for a full width rock ramp fishway
Condobolin Weir	Lachlan River	State Water	Recommended for a vertical slot fishway
Gonowlia Weir	Lachlan River	State Water	Management of drop boards
Hillston Weir	Lachlan River	State Water	Full width rock ramp fishway
Kiactoo Weir	Lachlan River	State Water	Recommended for a vertical slot fishway
Lake Brewster Weir	Lachlan River	State Water	Fishway option study
Lake Cargelligo Weir	Lachlan River	State Water	Recommended for a vertical slot fishway
Micabil Weir	Lachlan River	Private Water Trust	Partial width rock ramp fishway
Tallawanta Weir	Lachlan River	Private	Full width rock ramp fishway
West Condobolin Weir	Lachlan River	Private Water Trust	Removal
Willandra Weir	Lachlan River	State Water	Partial width rock ramp fishway

The current report builds upon these previous studies by identifying and assessing threatening processes to the aquatic environment of the lower Lachlan catchment. This includes assessing riparian and aquatic vegetation, as well as other instream structures such as road crossings, that potentially impact upon the aquatic habitat and biota of the catchment.

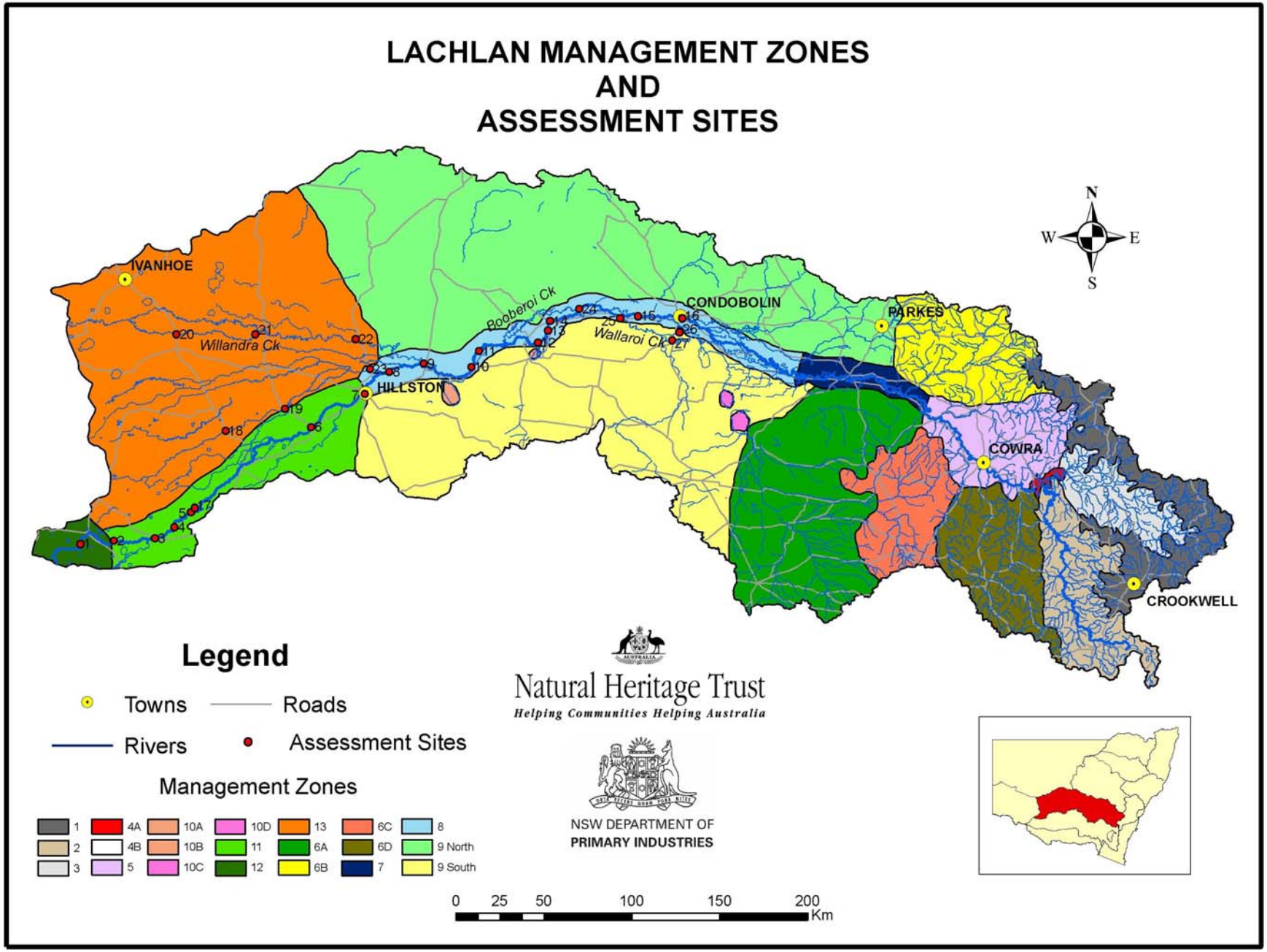
3.2 Desktop and field analysis

To identify, assess and prioritise the threatening processes that affect the aquatic habitat and biota of the lower Lachlan catchment, extensive desktop analysis and field work was completed during early 2005. This process required the catchment to be divided into smaller zones to ensure that analysis was completed efficiently and effectively. An assessment of the aquatic and riparian habitat, as well as the presence of barriers to fish passage was then undertaken for the lower Lachlan catchment.

3.2.1 Determination of zones

Due to the extensive size and complexity of the Lachlan region, the catchment was divided into 13 broad management zones (Map 2). These zones were established based on geomorphic and fish habitat parameters, with the extent of threatening processes in each zone assessed in greater detail.

These zones were determined with the assistance of NSW DPI staff that were familiar with the fish habitat and morphology of the catchment. During the process it was determined that the terrain and morphology of the river changes from east to west, with the catchment containing tributaries in the upper extent and effluent creeks in the lower reaches. The 13 zones were selected to reflect this trend in aquatic habitat of the Lachlan, with the details of each zone listed below and further information outlining the riverine condition and threatening processes for the zones provided in Appendix D.



Map 2: Location of the 13 management zones and aquatic habitat assessment sites in the Lachlan.

Zone 1: Upper Lachlan and Abercrombie Rivers (900m and above)

This zone includes the headwaters of both the Lachlan and Abercrombie Rivers in the highland regions. The area contains a combination of densely vegetated ranges and cleared grazing lands, with the aquatic habitat consisting of fast flowing waters with sandy and pebbly beds (DLWC, 1998). The fish communities consist of native mountain galaxias and other species that are suited to the cooler waters of the zone.

Zone 2: Upper Lachlan River (below 900m to Wyangala Dam)

This zone is characterised by the unregulated, upper Lachlan and Crookwell Rivers above Wyangala Dam. Zone 2 consists of fast to moderately flowing streams and ranges that are small to moderately steep. The majority of the area is cleared for grazing.

Zone 3: Upper Abercrombie River (below 900m to Wyangala Dam)

Zone 3 includes the upper area of the Abercrombie River that is above Wyangala Dam and below 900m elevation. The systems of this area are unregulated and characterised by steep terrain and fast to moderately flowing streams with well-vegetated banks. The surrounding land is predominantly used for grazing.

Zone 4: Wyangala Dam (4A) and Carcoar Dam (4B)

The water bodies of this zone are the main water storage dams in the upper region of the Lachlan catchment. Wyangala Dam (4A) is the main storage dam for the Lachlan River, while Carcoar Dam (4B) retains water from the Belubula River. They are both artificial impoundments and can therefore be treated similarly.

Zone 5: Main channel Lachlan River (downstream Wyangala to Gooloogong) and main channel Belubula River (to Lachlan junction)

This zone contains both the Lachlan and Belubula Rivers, both located in the slopes of the Lachlan catchment. The terrain in this area is undulating to hilly, with the streams flowing gently and containing snags with sandy or muddy beds (DLWC, 1998). The waterways are highly regulated, being located directly downstream of the two main storage dams.

Zone 6: Main upland tributaries - Boorowa River (6A), Mandagery Creek (6B), Crowther Creek (6C), and Bland Creek (6D)

These four main tributaries are also located in the slopes of the Lachlan catchment, however the waterways in this zone are not regulated. The landscape of this area is characteristically undulating to hilly and is mostly cleared, with pockets of native vegetation. For the purposes of this and future studies, the main tributaries have been subdivided into four zones.

Zone 7: Main channel Lachlan River from Gooloogong to Bedgerebong

This zone represents the beginning of the floodplains, where the river channel is no longer confined and the flow regime is highly regulated. The slopes of the floodplain are reduced and the landscape is characterised by flat plains and the occasional rocky outcrop.

Zone 8: Main channel Lachlan River from Bedgerebong to Hillston

Zone 8 marks the beginning of the lower Lachlan and consists of lowland floodplains where flows are reduced due to the large presence of instream structures upstream. Regulators and levee banks affect flows through to billabongs and other wetlands in this zone. Off-stream storages are also located on the floodplains, which are characteristically flat with the occasional rocky outcrop.

Zone 9 (South): South eastern effluent/ephemeral channels

This zone represents the area where the unregulated effluent creeks of the Lachlan River lie to the south of the main channel. The topography of the area consists of semi-arid rangeland, with the surrounding land predominantly used for grazing.

Zone 9 (North): North eastern effluent/ephemeral channels

This zone consists of the unregulated ephemeral creeks and channels that lie to the north of the Lachlan River channel, and is surrounded by semi-arid rangelands. Land use is dominated by agriculture, with grazing and travelling stock reserves occurring in the area.

Zone 10: Lake Brewster (10A), Lake Cargelligo (10B), Lake Cowal (10C), and Nerang Cowal (10D)

Zone 10 includes the floodplain lakes of the lower Lachlan catchment, including Lake Brewster, Cargelligo and Cowal. Lake Brewster and Lake Cargelligo are natural off-river lakes that have been modified to become the main water storage and flow regulating dams of the lower Lachlan. Lake Cowal is an unregulated ephemeral lake, and represents the largest natural lake in the Lachlan catchment.

Zone 11: Main channel Lachlan River from Hillston to Oxley

This zone includes the lowland floodplain region of the main channel Lachlan River. The systems are characterised by very low flows and are surrounded by flat plains with the occasional rocky outcrop. Grazing and broadacre cropping dominate the landuse in the area.

Zone 12: Great Cumbung Swamp (Oxley to Murrumbidgee junction)

Zone 12 is marked by the Great Cumbung Swamp and includes the stretch of river between Oxley and the junction of the Murrumbidgee River. The Great Cumbung Swamp is a large natural wetland that developed where the Lachlan River and its creeks terminate and spread out (Roberts and Sainty, 1996; DLWC, 1998). It covers an area of 50,000 hectares and is the terminal drainage swamp of the Lachlan River.

Zone 13: Western effluent Creeks (Willandra, Moolbang, and Merrowie)

This zone includes the three main effluent creeks of Willandra, Moolbang and Merrowie. These waterways transport flow away from the main channel of the Lachlan River, acting as a distributary network. Flow within the channels is reduced and the creeks become largely ephemeral, flowing infrequently. In this lowland region of the catchment, the land is flat and the vegetation sparse due to clearing, grazing and climatic conditions.

The Lachlan CMA identified the lower region of the Lachlan catchment as a priority area to be targeted during the study. This encompassed the area west of Condobolin, and includes Zone 8, Zone 9 South and North, Zone 10A and Zone 10B, as well as Zones 11, 12 and 13. The fieldwork component of the study was concentrated in this section of the catchment.

3.2.2 Habitat assessment

The field assessment of aquatic habitat in the lower Lachlan was based on methodology that had been developed and used in the lower Murray-Darling by Vey and McBurnie (2005).

The total number of sites selected for aquatic habitat assessment in the lower Lachlan was 27, however one selected area, Site 4, could not be accessed and no assessment was undertaken. This left 26 sites assessed during this study in April 2005 (Map 2 and listed in Appendix E). These sites included areas of habitat that had been used for fish population surveys in previous studies including the NSW Rivers Survey (Harris and Gherke, 1997), the Integrated Monitoring of Environmental Flows (DIPNR, 2001) and the Sustainable Rivers Audit (MDBC, 2004). In addition to this, two extra sites were selected on Merrowie Creek to ensure adequate representation of the effluent creeks in Zone 13.

The sampling of these sites did not provide an equal representation of the management zones in the lower Lachlan, with Zone 9 North and Zone 10 possessing no sampling sites. However, by sampling from the selected 26 sites there is the opportunity for comparisons to be drawn between fish populations and habitat components, allowing for a greater spatial and temporal understanding of the aquatic habitat in the lower Lachlan catchment.

The assessment of aquatic habitat in the lower Lachlan examined the four parameters of fish assemblage, aquatic vegetation, riparian vegetation, and large woody debris at each of the 26 sites. A one kilometre reach was established at each of these sites and the habitat parameters were measured and quantified using GPS and GIS interfacing hardware and software. To ensure that standardised data was collected from each of the sites, an Indexed Frequency Value (IFV) was established, using the submerged and riparian area of the reach, referred to as the plan form area, as a base. The four aquatic habitat components were then expressed as a percentage, allowing for comparisons to be made between sites.

Fish assemblage

Data for this parameter was obtained from the NSW DPI Fish Files Database for 25 of the 26 sites. This data was classified into large bodied natives (LBN), small bodied natives (SBN) and introduced fishes, with the fish communities being measured as a percentage of these classifications. Large bodied natives included golden perch, silver perch, Murray cod and Macquarie perch, whilst small bodied natives included numerous species of gudgeons, smelt, and bony bream. The introduced species included carp, goldfish, gambusia and redfin.

Aquatic vegetation

The dominant species of aquatic vegetation present at each site were firstly identified and then quantified and measured in hectares using the GPS and GIS technology. The area of the aquatic vegetation was then expressed as a percentage of the total size of the reach area, with this percentage divided into the species present.

Riparian vegetation

The length of the riparian vegetation was measured and quantified using a stream-side lineal approach in association with the GPS/GIS software. The riparian vegetation at each site was classified into the four grades of:
1. Full – significant and undisturbed native vegetation present;
2. Partial – degraded native vegetation present;
3. No vegetation present, and;
4. Willow species present.
Each grade of riparian vegetation was then expressed as a percentage of the total riparian length of the reach.

Large Woody Debris (LWD)

The complexity of LWD habitat at each site was classified into four grades:
1. Woody habitat stand that entails a single trunk or branch;
2. Woody habitat stand that entails a trunk with one or two branching;
3. Woody habitat stand that entails one or more trunks with multiple branching, and;
4. Woody habitat stand that entails highly complex complete tree with multiple branching, or an accumulation of separate branching to achieve a similar habitat complexity.
The presence and complexity of large woody debris at each site was then expressed as a percentage of the total size of the reach.

3.2.3 Barriers to fish passage

The field assessment of remaining instream structures was identified by:

- Assessment of 1:100,000 topographic maps for potential waterway crossing barriers;
- Regional staff of NSW DPI, who were contacted to provide any advice or comments regarding potential waterway barriers in the lower Lachlan catchment.

The total number of sites identified for assessment in the lower Lachlan catchment was 68. An assessment proforma was developed prior to fieldwork to ensure that data gathering was consistent and transferable to the prioritisation process (Appendix F). A total of 47 sites were assessed during the study, with the majority of fieldwork conducted in April 2005. Information for the remaining 21 sites was gathered from the Initial and Detailed Weir Review database. For each of the sites, location details (GPS readings or map grid references) and digital photographs were recorded.

In addition to this information, all sites identified for on-ground assessment required further desktop research to determine the geophysical setting, aquatic habitat quality (availability and condition) and biodiversity parameters for each instream structure. This information was obtained through various sources including:

- Available catchment data that included flow duration, catchment condition reports, and Stressed Rivers assessments;
- Fishfiles and the NSW DPI Freshwater Fish Database for fish species distribution, and;
- Waterway crossing and land tenure details from topographic maps.

A prioritisation scheme was developed to assist in ranking instream structures requiring remediation (Appendix G). The scheme was developed to determine regional priorities by ranking sites that were classified as barriers based on the categories of a) Habitat value b) Structure impact, and c) Modification criteria. The ranking process took into account various factors associated with each structure including the quality and condition of existing aquatic habitat, the potential impact on fish movement, and the modification possibilities, such as potential costs and effort.

This process provided a simple and effective method of determining regional priorities, allowing for the rapid assessment of each structure on a lower catchment scale. However, during potential remediation actions it is acknowledged that many associated environmental, social, cultural and economic considerations must also be reviewed before the actions occur.

4. ASSESSMENT RESULTS

4.1 Habitat assessment

The project included the assessment of four aquatic habitat parameters across seven management zones in the lower Lachlan catchment. Appendix H displays the sites that were assessed within each zone, outlining the raw data for each parameter at the site. The habitat assessment results will be examined in separate zones, highlighting significant findings for each of the four aquatic habitat parameters, with further detailed information located in Appendix I and maps displaying this information found in Appendix P.

Zone 8: Main channel Lachlan River from Bedgerebong to Hillston

Zone 8 possessed the greatest number of sampling sites, with eight out of the eleven sites located on the Lachlan River. Assessment of the four habitat parameters displayed levels of variation between the sites, reflecting the dynamic nature of the aquatic environment and the differences between the mainstem Lachlan River and effluent creeks. Fish assemblage and the coverage of large woody debris in Zone 8 were examined together, allowing for any relationships between the two parameters to be observed (Fig. 1).

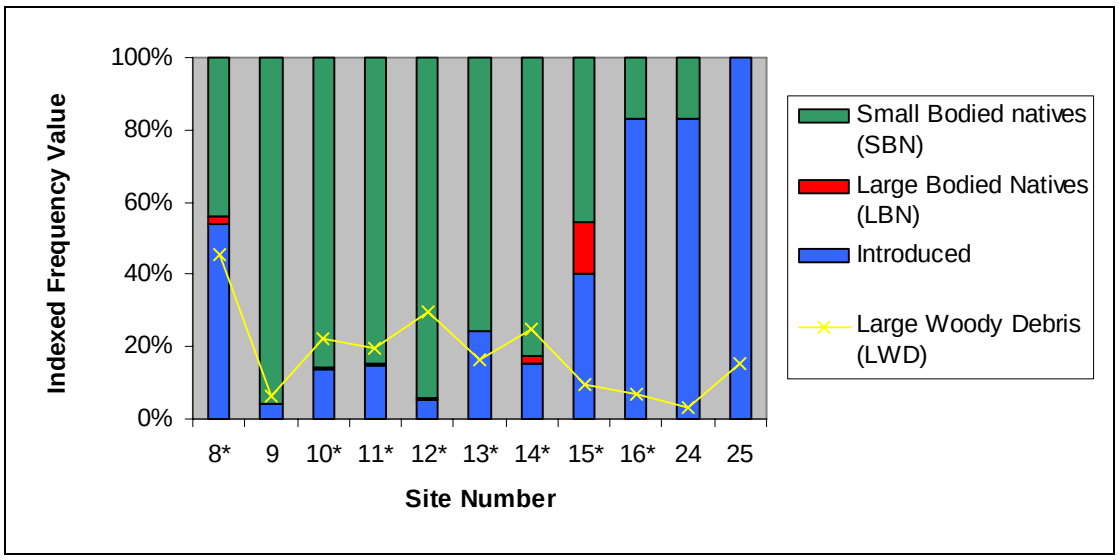


Figure 1: Comparison between fish assemblage and woody debris present at Zone 8 (Note: * denotes site located on Lachlan River).

The fish assemblage of Zone 8 was dominated by the presence of small bodied natives, which accounted for the highest percentage at seven of the eleven sites, all of which had significant coverage of woody debris (Fig. 1). However, this presence showed great variation within the zone, ranging from 0% at Site 25 through to 93.94% at Site 12. The presence of large bodied natives in Zone 8 showed a similar variation between sites, ranging from 0% through to 14.29%, however the majority of sites had less than 2%. Introduced species were present in all ten sites of Zone 8, dominating sites that had poor woody debris coverage.

The large woody debris of Zone 8 provided moderate instream habitat, with seven out of the eleven sites having a value greater than 15% (Fig. 1). Site 8, which occurs on the mainstem Lachlan River, had the largest value recorded in the zone (45.34%), whilst Site 24 had the lowest with 3.18%. This site was dominated by the presence of introduced fish species.

The composition and coverage of aquatic vegetation at Zone 8 is displayed in Figure 2. The zone showed great diversity in the composition of aquatic vegetation, possessing 11 forms of instream coverage, however the composition of vegetation varied amongst sites.

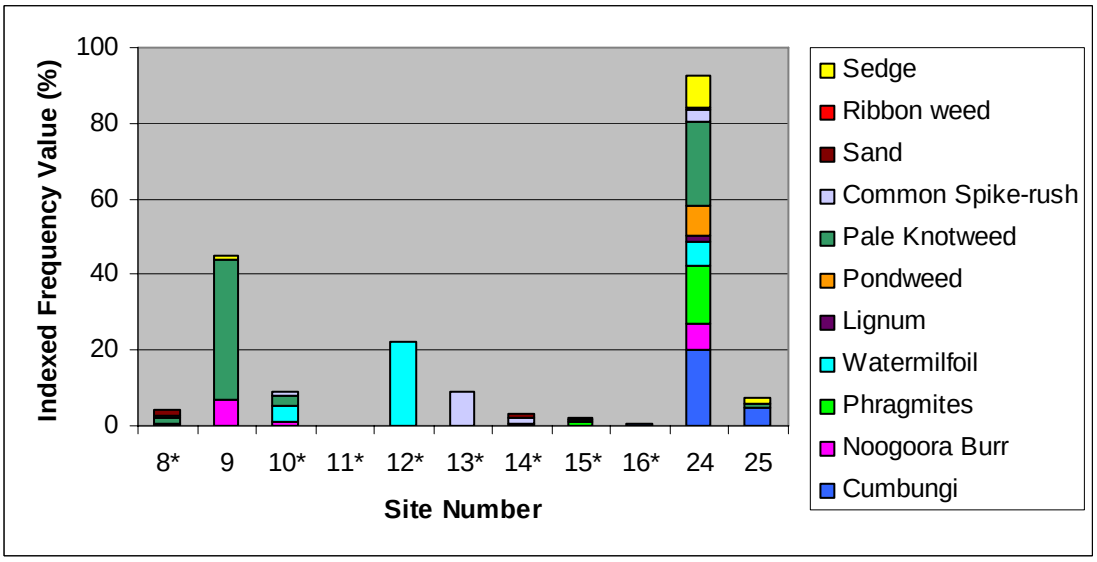


Figure 2: Aquatic vegetation cover and composition for Zone 8 (Note: * denotes site located on Lachlan River).

The aquatic vegetation of Zone 8 was in an overall poor condition, with eight out of the eleven sites having less than 10% cover (Fig. 2). Site 24, an effluent creek site dominated by introduced fish species, had the largest value (92.67%) and the greatest diversity (ten species), whilst Site 11 possessed 0% aquatic vegetation cover. Common spikerush was the most distributed species in Zone 8, being present at six sites, whilst water milfoil was the most abundant, accounting for 34.06% coverage in the zone.

The values for the coverage of aquatic vegetation contrast the results for the riparian vegetation coverage of Zone 8, with cover being in a good condition amongst all sites (Fig. 3).

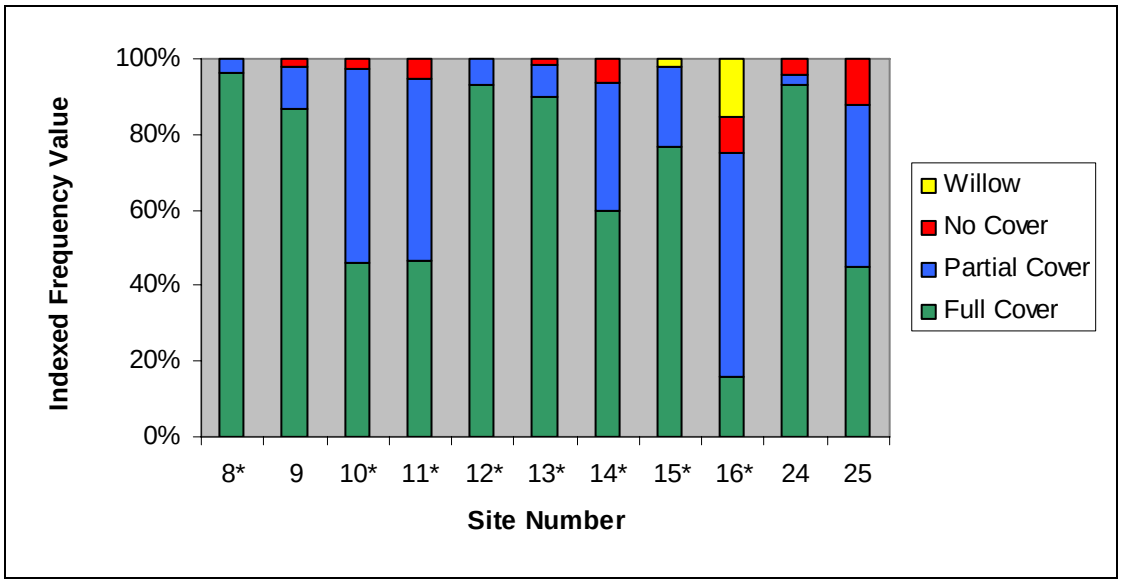


Figure 3: Riparian vegetation cover for Zone 8 (Note: * denotes site located on Lachlan River).

The sites within Zone 8 were dominated by full or partial cover of native vegetation (Fig. 3). However, Zone 8 does represent the only zone where willow was recorded during this study, with the species being found at two of the ten sites. One of these sites, Site 16, which had 15% willow vegetation, was dominated by introduced fish species and had the lowest value for full riparian cover in the zone.

Zone 9 (South): South eastern effluent/ephemeral channels

Two sites were sampled on effluent creeks within Zone 9 South. The instream habitat of this zone showed a significant level of variation between sites, whilst the fish assemblage and riparian vegetation were similar between both sites. The assemblage of fish in Zone 9 South was examined in association with the coverage of large woody debris within the area (Fig. 4).

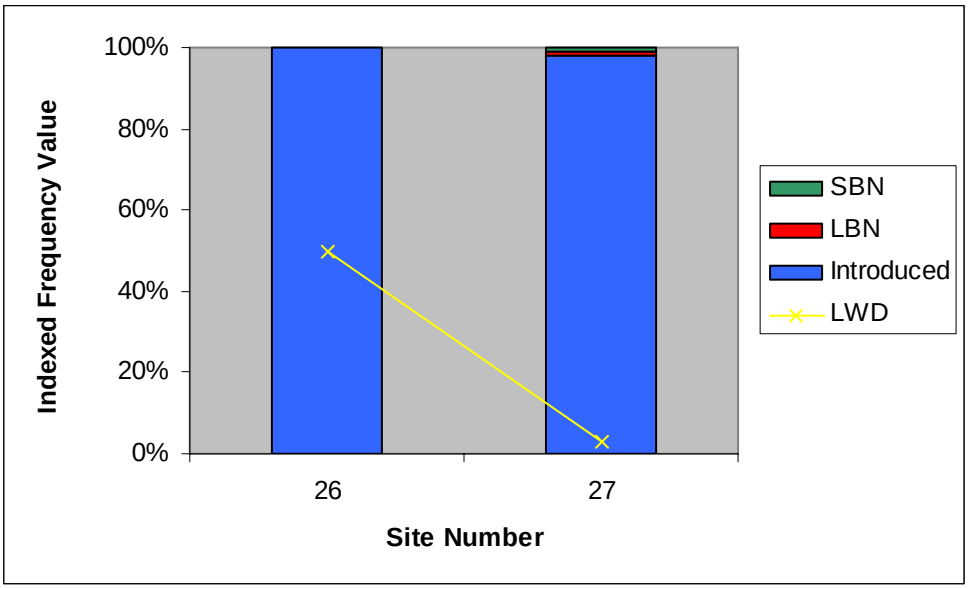


Figure 4: Comparison between fish assemblage and large woody debris at Zone 9 South.

The abundance of native fish at this zone was very poor, with both large bodied and small bodied natives only present at Site 27 and each accounting for 0.97% of the fish assemblage (Fig. 4). Introduced species dominated the fish found at Zone 9 South, being dominant at both sites, with Site 26 having 100% introduced fish as well as a significant cover of woody debris.

The large woody debris of Zone 9 South displayed a significant amount of variation between the two sites (Fig. 4). Site 26 had the highest value of large woody debris (49.51%), which was significantly higher than the woody debris present at Site 27. This site was dominated by aquatic vegetation (see Fig. 5) and only had a large woody debris value of 2.82%.

Zone 9 South showed great variation in the coverage of aquatic vegetation between the two sites (Fig. 5). This figure also shows that the zone had a very poor diversity in aquatic vegetation composition, possessing only four types of instream cover.

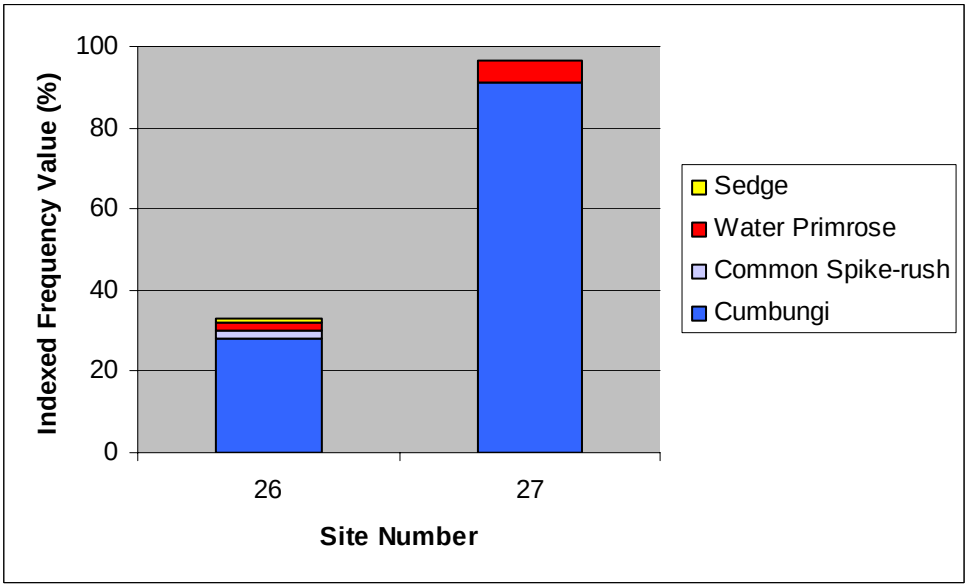


Figure 5: Aquatic vegetation cover and composition for Zone 9 South.

The aquatic vegetation of Zone 9 South was in an overall poor condition (Fig. 5). Although the site possessed the greatest IFV recorded for aquatic vegetation during the study (Site 27 - 96.44%), the vegetation at this site was dominated by the native cumbungi species. When accumulated in large abundances, cumbungi can act as a weed species, reducing the value

of aquatic habitat. This species was the most abundant in Zone 9 South, being present at both sites and dominating the composition.

The riparian values for the two sites within Zone 9 South were the same, reflecting the similarities in vegetation within the zone (Fig. 6).

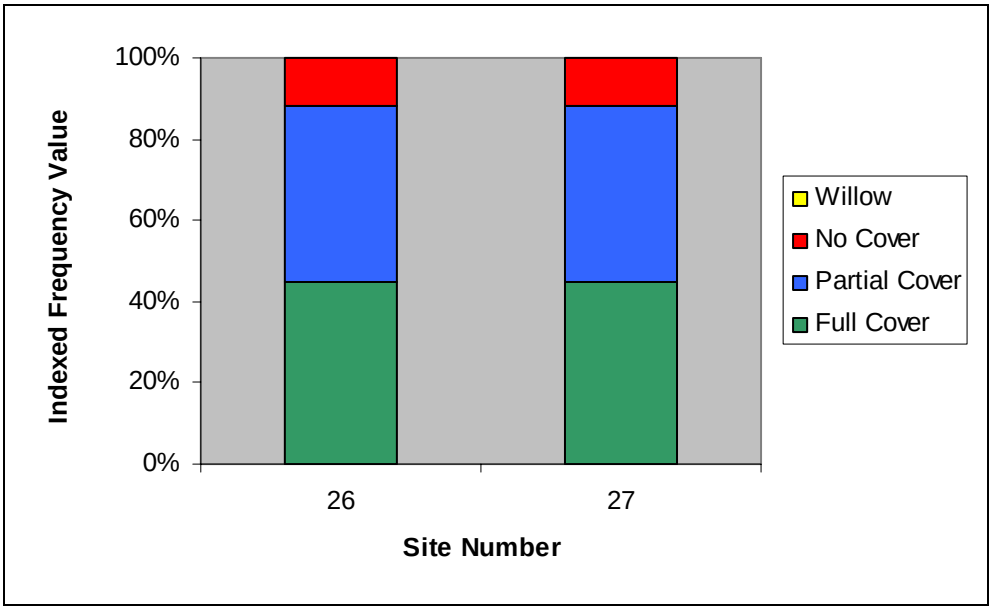


Figure 6: Riparian vegetation cover for Zone 9 South.

Riparian vegetation within Zone 9 South was in a good condition, with both sites dominated by full or partial vegetation cover (Fig. 6). No willow species were recorded at Zone 9 South.

Zone 11: Main channel Lachlan River from Hillston to Oxley

Zone 11 possessed six sampling sites that were assessed during the study, with five of these occurring on the Lachlan River. The habitat assessment for Zone 11 displayed levels of variation between the sites, reflecting the differences between the mainstem Lachlan River and the effluent creeks. Fish assemblage and the coverage of woody debris in Zone 11 were examined together, allowing for any relationships to be observed (Fig. 7).

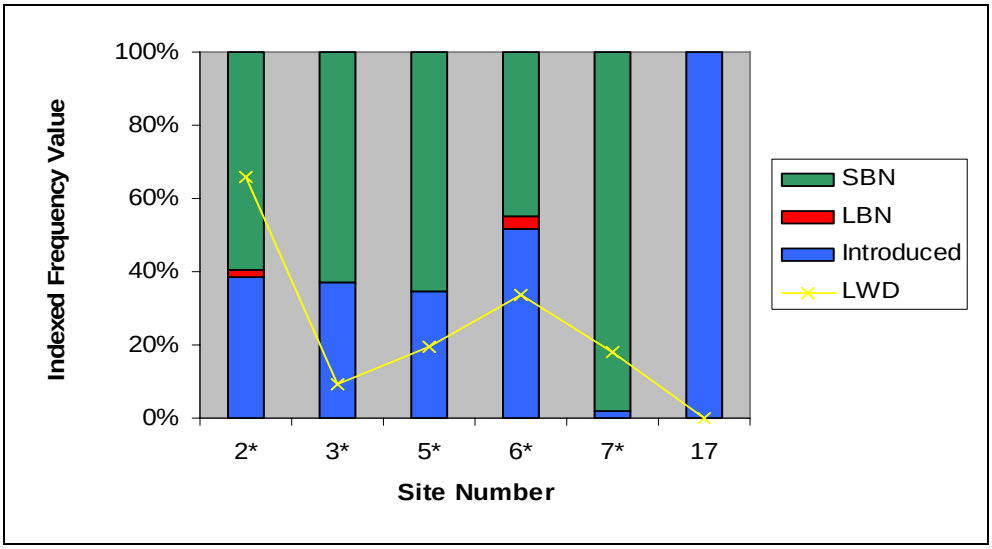


Figure 7: Comparison of fish assemblage and woody debris present at Zone 11 (Note: * denotes site located on Lachlan River).

Fish assemblage of Zone 11 was dominated by the presence of small bodied natives, which accounted for the highest percentage at four of the six sites (Fig. 7). Site 7 had the greatest value in the zone (98.20%), whilst Site 17 had no small natives in its assemblage. The assemblage of large bodied natives in Zone 11 was in a poor condition, with only Sites 2 and 6 recording these species as a very small proportion of the population. Introduced species were present in all six sites of Zone 11, dominating the effluent creek site (Site 17).

The large woody debris of Zone 11 provided moderate instream habitat, with four out of the six sites having a value greater than 15% (Fig. 7). Site 2, which occurs on the Lachlan River, had the largest LWD value recorded in the zone and during the study (65.61%). It can also be noted that the two sites with the largest woody debris cover (Sites 2 and 6) were the only two sites within the zone that had large bodied natives present in their fish assemblage. Site 17, which had the lowest woody debris cover (0%), was dominated by introduced fish species.

The composition and coverage of aquatic vegetation at Zone 11 is displayed in Figure 8. The zone showed great diversity in the composition of aquatic vegetation, possessing nine forms of instream coverage, however this composition varied amongst sites.

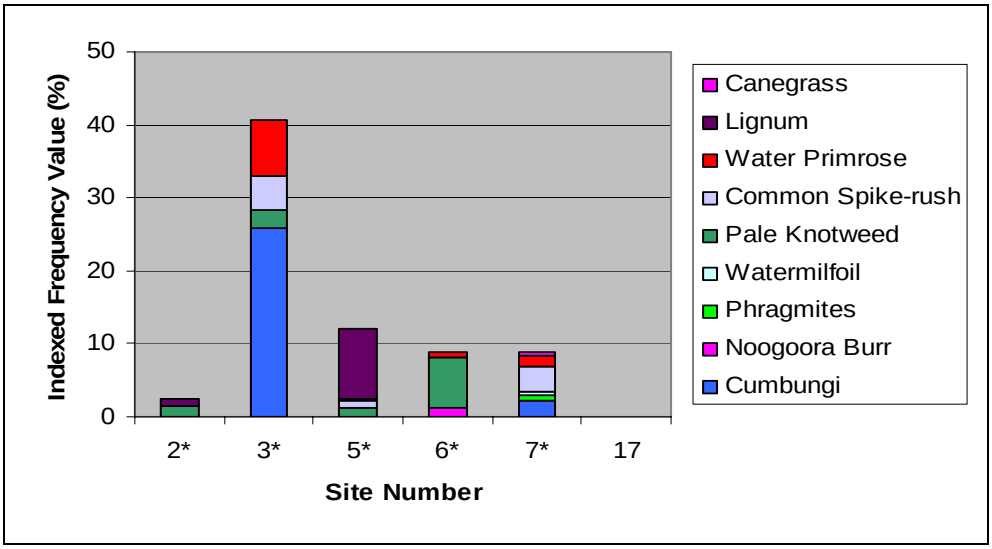


Figure 8: Aquatic vegetation cover and composition for Zone 11(Note: * denotes site located on Lachlan River).

The aquatic vegetation of Zone 11 was in an overall poor condition, with four out of the six sites having less than 10% cover (Fig. 8). Site 3, a mainstem site dominated by small bodied native fish species, had the largest value of 40.6% but was dominated by cumbungi. Site 17, an effluent creek site dominated by introduced fish species, possessed no aquatic vegetation cover. Pale knotweed was recorded at four of the six sites, whilst cumbungi was the most abundant, contributing 28.15% of instream cover at Zone 11.

Riparian vegetation within Zone 11 was in a good condition, with all sites dominated by full native vegetation cover (Fig. 9).

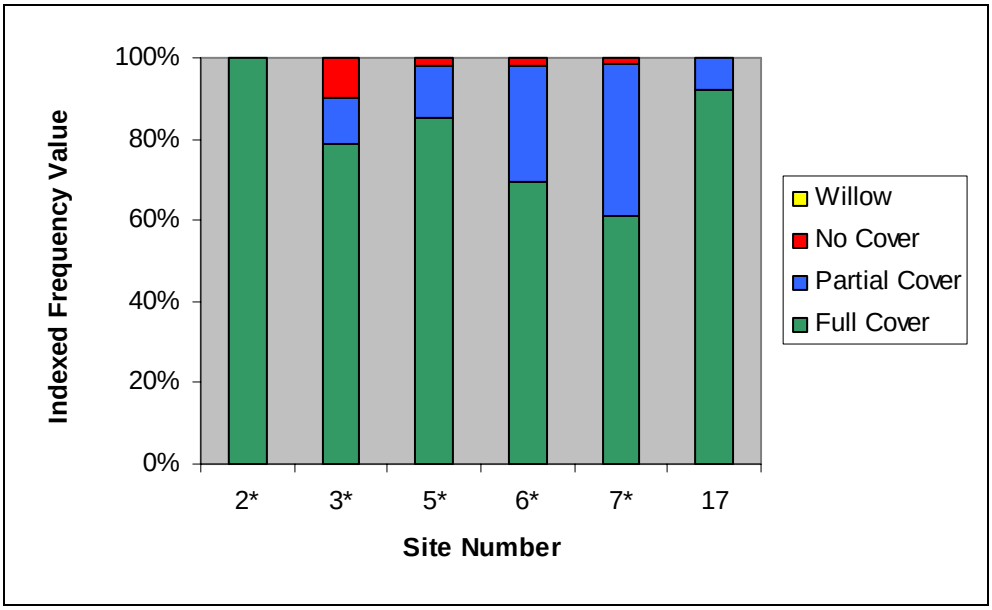


Figure 9: Riparian vegetation cover for Zone 11 (Note: * denotes site located on Lachlan River).

Site 2 had 100% full cover of native vegetation in the riparian zone, whilst the effluent creek site, Site 17, had 92.02% full cover. Full coverage riparian values for Zone 11 showed little variation, with the lowest value being 61% and the highest being 100%, reflecting the similarities in vegetation within the zone. No willow species were recorded at Zone 11.

Zone 12: Great Cumbung Swamp (Oxley to Murrumbidgee junction)

Only one site was assessed in Zone 12 during the current study. The site, which occurred on the Lachlan River, was in an overall poor condition dominated by introduced fish species, aquatic weed species and a lack of riparian vegetation. The assemblage of fish in Zone 12 was examined in association with the coverage of woody debris within the area (Fig. 10).

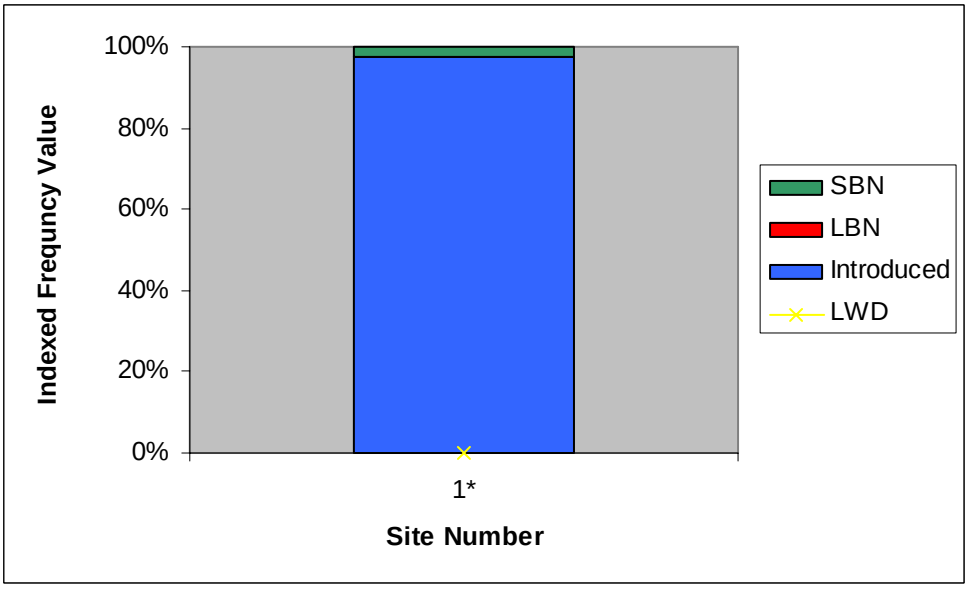


Figure 10: Comparison of fish assemblage and woody debris present at Zone 12 (Note: * denotes site located on Lachlan River).

The presence of native fish at this zone was very poor (Fig. 10). Large bodied natives were absent and small bodied natives only accounted for 2.45% of the fish assemblage. Introduced species dominated the fish found at Zone 12, being present at Site 1 and representing

97.55% of the fish assemblage. The large woody debris of Zone 12 appears to be in a very poor condition, representing only 0.12% of the instream area (Fig. 10).

Zone 12 was dominated by the presence of aquatic vegetation, with this aquatic habitat parameter covering 65.05% of the area (Fig. 11). The zone showed limited diversity in the composition of aquatic vegetation, possessing only three forms of vegetation coverage.

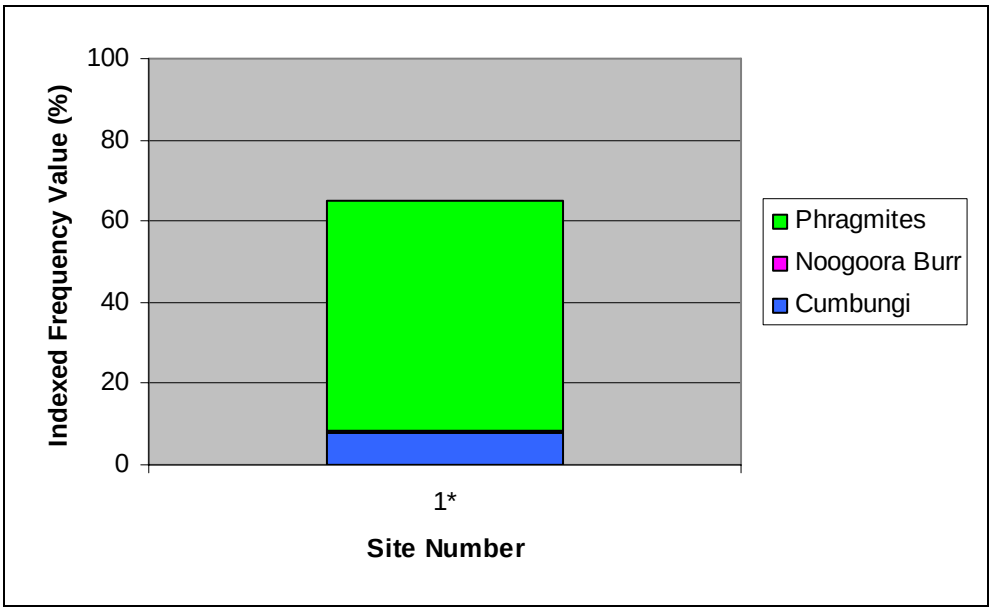


Figure 11: Aquatic vegetation cover and composition for Zone 12 (Note: * denotes site located on Lachlan River).

From the figure it can be seen that the high coverage of aquatic vegetation was dominated by the presence of native phragmites and cumbungi species, as well as the introduced noogoora burr. All of these species have the potential to become weed species in high abundances, negatively impacting on the health of the aquatic environment, resulting in the poor condition of aquatic vegetation in Zone 12.

Riparian vegetation within Zone 12 was in an overall poor condition, with the site dominated by no vegetation cover or partial native vegetation cover (Fig. 12).

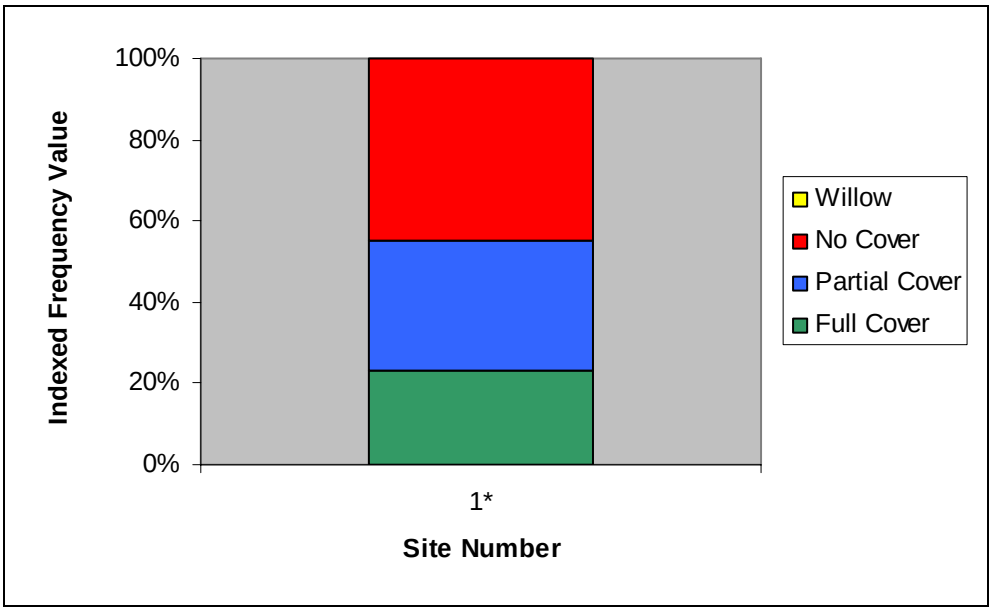


Figure 12: Riparian vegetation cover for Zone 12 (Note: * denotes site located on Lachlan River).

The riparian values for Zone 12 differ from the riparian values for the majority of other zones, with no vegetation cover (44.96%) contributing the greatest to the riparian zone of the area. Full native vegetation cover had the lowest IFV with 23.14%. Again, no willow species were recorded in this zone, reflecting the dominance of native vegetation in the lower Lachlan area.

Zone 13: Western effluent Creeks (Willandra, Moolbang, and Merrowie)

Zone 13 possessed six sampling sites that were assessed for aquatic habitat condition. All of these sites occurred on the effluent creeks of the lower Lachlan. The habitat assessment for Zone 13 displayed levels of variation between the sites for each parameter, reflecting the dynamic nature of the aquatic environment. Fish assemblage and the coverage of large woody debris in Zone 13 were examined together, allowing for any relationships between the two parameters to be observed (Fig. 13).

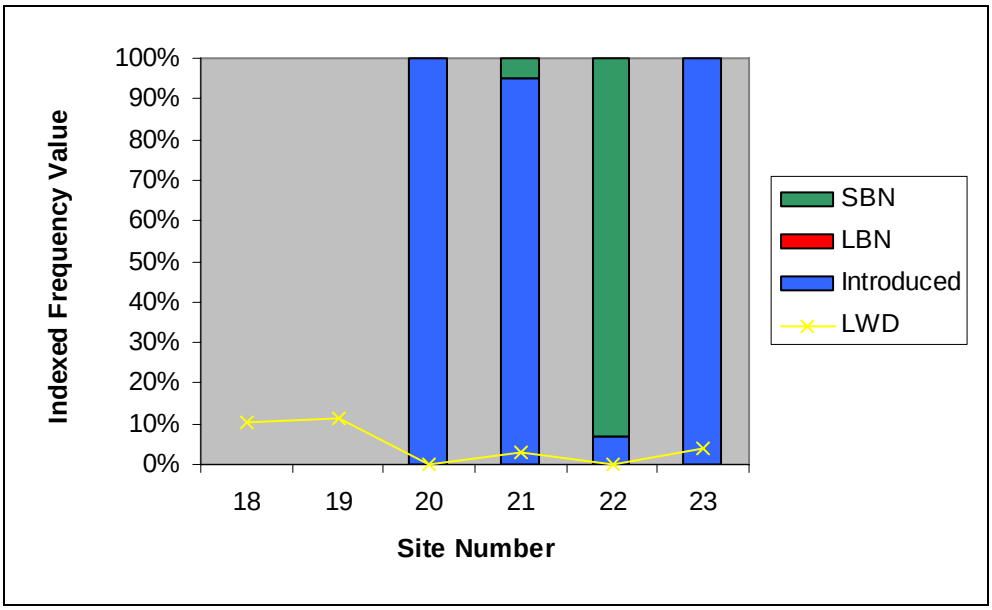


Figure 13: Comparison between fish assemblage and large woody debris at Zone 13.

Fish assemblage of Zone 13 was in a very poor condition with sampling at Sites 18 and 19 failing to record the presence of any fish (Fig. 13). Out of the remaining four sites, all contained introduced fish, with three sites dominated by introduced species. Small bodied natives were dominant at Site 22, predominantly through the presence of bony bream, but did not contribute to the fish assemblage at four of the six sites. Large bodied natives were not found in any sites throughout Zone 13.

The large woody debris of Zone 13 provided poor instream habitat, with four out of the six sites having a value less than 10% (Fig. 13). Site 20, which was dominated by introduced fish species, had the lowest value recorded in the zone of 0.04%.

Zone 13 showed moderate diversity in its composition of aquatic vegetation, possessing five forms of instream coverage, however this composition varied amongst sites (Fig. 14).

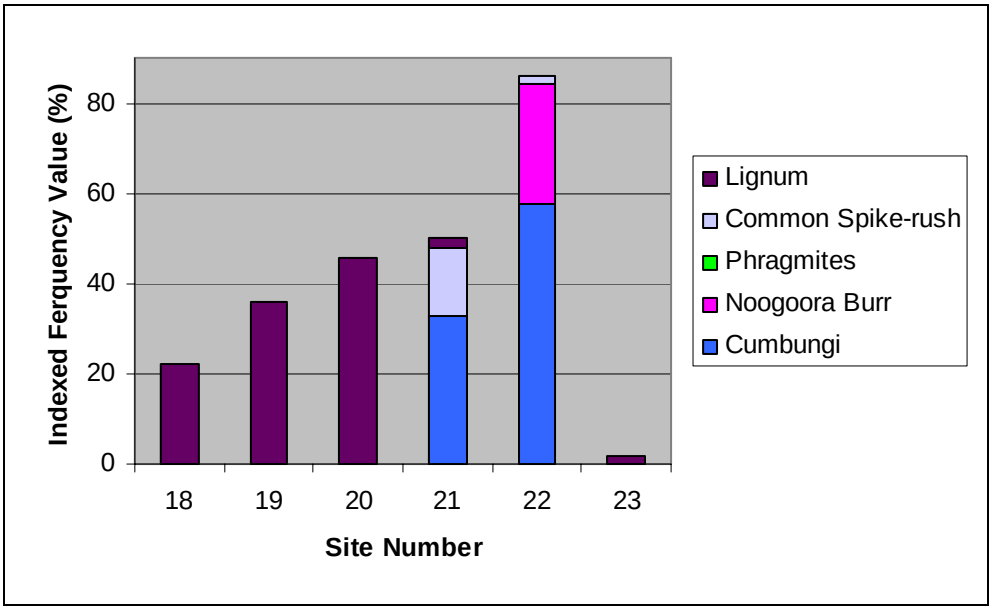


Figure 14: Aquatic vegetation cover and composition for Zone 13.

The aquatic vegetation of Zone 13 was in an overall moderate condition, with four out of the six sites having coverage greater than 35% (Fig. 14). Two of these sites however, were dominated by the presence of cumbungi whilst the remaining two sites possessed high coverage of lignum, which is indicative of periodically dry areas (Sainty and Jacobs, 1981). This species was the most diverse in Zone 13, being recorded at five of the six sites.

Riparian vegetation within Zone 13 was in good condition during the study, with the majority of sites dominated by full or partial native vegetation cover (Fig. 15).

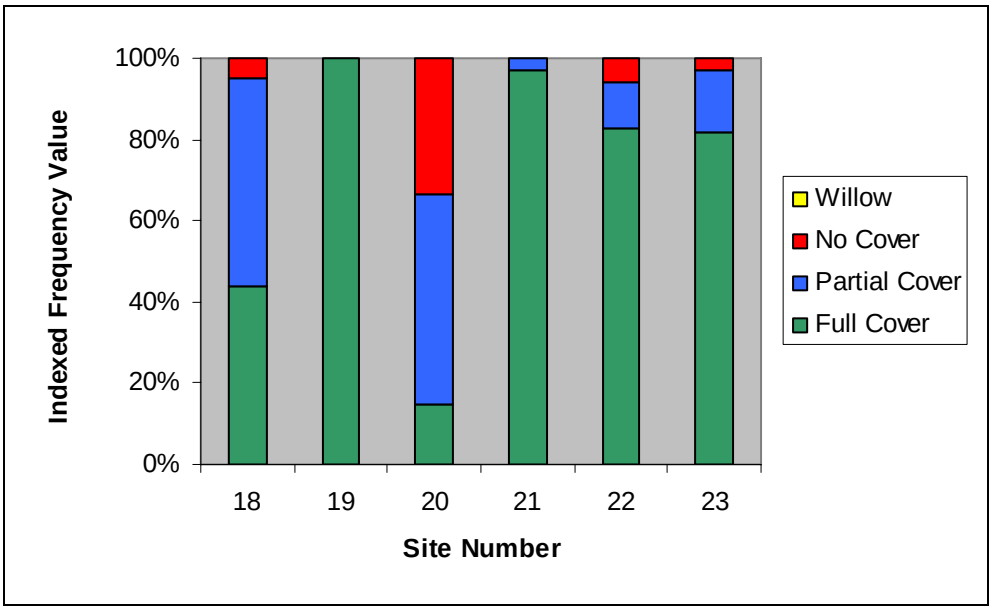


Figure 15: Riparian vegetation cover for Zone 13.

Site 19 had 100% full cover of native vegetation in the riparian zone, with three other sites having full coverage values greater than 80%. The lowest full cover riparian value was at Site 20, which had a composition that was dominated by partial native cover (51.80%) or no cover at all (33.36%). This site was dominated by introduced fish species and had the lowest woody debris value for the zone. No willow species were recorded at Zone 13.

4.2 Barriers to fish passage

4.2.1 Summary of field assessments

The project included the assessment of 68 instream structures across seven management zones in the lower Lachlan catchment. The majority of these structures were deemed to have negligible impact on fish passage, however 31 structures were identified as potential barriers to fish passage, requiring some form of remediation action.

Table 4 displays the management zones present within the lower Lachlan catchment, outlining the number of sites assessed in each area and the number of sites recommended for fish passage remediation.

Table 4: Summary of instream structures identified as potential fish passage barriers occurring within the management zones of the lower Lachlan.

Management Zone	Zone as % of Study Area (56,533 km^2)	Dominant Type of Waterway	Total # of Sites Assessed	Total # of Sites Recommended for Remediation
Zone 8	5.90	Mainstem	29	15
Zone 9 South	24.16	Effluent/Ephemeral Creeks	11	6
Zone 9 North	32.21	Effluent/Ephemeral Creeks	3	1
Zone 10	0.19	Lakes	1	0
Zone 11	7.14	Mainstem	17	4
Zone 12	1.38	Wetlands	0	0
Zone 13	29.02	Effluent Creeks	7	5
Total	**100.00**		**68**	**31**

The total number of sites assessed as potential fish barriers within each management zone reflected the geographical size of the area, as well as the dominant type of waterway in the zone. The larger Zone 9 South and Zone 13, which were dominated by effluent creeks, had a high number of sites assessed but a relatively low number of sites that were recommended for remediation. These areas encompassed a larger number of drainage systems where instream structures had less of an impact. The smaller Zone 8 and Zone 11 had a relatively high number of both sites assessed and sites recommended for remediation. These zones possessed a low number of drainage systems but encompassed mainstem channels, which had been highly modified to service the surrounding urban and agricultural areas.

The lowest number of sites assessed occurred in Zone 9 North, Zone 10 and Zone 12, with both Zones 10 and 12 having no sites recommended for remediation. These zones provided a minimal amount of area compared to the study site, possessed a low number of drainage systems and provided limited opportunity to incorporate infrastructure into their aquatic habitats, with Zones 10 and 12 dominated by lakes and wetlands.

There were several types of instream structures assessed during the study including weirs, bridges, culverts, causeways and fords. Table 5 outlines the total number of these structure types assessed during the study.

Table 5: Summary of instream structure types assessed in the lower Lachlan catchment.

Structure Type	Zone 8	Zone 9S	Zone 9N	Zone 10	Zone 11	Zone 12	Zone 13	Total
Bridge	10	6	1	0	13	0	2	**32**
Causeway	0	1	0	0	0	0	0	**1**
Culvert	5	3	1	0	0	0	4	**13**
Ford	0	0	0	0	0	0	1	**1**
Weir	14	1	1	1	4	0	0	**21**
Total	**29**	**11**	**3**	**1**	**17**	**0**	**7**	**68**

The most common instream structures identified during the project were bridges (32), weirs (21) and culverts (13). The remaining structures were composed of other potential barriers such as fords and causeways.

The majority of instream structures were found in management Zones 8 and 11. Of the common structure types, Zone 11 had the greatest number of bridges (13) but did not possess any weir structures, whilst Zone 8 had the greatest number of weirs (14), as well as a relatively large number of the other common structures including culverts (5) and bridges (10). This finding reflects the highly regulated nature of the mainstem Lachlan River, which dominates the waterways found in Zone 8.

4.2.2 Summary of priority sites

In this study, 37 sites were not recommended for remediation as the structure was deemed to have negligible impact on fish passage. These structures had a very minor obstruction to fish at limited times, with fish regularly being able to negotiate the structure (Appendix J).

The remaining 31 sites assessed in the lower Lachlan catchment were identified as barriers to fish movement that would require remediation to enhance fish passage. Details concerning these structures are listed in Appendix K and mapped in Appendix L. Remediation options suggested for these sites include:

- Basic management and maintenance of sites, such as the regular removal of sediment and debris.
- Modification of structures, such as retrofitting low-flow channels, modifying outlet levels, and installing fishways (see Appendix M for fishway types).
- Complete removal and, where necessary, replacement of structures.

The most common instream structures identified as fish passage barriers were weirs (15) and culverts (12). Weirs generally have a greater impact on fish passage than culverts or low-level crossings due to their design and function, which commonly results in them being larger structures that occur on perennial waterways. The most common instream structures assessed during the project were bridges, however only two of these sites were identified as fish passage barriers reflecting their minimal disturbance to flow.

Of the 31 sites identified as fish passage barriers, eleven were classified as high priority that required immediate remediation (Table 6). Overall the high priority sites included ten weirs and one culvert. It can be noted that the majority of these sites were all significant weir structures that occur on the Lachlan River, and as a result have been recommended for remediation in previous reports (NSW DPI, 2006a).

Table 6: Summary of high priority structures assessed in the lower Lachlan catchment.

Rank	Structure ID	Structure Name	Waterway	Structure Type	Recommendation
1	DWR02	Booligal Weir	Lachlan River	Weir	Full width rock ramp fishway
2	DWR04	Gonowlia Weir	Lachlan River	Weir	Management of dropboards
2	DWR07	Lake Brewster Weir	Lachlan River	Weir	Fishway option study
2	DWR10	Tallawanta Weir	Lachlan River	Weir	Full width rock ramp fishway
5	DWR01	Booberoi Weir	Lachlan River	Weir	Construct Vertical Slot Fishway
5	DWR05	Hillston Weir	Lachlan River	Weir	Full width rock ramp fishway
5	DWR08	Lake Cargelligo Weir	Lachlan River	Weir	Construct Vertical Slot Fishway
5	DWR12	Willandra Weir	Lachlan River	Weir	Partial width rock ramp fishway
9	412/803600/B0330	Torriganny Weir	Torriganny Creek	Weir	Management of dropboard use
10	DWR09	Micabil Weir	Lachlan River	Weir	Partial width rock ramp fishway
11	LL05	Pipe Culvert	Wallaroi Ck	Pipe Culvert	Removal

5. DISCUSSION

5.1 Threats to the lower Lachlan catchment

The highly modified nature of the lower Lachlan's waterways presents many challenges in protecting the environment and managing its natural resources. In many areas, extensive modification has occurred to the aquatic environment and its surrounding land. This makes it vitally important to gain a clear understanding of the extent of aquatic habitat degradation and where conservation and rehabilitation actions will achieve the best outcomes.

Overall, the aquatic habitat condition in the lower Lachlan catchment is severely degraded. There are numerous threatening processes occurring in the catchment associated with urban and agricultural development. These processes affect the environment on both a catchment level and a reach scale, dictating aquatic health within the catchment and controlling the success of localised rehabilitation actions.

The importance of protecting and managing the aquatic habitat of the Lachlan catchment has been recognised by the CMA, with management targets highlighted in the Lachlan Catchment Blueprint (2003). The intent of aquatic habitat related targets is to manage the riparian zone and drainage areas of the catchment, implementing on-ground works at priority areas to enhance aquatic diversity and habitat.

The current study has contributed to these management actions by achieving the following outcomes:

- Identification of key threats to the aquatic and riparian environments of the lower Lachlan;
- Assessment of aquatic and riparian habitat degradation in the lower Lachlan;
- Development of a fish passage barrier inventory for the lower Lachlan region and the application of a prioritisation method to rank fish passage barriers;
- Identification of remediation options for areas of high priority; and
- Promotion and distribution of the findings for the report.

5.2 Aquatic habitat in the lower Lachlan – Issues

The assessment of aquatic habitat parameters in the lower Lachlan indicated that the aquatic environment of the area was in an overall poor condition. Processes such as river regulation, the installation of instream structures, the clearance of riparian and aquatic vegetation, and the establishment of introduced fish species were all identified as significantly impacting the aquatic habitat of the lower Lachlan.

When studying the findings of the aquatic habitat assessment in the lower Lachlan it is important to recognise that not all management zones within the area were represented and, that the number of sites within assessed zones were not equally distributed. This does not give an equal representation of the lower Lachlan, however it does allow for comparisons to be made between the aquatic habitat parameters of past studies. The assessment of aquatic habitat in the lower Lachlan also occurred during severe drought conditions. This made it difficult to determine the condition of parameters and the processes that affected sites, producing significant differences between main channel sites and effluent creek sites that predominantly had no water.

Condition of native fish in the lower Lachlan

The abundance and diversity of native fish was in a very poor condition throughout the lower Lachlan. Large bodied natives were recorded in very low abundances, whilst small bodied natives were found to be in relatively high abundances with low species diversity that was dominated by bony bream. This finding is consistent with the study conducted by Growns (2001), who assessed the status of native fish in the Lachlan River. During this study it was established that populations of native species were relatively rare and sparsely distributed along the river system, with the abundance and distribution of the dominant native species, bony bream, being highly variable (Growns, 2001). The poor condition of native fish

assemblage in the lower Lachlan can be largely attributed to the establishment of introduced fish species, habitat degradation and the use of structures that act as barriers to fish passage.

Introduced fish species, especially carp, have become widespread throughout the lower Lachlan catchment causing environmental damage and competing with native species for habitat and food. These species dominated reaches where there was little or no remnant instream habitat, with their presence at all assessment sites providing evidence that habitat degradation is a significant threatening process in the lower Lachlan. The poor condition of aquatic habitat has resulted in low numbers of large bodied natives, as well as the low diversity of all native species. However, it should be noted that the presence of large bodied natives were typically associated with areas that had high densities of large woody debris. This is consistent with previous studies, including Growns *et al* (2003) who found a positive correlation between large fish and woody debris along the Hawkesbury-Nepean River due to the cover provided by the debris. Significant numbers of small bodied natives were recorded in the lower Lachlan, however these were usually dominated by a limited number of species. This lack of diversity is an on-going concern in the Lachlan catchment and can be attributed to reduced habitat quality and variety, as well as the presence of instream structures that act as barriers to fish passage. These structures have the potential to interrupt the migration of native fish, fragmenting previously connected communities and significantly reducing the diversity of native fish throughout the catchment (Thorncraft and Harris, 2000).

Aquatic vegetation in the lower Lachlan

The coverage of aquatic vegetation was in a poor condition throughout the lower Lachlan. The majority of instream habitat had minimal aquatic vegetation coverage, with the distribution being highly variable. Areas that did have significant instream vegetation were dominated by native cumbungi and phragmites species, both of which can become invasive in high abundances and reduce the instream habitat available to aquatic biota. The exotic noogoora burr species was also present within the lower Lachlan region. This introduced weed species can survive semi-arid conditions and tolerate flooding, and competes with both native vegetation and local pasture crops, increasing its degrading impact on aquatic habitat (Parsons and Cuthbertson, 1992). Similar findings were recorded by Massey (1998), who studied the health of the riverine environment in the Lachlan catchment. From the assessment, Massey found that 76% of aquatic vegetation in the Lachlan catchment was in a very poor condition, with the cumbungi species present in most sites and choking the shallow water courses (Massey, 1998). The poor coverage of aquatic vegetation in the lower Lachlan has been impacted on by the regulation of flows and the direct removal of vegetation associated with extraction activities and landuse practices.

The construction of weirs, dams and other instream structures throughout the lower Lachlan has disrupted natural flow conditions of the Lachlan River and its tributaries, reducing water levels throughout the catchment particularly in the lower reaches. In areas where flow has been particularly impeded, there has been an inundation of invasive aquatic vegetation including cumbungi and phragmites. These species predominantly occurred immediately upstream of areas where weirs were present and reducing the flow. The dominant abundance of these species can further alter the flow regime of a waterway and limit the productive habitat available for native fish and other aquatic fauna. Habitat degradation has also impacted aquatic vegetation through activities associated with aggregate extraction, disturbances from stock grazing and trampling, and foraging by introduced fish species. These impacts directly remove native aquatic vegetation, and can also result in an increase in sedimentation, which further affects aquatic biota within the waterway. This reduces the abundance and diversity of aquatic vegetation, as well as the habitat available, leading to an overall reduction in the health of the aquatic environment.

Condition of riparian vegetation in the lower Lachlan

Riparian vegetation in the lower Lachlan catchment was in an overall good condition, with the majority of sites being dominated by full coverage of native vegetation. It is important to note that during the classification of riparian cover the quality of vegetation was not assessed. As a result, a classification of ‘full coverage’ reflects only the presence of some form of continuous riparian vegetation and does not indicate the diversity and function of the vegetation present.

Riparian vegetation in the lower Lachlan still contained significant stands of native trees, with few exotic species such as willows found during the study. However, in most areas there were very few understorey plants such as shrubs, low trees and grasses. This finding is similar to the results obtained by Massey (1998), who found that although the condition of riparian vegetation in the entire Lachlan catchment was very poor, the riparian vegetation of the lower Lachlan possessed relatively undisturbed stands of native species. Localised tree regeneration events were also found in the lower Lachlan, whilst the presence of understorey species was rare (Massey, 1998). This appears to be a result of landuse practices in the area, with the vegetation in most reaches being cleared to increase the area of land available for holders, as well as to improve stock access to water.

The degradation of the riparian zone is a significant threatening process that eliminates the important functions that riparian land performs for the aquatic environment, impacting on the aquatic health of a system. The removal of large tree stands to increase grazing and cropping area can alter the light and temperature of streams and lead to a reduction in water quality by increasing the prevalence of algae within a waterway. Such practices can also cause a reduction in bank stability and lead to the occurrence of erosion, as well as the promotion of weed invasion by species such as willow (Massey, 1998). The direct or indirect removal of understorey species from the riparian zone to improve stock access to water, as well as by stock grazing, has resulted in a consistent lack of an understorey throughout the lower Lachlan. This can have a profound impact on aquatic health, limiting the interaction between aquatic and terrestrial habitats, and reducing the availability of food and shelter for aquatic and terrestrial species. As a result, the rehabilitation of riparian zones in the lower Lachlan should focus on the restoration of a diverse understorey to improve riparian complexity.

Large woody debris in the lower Lachlan

The large woody debris provided poor to moderate instream habitat in the lower Lachlan, with a significant difference in condition between mainstem areas and effluent creeks. Sites along the Lachlan River contained a reasonable coverage of large woody debris, representing 22% of the plan form area on average, whilst areas within effluent creeks possessed woody debris that was in poor condition with an average coverage of 9%. This finding is consistent with previous studies conducted in the Murray-Darling basin, which found that the density of large woody debris was greater in meandering rivers, such as the Lachlan, when compared with debris coverage in braided channels similar to the effluent creeks of the lower Lachlan (Nicol *et al*, 2002). The findings are also similar to the study conducted by Massey (1998), who found that the overall diversity and cover of aquatic habitat in the Lachlan catchment was in a moderate condition, with minimal presence of woody debris. The state of large woody debris in the lower Lachlan is predominantly a result of native riparian vegetation clearing, and the removal of natural debris to improve water passage (Massey, 1998; Smith and Pollard, 1999).

Large woody debris provides important habitat for a range of aquatic and terrestrial species. These structures offer valuable shelter for native fish from strong water currents and predators, whilst also providing shade, feeding sites, spawning sites and nursery areas for larvae and juvenile fish (Treadwell, 1999). Woody debris also provides an important substrate for the colonisation of invertebrates and the growth of algae, playing an important role in supplying carbon to lowland systems, which provides a major food source to all aquatic biota (Treadwell, 2000). The clearing of native vegetation from the riparian zone of the lower Lachlan has the potential to reduce the natural recruitment of large woody debris into these systems, significantly reducing the aquatic health of the region. The removal of native vegetation for agricultural development reduces the quantity and availability of woody debris, whilst the replacement of native vegetation with exotic species such as willow reduces the quality of woody debris available to aquatic biota (Read, 2000). Adding to these processes is the past practice of directly removing large instream debris to enhance water passage and flow. This threatening process has resulted in the immediate removal of key aquatic habitat and significantly impacted on channel morphology, with de-snagged areas becoming uniform in their drainage and habitat diversity (Treadwell, 1999).

5.3 Fish passage in the lower Lachlan – Issues

The assessment of instream structures in the lower Lachlan indicated that there is a considerable impact on the movement of fish in the area, with 68 structures assessed and 31 of these classified as barriers to native fish passage. Structures associated with urban and agricultural development of the region have contributed significantly to the impact on native fish passage. Regulating weir structures on mainstem channels and culverts used to cross effluent creeks dominated both the sites that were identified as barriers and classified as high priority structures. The majority of weirs included in this classification have undergone a detailed review, reiterating the significant impact they have on native fish passage and aquatic habitat in the lower Lachlan (NSW DPI, 2006a).

Instream structures can have a significant impact on the condition of native fish populations, directly and indirectly affecting the presence of native species within the system. Larger structures that span the whole channel, such as weirs and culverts, present a physical barrier to fish passage, as well as provide conditions that may result in hydrological and behavioural barriers (Thorncraft and Harris, 2000). The vertical wall of weir structures presents the most evident barrier to fish passage, with the excessive drop between water levels (headloss) creating a physical barrier that impedes native fish movement (Thorncraft and Harris, 2000). This type of barrier may also occur with culverts, especially if there is excessive variation in water level across the outlet of the crossing. Associated with headloss height is the hydrological barrier of excessive water turbulence and water velocity. This directly impedes native fish passage by creating unsuitable flow conditions for fish that can reduce their passage and increase the occurrence of fatigue (Fairfull and Witheridge, 2003). Changes in habitat features associated with weir and culvert structures may also present behavioural barriers to migrating native fish. Species that are able to pass into weir reservoirs may find the pooled lentic system unsuitable due to the loss of critical lotic habitat features such as riparian and aquatic vegetation cover, whilst altered water temperatures and dissolved oxygen regimes may also deter migrating fish (Gehrke *et al*, 2001). A lack of lighting, which is commonly associated with road crossings such as culverts, can also act as a behavioural barrier to some native fish and impede their movement through such structures.

These different barrier types can have significant negative impacts on the native fish populations within the Lachlan including interrupting migration, increasing susceptibility to predation and disease, restricting access to preferred habitat and food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of these structures in the lower region of the catchment increases the impact on native fish, restricting the movement of species to critical perennial habitat upstream, as well as important ephemeral creeks and wetlands that exist in the lower Lachlan (Harris and Gherke, 1997). To minimise the impact of instream structures on native fish populations, and the overall condition of aquatic habitat, a range of remediation actions may be implemented. On larger structures such as weirs, this includes the installation of appropriate fishway designs, the removal of obsolete structures, or the suitable management of water releases. For smaller road crossing structures that act as barriers to fish passage, remediation may involve structural modification, the removal of obsolete crossings and, where necessary, the replacement of structures with less intrusive crossings. In this instance, bridges and culverts are the preferred designs on the majority of waterways (Fairfull and Witheridge, 2003). When implementing these actions it is important to ensure that well-defined goals and strategies are developed prior to the commencement of works, with suitable designs and rehabilitation techniques created specific to each site. It is also essential that continued monitoring and maintenance programs are considered during the process of remediating fish passage (Rutherford *et al*, 2001).

5.4 Lower Lachlan management options

To address the threatening processes and overall poor condition of the aquatic environment in the lower Lachlan it is suggested that an integrated remediation program be implemented, focussing on areas that retain a number of beneficial habitat features. This approach targets multiple impacts that affect the system and provides a more efficient and effective method of remediating aquatic habitat. The assessment of aquatic habitat in the lower Lachlan identified areas within management zones 8 and 11 that, whilst being in an overall good condition,

would greatly benefit from remediation to various habitat features that are currently impacted upon by threatening processes. Recommended actions to remediate these areas include the regeneration of riparian understorey vegetation, reinstatement of woody debris and the remediation of fish passage barriers.

To achieve the greatest results during the rehabilitation of aquatic habitat it is far more effective and efficient to preserve waterways that are in a good condition, focussing on the processes that have been correctly attributed to affecting the habitat (Rutherfurd *et al*, 2000; Growns, 2001). This approach allows the greatest amount of natural biodiversity to be conserved in relation to the amount of time, money and effort required, with emphasis placed on achieving this for the greatest length of waterway (Rutherfurd *et al*, 2000). The current project has implemented this approach towards aquatic habitat rehabilitation in the Lachlan by identifying the most important problems that are affecting areas within the lower part of the catchment. Assessment of the results has highlighted sites that are in good condition but still significantly impacted by threatening processes, allowing for recommendations to be made that integrate a number of activities to rehabilitate the greatest area of aquatic habitat.

The assessment of threatening processes in the lower Lachlan revealed that the majority of sites were in a poor condition, as outlined in Sections 5.2 and 5.3, with the condition of native fish of particular concern. However, the assessment also showed that some areas of the lower Lachlan were in a relatively good condition and identified specific habitat parameters that may be improved at these sites to enhance the aquatic habitat and biota. To determine priority areas where rehabilitation would provide the greatest benefits to the lower Lachlan a prioritisation scheme was developed (Appendix N). The scheme determined regional priorities by ranking all habitat assessment sites based on the parameters of native fish diversity and abundance, coverage of riparian vegetation, condition of understorey vegetation and coverage of woody debris. The ranking process also took into account various factors associated with each site including the presence of fish passage barriers in the surrounding area, and additional uses of the site, such as recreational areas.

This process provided an effective method of determining regional priorities, allowing for the rapid assessment of each site on a lower catchment scale to determine priority areas (Appendix O). From the prioritisation it can be seen that the majority of priority sites were located on the mainstem Lachlan River, predominantly in management zones 8 and 11, and possessed such attributes as remnant native fish populations, diverse assemblages of aquatic vegetation, higher densities of woody debris and a good coverage of native riparian vegetation, particularly in the upper storey (Table 7). Within these sites, specific habitat parameters were identified that could form the basis of an integrated management approach to protect the waterway and improve native fish populations. Information collected during the study, such as the positive correlation between the presence of large bodied natives and coverage of woody debris, give confidence in developing rehabilitation options that will produce tangible benefits for native fish populations. The recommendations listed below are based on sound ecological restoration principles that are in common use throughout the Murray-Darling basin.

Table 7: Summary of prioritised rehabilitation areas assessed in the lower Lachlan catchment.

Rank*	Site	Zone	Site Location/Information	Comments
1	13	8	Lachlan River at Euabalong	Maintains fair to good habitat values and fish diversity and abundance. Fish passage barrier 11 km downstream.
2	12	8	Lachlan River at The Poplars	Maintains good habitat values and fish diversity and abundance, including large bodied natives. Fish passage barrier 9 km upstream.
3	6	11	Lachlan River at Wheelba Bridge	Maintains good habitat values and fish diversity and abundance, including large bodied natives. Fish passage barrier 3.5 km upstream. Moderate public profile.
4	14	8	Lachlan River at Euabalong Bridge	Maintains good habitat values and fish diversity and abundance. Recreational area.
4	15	8	Lachlan River at Marigold	Maintains good habitat values and fish diversity and abundance, including greatest abundance of large natives. Fish passage barrier 4 km upstream. Recreational area.
6	8	8	Lachlan River at Moora Farm	Maintains good habitat values and fish diversity and abundance, including large bodied natives. Fish passage barrier 14.5 km downstream.
6	2	11	Lachlan River at Braebuck Woolshed	Maintains good habitat values and fish diversity and abundance, including large natives.
6	7	11	Lachlan River at Hillston	Maintains fair to good habitat values and fish diversity and abundance. Fish passage barrier 3.5 km downstream. Recreational area.
9	10	8	Lachlan River at Maryabba	Maintains fair habitat values and fish diversity and abundance. Fish passage barrier 17 km downstream.
9	11	8	Lachlan River at Horseshoe Bend	Maintains fair habitat values and fish diversity and abundance.
9	25	8	Wallaroi Creek at Koobothery	Maintains fair to good habitat values, but very poor fish diversity and abundance. Two fish passage barriers occur at 1 km and 2 km upstream.
9	3	11	Lachlan River at Corrong	Maintains good habitat values and moderate fish diversity and abundance.
13	9	8	Willandra Creek at Kidman	Maintains good habitat values and moderate fish diversity and abundance.
13	16	8	Lachlan River at Condobolin	Maintains poor habitat values and fish diversity and abundance. Fish passage barrier 1 km downstream. Recreational area.
13	24	8	Booberoi Creek at Booberoi Creek East	Maintains fair habitat values and poor fish diversity and abundance. Fish passage barrier 2 km upstream.
16	23	13	Merrowie Creek at Roto Road	Maintains poor habitat values and very poor fish diversity and abundance. Fish passage barrier 7 km upstream.
17	27	9S	Wallaroi Creek at Blue Range	Maintains fair habitat values and poor fish diversity and abundance. Two fish passage barriers occur, one within the reach and one 4.5 km downstream.
17	5	11	Lachlan River at Ulonga	Maintains fair to good habitat values and moderate fish diversity and abundance.
17	22	13	Willandra Creek at Lowlands	Maintains poor habitat values and fair fish abundance but poor diversity.
20	19	13	Merrowie Creek at Roeta Road	Maintains fair habitat values and very poor fish diversity and abundance.
21	17	11	Lake Waljeers at Lake Waljeers	Maintains poor habitat values and very poor fish diversity and abundance.
21	18	13	Merrowie Creek at Cobb Highway	Maintains poor habitat values and very poor fish diversity and abundance.
21	21	13	Willandra Creek at Willandra National Park	Maintains fair to poor habitat values and poor fish diversity and abundance. Remote site.
24	1	12	Lachlan River at Geramy	Maintains very poor habitat values and fish diversity and abundance. Remote site.
24	20	13	Willandra Creek at Mossgiel	Maintains very poor habitat values and fish diversity and abundance.
26	26	9S	Wallamundary Creek at Wallamundary	Maintains fair to moderate habitat values, but very poor fish diversity and abundance. Remote site.

*Rank obtained from the total of the Habitat value and Additional Criteria during the prioritisation scheme (Appendix N), which used the data in Appendix O.

Recommendations

Potential rehabilitation actions have been identified for two areas within the lower Lachlan, which encompass four priority sites and concentrate on the lower and middle reaches of the mainstem Lachlan River.

Lower reach: Lachlan River at Wheelba Bridge

This site is located approximately 50 km south west of Hillston on the Lachlan River, with the proposed actions focussing on the aquatic habitat within Site 6, but also incorporating modifications to fish passage barriers upstream and downstream of the site. The land adjacent to the river is privately owned and dominated by grazing activities. The site contains a significant coverage of instream woody debris that ranges in complexity from single stands to highly complex habitat, and the riparian vegetation is in a fair condition dominated by remnant river red gums but containing no understorey (Map 19). The aquatic vegetation of the site contained the exotic noogoora burr species. The fish assemblage at Site 6 was dominated by introduced species, however small and large bodied natives were recorded and anecdotal evidence from local anglers and landholders have indicated that freshwater catfish, golden and silver perch and Murray cod occur in the area and have recently been caught (NSW DPI, 2006a).

Approximately 3.5 km upstream of Site 6 is the privately owned Tallawanta Weir (DWR10), which has been classified as a high priority barrier to fish passage in the Lachlan River. This structure acts as a barrier to fish during the majority of flows and as a result a full width rock ramp fishway has been recommended to remediate passage (NSW DPI, 2006a). In addition to this structure, there is only one other major barrier located downstream on the Lachlan River, Booligal Weir (DWR02), which is 55 km away and has also been classified as a high priority structure. A full width rock ramp fishway has been recommended for this State Water owned weir (NSW DPI, 2006a). Remediation at these two structures would significantly benefit native fish in the lower Lachlan by reinstating over 200 km of aquatic habitat.

This site would benefit from on-ground rehabilitation works that complement the proposed fish passage remediation, with the aim of improving aquatic habitat and connectivity for native fish in the lower reaches of the Lachlan River. Priority actions include:

- **Realignment of existing woody debris** to increase bed scour and create deeper pools, enhancing native fish habitat and arresting bank erosion;
- **Riparian revegetation** with native species in strategic locations, focussing on reinstating the understorey throughout the majority of the site and establishing larger native stands in certain bare areas;
- **Riparian fencing** (plus provision of alternative stock watering points) done in conjunction with revegetation works to exclude stock and allow natural regeneration of the riparian zone;
- **Targeted removal of weed species** (especially noogoora burr) to enhance flow conditions and terrestrial biodiversity in the Lachlan River, and;
- **Fish passage remediation** at nearby high priority sites to improve fish passage and enhance flow conditions in the lower reaches of the Lachlan River.

Mid reach: Lachlan River at Euabalong Station and surrounding area

The proposed rehabilitation area encompasses three sites along the Lachlan River, including Site 12 at Poplars, Site 13 at Euabalong Station and Site 14 at Euabalong Bridge, that span a distance of approximately 30 km. The proposed actions focus on the aquatic habitat in the immediate area of these three sites and complement future fish passage remediation works in adjacent areas. All three sites contain a substantial coverage of instream woody debris that ranges in complexity from single stands to highly complex habitat, and the riparian vegetation is in a fair condition with full cover dominating (Maps 7, 8 and 9). However, minimal understorey vegetation was noted at all three sites and the aquatic vegetation at Site 14 contained willow and noogoora burr weed species (Map 9). The fish assemblage at these

sites was dominated by small bodied native species, with large bodied natives also recorded at Sites 12 and 14, indicating the potential to reinstate the native fish population in the area.

Associated with Site 12 and Site 13 is the State Water owned Lake Cargelligo Weir (DWR08), which has been classified as a high priority barrier to fish passage in the Lachlan River. This structure, which is 9 km upstream of Site 12 and 11 km downstream of Site 13, acts as a barrier to fish during the majority of flows and as a result construction of a vertical slot fishway is set to commence at this site to remediate passage (NSW DPI, 2006a). Remediation of this structure has the potential to reinstate over 120 km of aquatic habitat in the mid Lachlan region. In addition to this, the high profile of Site 14, which contains a recreational area accessible by the public, presents an opportunity to promote the works occurring at this site and the two downstream areas.

These sites would benefit from on-ground rehabilitation works that complement future fish passage remediation, with the aim of improving aquatic habitat and connectivity for native fish in the mid reaches of the Lachlan River. Priority actions include:

- **Reinstating and realigning existing woody debris** to increase bed scour and create deeper pools, enhancing native fish habitat and arresting bank erosion;
- **Riparian revegetation** with native species in strategic locations, focussing on reinstating the understorey throughout the majority of the sites and establishing larger native stands in certain bare areas;
- **Riparian fencing** (plus provision of alternative stock watering points) done in conjunction with revegetation works to exclude stock and allow natural regeneration of the riparian zone;
- **Targeted removal of weed species**, including willow and noogoora burr, to enhance flow conditions in the Lachlan River;
- **Information signs** at Site 14 to promote and inform the public of the rehabilitation works at the three sites, and;
- **Fish passage remediation** at the nearby high priority site to improve fish passage and enhance flow conditions in the mid reaches of the Lachlan River.

By implementing the proposed actions at the two priority areas it is anticipated that the riparian and aquatic habitat will be significantly improved, benefiting native fish assemblages and leading to an increase in their numbers and diversity. It is predicted that riparian vegetation, especially the understorey, will provide improved coverage and interaction with the aquatic environment, contributing to woody debris coverage, with the reinstatement of woody debris improving the diversity and complexity of habitat for aquatic biota. This, along with fish passage remediation works, will significantly benefit the movement and recruitment of native fish in the lower Lachlan. Given the significant size of the Lachlan catchment and the relatively poor condition of the remaining aquatic habitat, concentrating expenditure in the immediate future on two priority areas is likely to give the greatest potential for measurable improvements in both habitat parameters and native fish populations.

Before implementing these suggested actions it is understood that many environmental, social, cultural and economic considerations need to be reviewed. This includes assessing the existence of sensitive terrestrial habitat and threatened species in the surrounding area, identifying support and potential opposition from stakeholders, and estimating associated costs and identifying potential funding sources. Detailed project plans can then be developed to meet the objectives of the rehabilitation work. Following the implementation of these actions it is important to monitor and maintain the work completed at sites, evaluating their effectiveness in rehabilitation. The results of the actions undertaken, and the whole process completed during the current project, has the potential to be used in guiding similar projects that assess and remediate threatening processes in the remaining Lachlan catchment.

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7. APPENDICES

Appendix A – Freshwater native finfish of the Lachlan catchment

Scientific Name	Common Names	Status	Migration and habitat
Ambassis agassizii	Olive perchlet	Threatened species (Endangered western population)	Local migration; Freshwater streams and swamps in lowland and slope environments
Bidyanus bidyanus	Silver perch	Threatened species (vulnerable - *Fisheries Management Act* 1994)	Large scale migration; Habitat is predominantly in lowland and slope waterways
Craterocephalus fluviatilis	Murray hardyhead	Threatened species (endangered - *Fisheries Management Act* 1994)	Unknown migration; Inhabits slow lowland rivers, as well as lakes, billabongs and backwaters.
Craterocephalus stercusmuscarum	Flyspecked hardyhead	Unknown	Local migration; Freshwater streams in lowland habitat
Gadopsis marmoratus	River blackfish	Common	Local migration; Widespread in slope and montane waterways
Galaxias olidus	Mountain galaxias	Common	Local migration; Moderate and high elevations in coastal and inland rivers
Galaxias rostratus	Murray jollytail	Unknown	Local migration; Still or gently flowing waterways dominated by coarse substrate, debris and phragmites.
Hypseleotris compressa	Empire gudgeon	Common	Unknown migration; Common in lowland and slope habitats
Hypseleotris klunzingeri	Western carp gudgeon	Common	Unknown migration; Common in lowland and slope waterways
Hypseleotris spp	Gudgeon	Common	Unknown migration; Inhabit streams, backwaters and drains, usually around aquatic vegetation and woody debris.
*Hypseleotris sp*4	Midgley's carp gudgeon	Common	Unknown migration; Inhabit streams, backwaters and drains, usually around aquatic vegetation and woody debris.
*Hypseleotris sp*5	Lake's carp gudgeon	Common	Unknown migration; Inhabit streams, backwaters and drains, usually around aquatic vegetation and woody debris.
Leiopotherapon unicolor	Spangled perch	Common	Local migration; Warm waters in inland streams, backwaters and dams
Maccullochella peelii peelii	Murray cod	Threatened species (vulnerable - EPBC)	Local migration; Habitat predominantly in lowland and slope waterways
Macquaria ambigua	Golden perch	Relatively common	Large scale migration; Common in lowland and slope waterways
Macquaria australasica	Macquarie perch	Threatened species (vulnerable - *Fisheries Management Act* 1994)	Local migration; Slow moving, cool clear waters of rivers and lakes.
Melanotaenia fluviatilis	Crimson-spotted rainbowfish	Relatively common	Local migration; Waters in lowland and slope environments
Mogurnda adspersa	Purple-spotted gudgeon	Threatened species (Endangered western population)	Local migration; Waters in lowland and slope environments
Nannoperca australis	Southern pygmy perch	Threatened species (vulnerable - *Fisheries Management Act* 1994)	; Inhabit vegetated margins of streams, billabongs, drains and swamps in still or slow flowing waters.
Nematalosa erebi	Bony herring	Relatively common	Local migration; Waterways of lowland and slope environments
Philypnodon grandiceps	Flathead gudgeon	Unknown	Uncertain; Lowland and slope waterway environments
Retropinna semoni	Australian smelt	Common	Local migration; Common in lowland and slope waterways
Tandanus tandanus	Freshwater catfish	Relatively common	Local migration; Lowland lakes and slow-flowing rivers

Sources: McDowall (1996); Thorncraft and Harris (2000); Allen *et al.* (2002) and Classon and Boon (2002).

Appendix B – Freshwater introduced finfish of the Lachlan catchment

Scientific Name	Common Names	Status	Migration and habitat
Carassius auratus	Goldfish	Exotic	Local migration; Widespread in lowland rivers
Cyprinus carpio	Common carp	Exotic (Noxious)	Local migration; Still gentle flowing rivers, being abundant in weir pool environments
Gambusia holbrooki	Gambusia	Exotic (Noxious)	Unknown migration; Widespread throughout inland waterways of NSW
Oncorhynchus mykiss	Rainbow trout	Exotic (Stocked)	Local migration; Associated with cold water below or in impoundments
Perca fluviatilis	Redfin perch	Exotic (Noxious)	Local migration; Associated with cold water below or in impoundments
Salmo trutta	Brown trout	Exotic (Stocked)	Local migration; Montane regions along the Great Dividing Range

Sources: McDowall (1996); Thorncraft and Harris (2000); Allen *et al.* (2002) and Classon and Boon (2002).

Appendix C – Lachlan catchment Detailed Weir Review summary

Priority	Barrier Name	Watercourse	Ownership	Operational Fishway	Preferred Option	Estimated Cost of Preferred Option ($)	Alternative Option	Estimated Cost of Alternative Option ($)
1	Booberoi Weir	Lachlan River	State Water	No	Construct Vertical Slot Fishway	>500k	Partial width rock ramp fishway	150 – 250k
2	Booligal Weir	Lachlan River	State Water	No	Full width rock ramp fishway	150 – 250k	Partial width rock ramp fishway	50 – 150k
3	Bumbuggan Creek Weir	Bumbuggan Creek	State Water	Yes	Vertical Slot Fishway (completed in 2004)	>1M	N/A	N/A
4	Brady's Weir	Goobang Creek	Private	No	Full width rock ramp fishway	50 – 150k	Removal	<50k
5	Burrawang West Weir	Bumbuggan Creek	Private	No	Partial width rock ramp fishway	<50k	Full width rock ramp fishway	50 – 150k
6	Condobolin Weir	Lachlan River	State Water	No	Construct Vertical Slot Fishway	250 – 500k	Full width rock ramp fishway	150 – 250k
7	Cottons Weir	Lachlan River	State Water	No	Construct Vertical Slot Fishway	250 – 500k	Partial width rock ramp fishway	150 – 250k
8	Gonowlia Weir	Lachlan River	State Water	No	Management of dropboard use	N/A	N/A	N/A
9	Jemalong Weir	Lachlan River	State Water	No	Construct Vertical Slot Fishway (investigations underway)	>1M	N/A	N/A
10	Hillston Weir	Lachlan River	State Water	No	Full width rock ramp fishway	250 – 500k	Partial width rock ramp fishway	150 – 250k
11	Kennedy's Weir	Goobang Creek	Private	No	Partial removal and rock ramp fishway	<50k	N/A	N/A
12	Kiactoo Weir	Lachlan River	State Water	No	Construct Vertical Slot Fishway	250 – 50k	Full width rock ramp fishway	50 – 150k
13	Lachlan Shire Council Weir	Goobang Creek	State Water	No	Partial width rock ramp fishway	150 – 250k	Full width rock ramp fishway	250 – 500k
14	Lake Brewster Weir	Lachlan River	State Water	No	Fishway option study	>1M	Construct bypass channel	500k – 1M
15	Lake Cargelligo Weir	Lachlan River	State Water	No	Construct Vertical Slot Fishway (completed 2006–2007)	>1M	N/A	N/A
16	Micabil Weir	Lachlan River	Private Water Trust	No	Partial width rock ramp fishway	<50k	Construct Vertical Slot Fishway	150 – 250k
17	Tallawanta Weir	Lachlan River	Private	No	Full width rock ramp fishway	50 – 150k	Removal	<50k
18	TSR Weir	Bumbuggan Creek	RLPP	No	Removal	<50k	Full width rock ramp fishway	50 – 150k
19	West Condobolin Weir	Lachlan River	Private Water Trust	No	Removal	<50k	Full width rock ramp fishway	50 – 150k
20	Willandra Weir	Lachlan River	State Water	No	Partial width rock ramp fishway	150 – 250k	Full width rock ramp fishway	250 – 500k

Appendix D – Management zones of the Lachlan catchment

Zone 1: Upper Lachlan and Abercrombie Rivers (900m and above)

Habitat setting and aquatic species

Zone 1 covers the headwaters of the Lachlan and Abercrombie Rivers above 900m elevation. The area is characterised by small, moderately fast flowing, incised streams with sand and gravel substrates. Dry sclerophyll woodlands previously dominated the landscape, however the land has been extensively cleared for sheep and beef cattle grazing. Other land use activities include irrigated broadacre crops and mining.

Data obtained from the NSW DPI Fishfiles database, which used information from studies conducted between 1994 and 2002, indicated that introduced fish species dominated the composition in the Lachlan headwaters, with the abundance of the catch dominated by native mountain galaxias (88% of fish caught). Other native fish expected to occur include river blackfish, Macquarie perch and purple spotted gudgeon, however these species were not detected during surveys. Fish stocking has occurred extensively for recreational fishing purposes. Due to the cool, upland conditions, the majority of fish stocked include introduced brown trout and rainbow trout. Golden perch, silver perch and Murray cod are also released for recreational fishing purposes.

Primary threatening processes in Zone 1

Water extraction

The waterways of Zone 1 are unregulated as they are located above Wyangala and Carcoar dams. As such, water users rely on natural flows for water supplies. Environmental stress due to over-extraction can result, particularly during dry periods when the demand for water is equal to or greater than the supply available (DLWC, 1999).

Barriers to fish passage

A total of three weir structures were identified in Zone 1 during the NSW Initial Weir Review study, with none of these sites recommended for further detailed investigation. Despite this fact, these structures still have the potential to interrupt natural flow regimes of waterways and impact upon the population of native fish. This is predominantly through interrupting spawning or seasonal migrations, restricting access to preferred habitat and available food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of these structures on smaller creeks also restricts passage to important seasonal and ephemeral habitats.

Degradation of riparian zone

The condition of the riparian zone in Zone 1 was generally poor with vegetation degradation and riverbank erosion identified as issues. Stream vegetation in the upper Abercrombie Catchment, has been assessed as being in a poor to very poor condition (Massey, 1998). Agriculture and associated vegetation clearance has occurred on both sides of waterways, resulting in a narrow or absent riparian zone dominated by exotic species such as willow and blackberry. Riparian vegetation in the upper sections of the Abercrombie and Retreat Rivers is in a better condition, possessing wide riparian zones, links to native floodplain vegetation, good structural diversity, no exotic species and little or no intrusion of agricultural practices. The riparian zone in the upper Lachlan, upper Belubula and upper Crookwell catchments is in a poor to very poor condition, with extensive vegetation clearance and a dominance of weeds species.

Riverbank erosion has also been identified as a problem in Zone 1 and can result in an increased sediment load, reduced water quality and degraded aquatic habitat. Loss of riparian vegetation can increase the problem by destabilising riverbanks however, bank erosion can still occur in well-vegetated areas where susceptible soils may be present (Massey, 1998).

Introduced fish species

Five of the six introduced species in the Lachlan catchment occur in Zone 1. The only species not found in this zone is carp, which prefers the still, slower waters found in lower parts of the catchment. Brown trout and rainbow trout have developed self-sustaining populations in the

catchment, with population numbers enhanced through stocking programs. Trout can impact on native fish species through competition and predation, having a significant impact on mountain galaxiids (Faragher and Lintermans, 1997; Allen *et al*, 2002).

Zone 2: Upper Lachlan River (below 900m to Wyangala Dam)

Habitat setting and aquatic species

The waterways in Zone 2 are unregulated, fast flowing streams with moderately steep, densely vegetated ranges and gorges. Sections of the area have been extensively cleared for agricultural purposes, which are dominated by grazing and cropping practices.

Results from the NSW DPI Fishfiles database, which used information from various fish sampling projects conducted between 1976 and 2003, showed that eight of the twelve fish species caught were native, including the threatened southern pygmy perch and Macquarie perch. These studies showed that it wasn't until 2002 and 2003 that southern pygmy perch were captured, with substantial numbers found in 2003. This finding also occurred for river blackfish, which had only been caught in recent years. Fish stocking occurs above Wyangala Dam for recreational purposes, with rainbow trout extensively stocked, along with brown trout and native golden perch.

Primary threatening processes in Zone 2

Barriers to fish passage

A total of four weir structures were identified in Zone 2 during the NSW Initial Weir Review study, with one site assessed during detailed investigation. These structures have the potential to interrupt natural flow regimes of the waterways, as well as impact upon the population of native fish by interrupting spawning or seasonal migrations, restricting access to preferred habitat and available food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of the assessed weir on a smaller creek also restricts passage to ephemeral habitats.

Degradation of riparian zone

Riparian vegetation along the Lachlan and Crookwell Rivers above Wyangala Dam were in a highly stressed condition, with 91% and 100% of the stream length in poor condition respectively (DLWC, 1999). Extensive vegetation clearance and agricultural practices have occurred along the waterways, reducing the native riparian vegetation and resulting in the dominance of weeds in the narrow riparian zones (Massey, 1998). The condition of riparian vegetation, as well as instream habitat, has also been affected by aggregate extraction that occurs in the zone. There are two sites of sand and gravel extraction on the Lachlan River, from which an estimated extraction of 50,000 m^3 per year occurs, impacting the aquatic and riparian health of the system (DLWC, 1999).

There are a number of waterways in Zone 2 that possess riparian vegetation that is in a good condition (Massey, 1998). Streams such as Blocker Creek, Reedy Creek and Sandy Creek, have all been identified as having good riparian vegetation cover, with the riparian zones dominated by stands of native species (Massey, 1998)

Introduced fish species

Four out of the six introduced species established in the Lachlan catchment occur in Zone 2, dominated by the presence of carp and gambusia. These species have contributed significantly to the condition of aquatic habitat in this area of the Lachlan catchment, with the presence of carp reflecting the poor quality of the environment.

Salinity

Areas of Zone 2 have been identified as having some of the highest salinity levels of the catchment, with sites at Numby and Narrawa yielding concentrations greater than 800uScm^{-1} (Thurtell and Burton, 2003). These levels exceed the threshold for drinking water taste and reduce the overall value of available water. The impacts of these salt concentrations on instream biota is relatively unknown, however it is likely that it would reduce reproductive success and growth, significantly impacting on the health of the waterway (Thurtell and Burton, 2003).

Zone 3: Upper Abercrombie River (below 900m to Wyangala Dam)

Habitat setting and aquatic species

This area of the Lachlan covers the Upper Abercrombie River catchment below 900m elevation to Wyangala Dam. Landuse in this zone is dominated by grazing, with irrigated cropping also occurring. Approximately 10% of the land has been classified as National Parks or Reserves, with native vegetation communities consisting of wet and dry sclerophyll forest, and eucalypt woodland.

The majority of riverine environment of the upper Abercrombie catchment is in a moderate to good condition, with only 20% of the area classified as being in a poor state (Massey, 1998). The main disturbances to the aquatic environment include impacts to the riparian zone by grazing and forestry, which can lead to the removal of native vegetation and the promotion of weed species.

Data from NSW DPI Fishfiles database, which used information from fish sampling projects conducted between 1994 and 2002, showed that seven of the twelve fish species present were native, including the threatened Macquarie perch and southern pygmy perch. The most abundant species in the zone were the mountain galaxiids and gudgeons, which comprised over half the total abundance. Carp, which were the third most abundant species, represented nearly 20% of the total fish abundance. Fish stocking has taken place in Zone 3 since 1978, with the majority of fingerlings released being rainbow trout. Brown trout and some native species, including trout cod and golden perch have also been released into the waterways of the management zone.

Primary threatening processes in Zone 3

Degradation of riparian zone

Riparian vegetation in Zone 3 has been classified as being highly stressed, with 60% of the catchment in poor condition (DLWC, 1999). The degradation of the native vegetation has resulted in the infestation of weed species, with extensive stands of willow found along the banks of the Abercrombie River, Bolong River, Phil's River, Rocky Bridge Creek and Thompsons Creek (Massey, 1998). This process has the potential to reduce the stream channel width and obstruct the flow of water, increasing erosion and flood events in the area, as well as reducing the quality of instream habitat available to aquatic biota (DIPNR, 2004b).

Introduced fish species

Fish surveys indicate that introduced fish species make up five of the twelve species in the management zone, with the presence of carp being the most abundant. The establishment of these introduced species reduces habitat and food resources available for native fishes, as well as impacting native populations through predation, introduction of diseases, interference and disturbance of the instream environment.

Zone 4: Wyangala Dam (4A) and Carcoar Dam (4B)

Habitat setting and aquatic species

Wyangala Dam (Zone 4A) is located at the junction of the Lachlan and Abercrombie Rivers and was completed in 1936, with enlargement of the dam taking place in 1971 (DLWC, 1998; Driver *et al*, 2002). The dam has a height of 83 m and a capacity of 1,200,000 ML, making it the largest licensed structure and artificial water storage dam in the Lachlan Catchment. The water levels of Wyangala Dam fluctuate according to associated inflow and release of water, which is primarily used for irrigated crops such as wheat and lucerne. Carcoar Dam (Zone 4B) is situated on the upper reaches of the Belubula River and was constructed in the early 1970s. The dam has a vertical height of 53 m and a capacity of 36,000 ML.

Fish species found in both Zone 4A and 4B include large natives such as silver perch, golden perch and Murray cod, small native species such as mountain galaxias, flat-head gudgeon, carp gudgeons, and Australian smelt, and introduced species that include carp, brown trout, gambusia, goldfish, redfin perch and rainbow trout (D. Gilligan pers. comm.). The majority of fish in these water storages are part of an extensive stocking program to improve recreational fishing

opportunities. The program has included the release of native fingerlings, including golden perch, silver perch and Murray cod, as well as the exotic brown and rainbow trout species.

Primary threatening processes in Zone 4

River regulation

Wyangala and Carcoar Dam control approximately 70% of the Lachlan catchment's runoff, significantly affecting the natural dynamics of the aquatic environment (DLWC, 1998; Driver *et al*, 2002). Waterways above these storages are considered to be unregulated systems, whilst waterways downstream of the dams are regulated, receiving measured flows for irrigation purposes that are greatly altered from natural conditions. The changes in natural flow conditions throughout the lower Lachlan has impacted on aquatic health, significantly affecting aquatic and riparian vegetation, as well as native fish populations that rely on seasonality, variability and frequency of high flows to complete their life cycles.

Blue green algal blooms are another problem associated with the two dams, especially in Wyangala Dam. Favourable conditions are produced in this large open water storage, particularly during summer when temperature and nutrient levels are high and water levels are low. Blue green algae blooms also occur in Carcoar Dam as a result of high phosphorous levels and erosion upstream of the dam. Blue green algae levels can eventually become toxic and may pose health problems to humans and stock, as well as being harmful to fish and macroinvertebrates and reducing downstream water quality (DLWC, 1998).

Another significant impact associated with both Zones 4A and 4B is the occurrence of cold water pollution. This has been identified downstream of both of the dams, with significant reductions in water temperature associated with these structures (Lugg, 1999). The larger of these two dams, Wyangala Dam, has been identified as causing severe cold water pollution in the catchment, impacting on the aquatic flora and fauna of the Lachlan (Preece, 2004).

<u>Zone 5</u>: Main channel Lachlan River (downstream Wyangala to Gooloogong) and main channel Belubula River (to Lachlan junction)

Habitat setting and aquatic species

Zone 5 is located in the upper Lachlan slopes and is characterised by undulating land cleared for grazing purposes, which graduates to flatter areas with some pockets of remnant vegetation (DLWC, 1999). The reaches of the Lachlan and Belubula Rivers in Zone 5 are located below Wyangala and Carcoar Dams, resulting in confined channels and highly regulated flows. Vegetation is dominated by open woodland eucalypts, as well as eucalypt woodlands and open forests, with grasslands and belah scrub also found along the main channel.

Data from the NSW DPI Fishfiles database, which used information from surveys completed between 1998 and 2002, showed that six out of the thirteen species recorded were introduced fish, with their abundance dominated by carp. Of the seven native fish species caught, Australian smelt and river blackfish were the most abundant. Fish stocking, predominantly below Wyangala Dam, has been conducted and involves golden perch, Murray cod, brown trout and rainbow trout.

Primary threatening processes in Zone 5

River regulation

Zone 5 includes the main streams that occur immediately below the major water storages of Wyangala and Carcoar Dams, resulting in the effects of cold water pollution being most severe. In a study conducted by Lugg (1999), there was a marked decrease in summer water temperatures of 13.5^{o}C and 5.5^{o}C found at Wyangala and Carcoar Dams respectively. A gradual increase back to expected temperature profiles occurred with an increase in distance downstream, however in the waters below Wyangala Dam this did not occur until 200 km from the dam (Lugg, 1999). A similar study conducted by Burton (2000) also found that the water temperature regime downstream of Wyangala Dam was considerably altered, being up to 7^{o}C colder in summer. The extent of this temperature suppression ranged between 150 and 170 km, resulting in the effects of cold water pollution occurring throughout all of Zone 5 (Burton, 2000).

The expected effects of altered temperatures below Wyangala Dam include reducing the numbers of phytoplankton and bacteria, causing localised extinctions of macroinvertebrates (depending on which life stage is affected), affecting the movements, spawning and survival of native fish species, and causing an overall reduction in the health of the aquatic environment (Burton, 2000).

Barriers to fish passage

A total of six licensed weirs were identified in Zone 5 during the NSW Initial Weir Review, with one of these structures assessed in detail. These structures have the potential to interrupt natural flow regimes of waterways and impact upon the population of native fish, particularly through interrupting spawning or seasonal migrations, restricting access to preferred habitat and available food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of the assessed structure on a smaller creek also restricts fish passage to important seasonal and ephemeral habitats.

A separate study examining the presence of instream structures that may act as barriers to fish passage in Zone 5 was conducted by NSW DPI. The study examined 110 structures, including weirs, dams, causeways and bridges, and found that 17 of these acted as major or complete barriers to fish passage (Lugg, unpublished). These barriers were dominated by weirs (6), causeways (6) and two bridges (Lugg, unpublished). The majority of structures were found to be minor or insignificant barriers, with bridges, which were the most common structures assessed, dominating this category with 45 recorded (Lugg, unpublished).

Degradation of riparian zone

The majority of riparian vegetation along the Lachlan River in Zone 5 has been classified as highly degraded, with waterways being in a poor to very poor condition (Massey, 1998). In these areas vegetation clearance and agricultural practices have occurred on both sides of the waterway, leaving a narrow riparian zone dominated by exotic species such as willows and blackberries (Massey, 1998). The removal of native vegetation has assisted in causing events of bank collapsing and slumping, particularly between Cowra and Forbes (Driver *et al*, 2002). The cause of the erosion can also be linked to sudden periods of wetting and drying from flow regulation, which has also resulted in channel incision and widening (Driver *et al*, 2002). Regulated flows have caused the waterways to become incised and disconnected from the floodplain, whilst erosion processes have resulted in the widening of some streams in Zone 5 (Driver *et al*, 2002).

Introduced fish species

Studies of the aquatic biota in Zone 5 indicate that introduced fish species are present in both the Belubula and Lachlan Rivers. In the Belubula River, introduced fish comprised the greater number of species present (75%), as well as the greatest number of fish caught (78.5%). Introduced species also accounted for the greatest abundance of fish in the Lachlan channel of Zone 5, with carp dominating, however there were a greater number of native species recorded. The establishment of introduced species reduces habitat and food resources available for native fishes, as well as impacts on native populations through predation, introduction of diseases, interference and disturbance of the instream environment.

Water pollution

Diffuse pollution has been recorded in Zone 5 during recent pesticide studies of the Lachlan catchment. The studies found that pesticide contamination had occurred in the Lachlan River at both Cowra and Nanami (Lloyd-Jones, 1999). Pesticides detected included atrazine, endosulfan, metolachlor, MCPA and simazine, with endosulfan levels detected up to three times greater than the ANZECC Australian Water Quality Guidelines for the protection of aquatic ecosystems (Lloyd-Jones, 1999). These chemicals are toxic and do not distinguish between pest and non-pest species, increasing their potential impact on biota that is associated with the aquatic environment (Lloyd-Jones, 1999; Lloyd-Jones and Raisin, 2003).

Zone 6: Main upland tributaries - Boorowa River (6A), Mandagery Creek (6B), Crowther Creek (6C), and Bland Creek (6D)

Habitat setting and aquatic species

Zone 6 is divided into four zones and consists of the main upland tributaries of the Boorowa River, Mandagery Creek, Crowther Creek and Bland Creek. The landscape of these subcatchments is characteristically undulating to hilly and is mostly cleared, with pockets of native vegetation. The streams are confined and gently flowing with sand and mud based beds (DLWC, 1998).

The Boorowa River (Zone 6A) is the most upland of the main waterways in the management zone, containing the tributaries of Breakfast, Castles, Hovells and Mackay Creeks. The area has had a large portion of the land cleared for agricultural purposes, including sheep and wool production, beef cattle, goats, pastures and mixed cropping. The landscape of the zone consists of steep hills and skeletal soils in the east, and slightly undulating hills that have deep soils on the western side.

Mandagery Creek (Zone 6B) lies to the north of the Lachlan River at an elevation of about 600 m. The headwaters of the main creek begin near the town of Molong, with the zone containing tributaries that include Boree, Coates, Manildra and Reedy Creeks. The overall condition of Zone 6B is mostly poor, with the sparse vegetation remnants consisting of eucalypt open woodland, eucalypt woodland, and small amounts of grasslands and heath (Massey, 1998).

Crowther Creek (Zone 6C) incorporates the tributaries of Cherry, Conimbla, Middle and Warrangong Creeks. The majority of aquatic environment in the zone has been classified as being in a poor condition, with grazing being the main disturbance to reach environments in the area (Massey, 1998). The dominant vegetation type is eucalypt open woodland, with eucalypt open forest, eucalypt woodland and grasslands also being common (Massey, 1998).

Bland Creek (Zone 6D) is the most westerly of the upper tributaries in the management zone, with a generally flatter landscape consisting of floodplains and some undulating hills. Tributaries of Zone 6D include Back, Barmedman, Burrengong and Memagong Creeks. Local vegetation in the area is predominantly composed of eucalypt open woodland, with some grasslands and eucalypt woodland also present. Landuse in the area consists of grazing, irrigation crops, and urban and rural residential zones, with National Parks and reserves also present in the zone (Massy, 1998).

Aquatic biota data from the NSW DPI Fishfiles database, which used information obtained between 1976 and 2003, showed that the fish assemblage for Zone 6 was dominated by introduced fish, which accounted for five out of the eight species caught. Introduced species also dominated the abundance of fish in the area, with gambusia representing the greatest number of fish. Fish stocking has also occurred, with both native and introduced species stocked. Silver perch, golden perch and Murray cod fingerlings have all been released into the Boorowa River, Mandagery Creek and Bland Creek zones, whilst introduced species including brown trout and rainbow trout, have also been released for recreational purposes.

Primary threatening processes in Zone 6

Barriers to fish passage

During the Initial Weir Review 56 licensed weirs structures were identified in Zone 6, with only two of these sites assessed during the initial review. These structures have the potential to interrupt natural flow regimes of waterways and impact upon the population of native fish, particularly through interrupting spawning or seasonal migrations, restricting access to preferred habitat and available food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of these structures on both large and small tributaries also restricts fish passage to important seasonal and ephemeral habitats.

In addition to these weirs, other instream structures that may act as barriers to fish passage along Mandagery Creek (6B) were examined in a study conducted by NSW DPI. The study examined 55 structures, including weirs, causeways, culverts, fords and bridges, and found that three of these structures, two causeways and a weir, acted as major barriers to fish passage (Lugg, unpublished). The majority of structures (49) were found to be minor or insignificant barriers, with bridges dominating this category with 26 recorded (Lugg, unpublished).

Degradation of riparian zone

The majority of riparian vegetation in Zone 6 has experienced some form of degradation, with both the Mandagery Creek (6B) and Bland Creek (6D) management zones having riparian vegetation in poor to very poor condition (Massey, 1998). In areas of poor condition, exotic species such as willows dominate the vegetation in the narrow riparian zones, with minimal native vegetation present. The major pressures placed on vegetation on both sides of the waterways included clearing for agriculture, and disturbance from stock.

Dryland salinity

Dryland salinity has been identified as being a significant issue in Zone 6, especially in the Boorowa River management zone. It has been estimated that dryland salinity in the Boorowa catchment could reach as much as 10,000 ha if it remains unmanaged, with the main cause for the salt load being surface flows from scalds (Jenkins, 2004). As well as reducing the water quality in the waterways of Zone 6, salinity also reaches the main channel Lachlan River, resulting in poor water quality and also reducing soil structure. This can lead to an increase in soil erosion, causing large areas of the landscape to become bare and scalded. As a result of the compounding affects of dryland salinity the overall biodiversity of Zone 6 has been reduced, especially in Zone 6A. To minimise the impact of salinity on the aquatic environment it is important to improve farming practices and allow the revegetation of native plant species (Marsh and Marsh, 2005).

Zone 7: Main channel Lachlan River from Gooloogong to Bedgerebong

Habitat setting and aquatic species

Zone 7 is the beginning of the floodplains, where the river channel is no longer confined and the flow regime is highly regulated. The landscape is characterised by flat plains with the occasional rocky outcrop. The waterways of this zone finish at the start of the Jemalong Wyldes Plains Irrigation District. The overall condition of the riverine environment is in a moderate to poor condition, with land use dominated by grazing, irrigation crops, residential areas, and National Parks or State Reserves (Massey, 1998). The local vegetation types include eucalypt open woodland and eucalypt woodland, with grasslands and belah scrub also occurring (Massey, 1998).

Data from the NSW DPI Fishfiles database indicated that all 23 native species that have a distribution in the Lachlan catchment are expected to occur in Zone 7. The database, which used data from sampling occasions between 2000 and 2002, showed that native fish accounted for six of the eleven fish found in the zone, with the native Australian smelt dominating the abundance of all fish species recorded. Fish stocking has also occurred in Zone 7, with native silver perch, golden perch and Murray cod stocked in the mainstem Lachlan River, as well as introduced rainbow trout fingerlings for recreational purposes.

Primary threatening processes in Zone 7

River regulation

Zone 7 includes the main waterways that occur within the affected ranges of cold water pollution from upstream water storages, with the summer temperature profile of the Lachlan River indicating that cooler waters extend as far downstream as the border of Zone 7 (Burton, 2000). The effects of this cold water pollution are not as severe as the effects in Zone 5 because of the difference in distance, however these temperature alterations still impact on the physiology and reproductive success of aquatic biota (Burton, 2000; Preece, 2004).

Barriers to fish passage

A total of four weir structures were identified in Zone 7 during the NSW Initial Weir Review study, with two of these sites recommended for further detailed investigation. These structures have the potential to interrupt natural flow regimes of waterways and impact upon the population of native fish, particularly through interrupting spawning or seasonal migrations, restricting access to preferred habitat and available food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of these structures on the mainstem channel and associated tributaries restricts fish passage to important habitats.

Degradation of riparian zone

The riparian vegetation of Zone 7 has been highly degraded, with the majority of vegetation in a poor to very poor condition (Massey, 1998). Riparian vegetation in the area has been cleared on both sides of waterway s, with vegetation dominated by willows and few natives species present. The area approximately 30 km west of Forbes on the Lachlan River is heavily infested with Lippia (*Phyla canescens*), with its presence dominating the river banks, timbered areas and floodplains, and causing significant problems (Earl, 2003). This has resulted in extensive spraying of herbicides in the area to attempt to control this weed.

Direct impacts to native fish

Studies of the aquatic biota in Zone 7 indicate that introduced fish species are present throughout the area. In the Lachlan River, five introduced fish species are present, with carp dominating the abundance of these species. The establishment of introduced species reduces habitat and food resources available for native fishes, as well as impacts native populations through predation, introduction of diseases, interference and disturbance of the instream environment. Illegal fishing also impacts the population of native fish, with such practices occurring throughout the Lachlan River above and below Forbes (P. McCarthy, pers. Comm.). The setting of wire traps in these waterways can result in the deaths of fish as well as other wildlife species, including turtles, water rats, platypus and various species of birds.

Zone 8: Main channel Lachlan River from Bedgerebong to Hillston

Habitat Setting and aquatic species

Zone 8 is predominantly a floodplain area that consists of very flat topography with occasional rocky outcrops. Land use is dominated by grazing, as well as irrigated crops, resulting in major off-takes for irrigation. This can impact on the flow regime of the main waterways due to the presence of diversion channels, whilst associated regulators and levee banks reduce flows to billabongs and wetlands. Riparian vegetation in Zone 8 is dominated by eucalypt open woodland, with grasslands, shrub land, river red gum forest and belah scrub also present.

Data from the NSW DPI Fishfiles database showed that only seven of the 23 native species with expected distribution in the Lachlan catchment are found in the waterways of Zone 8. However, native species did dominate the fish assemblage in the zone, with bony bream and Australian smelt dominating the abundance of all fish. Introduced fish in Zone 8 were dominated by carp and goldfish. Fish stocking has taken place, predominantly in the three areas along the Lachlan River, Gum Bend Lake and Bumbuggan Creek Weir. This process has involved the stocking of native species such as golden perch, silver perch, Murray cod and trout cod.

Primary threatening processes in Zone 8

Barriers to fish passage

During the Initial Weir Review 40 licensed weirs structures were identified in Zone 8, with 34 of these sites assessed during the review. Nine of these structures were further assessed during the Detailed Weir Review, demonstrating the significance of their impact on the catchment, which includes interrupting natural flow regimes and impacting upon the population of native fish (Fairfull and Witheridge, 2003). The location of these structures on the mainstem channel increases the impact on native fish by restricting fish passage to important seasonal and ephemeral habitats.

In addition to these weirs, other instream structures that may act as barriers to fish passage in the zone were assessed by NSW DPI as part of this project. The study examined 29 structures within Zone 8 including fourteen weirs, ten bridges and five culverts, and found that 15 of these structures acted as major barriers to fish passage. The majority of these structures were weirs (10) and culverts (5).

Degradation of riparian zone

The riparian vegetation of Zone 8 was in a degraded condition, with the majority of vegetation in a poor to very poor condition (Massey, 1998). The majority of waterways have narrow or absent riparian zones that are dominated by exotic willow species, with native vegetation minimal or

absent (Massey, 1998). This degradation is predominantly a result of agricultural practices such as grazing, which has encroached close to the banks of waterways. The presence of Lippia is also causing a significant environmental problem along waterways and floodplains, adding to the degradation of the riparian zone in the area (Earl, 2003). The extent of riparian degradation in has caused significant erosion problems along waterways, especially Wallaroi and Bumbuggan Creeks, with both of their channels becoming shallower and wider (Driver *et al*, 2002).

Direct impacts to native fish

The waterways of Zone 8 inhabit a total of four introduced fish species with the presence of carp dominating the abundance. Carp can significantly impact on the population of native fish, as well as contribute to a reduction in water quality and biodiversity instream biota (Driver *et al*, 2002).

Native fish in Zone 8 are also affected by the practice of illegal fishing activities that occur within the waterways. This includes the frequent setting of fish traps and setlines, which are often left unattended resulting in the death of native fish and wildlife species (P. McCarthy pers. comm.).

Water pollution

Diffuse pollution has been recorded in Zone 8 during recent pesticide studies of the Lachlan catchment. Low level contamination of endosulfan, a pesticide used to control insect pests in cotton, fruit and vegetables, was detected in the waterways of the area (Lloyd-Jones and Raisin, 2003). The presence of this chemical indicates a risk to the health of the aquatic environment increasing the potential impact on biota (Lloyd-Jones, 1999; Lloyd-Jones and Raisin, 2003).

Zone 9 (South): South eastern effluent/ephemeral channels

Habitat setting and aquatic species

Zone 9 South consists of semi arid rangeland that contains unregulated ephemeral creeks that drain the Lachlan River. The main land use is grazing and broad acre crops, with these practices impacting on the aquatic environment of the area. The local vegetation includes eucalypt open woodland, shrub land, grassland and eucalypt open forest.

Data obtained from the NSW DPI Fishfiles database, which used information from studies conducted between 2001 and 2002, showed that introduced fish species dominated the assemblage of fish, accounting for five of the seven species. The abundance of introduced species was dominated by goldfish, with carp also found in significant numbers. Fish stocking also takes place, with native Murray cod fingerlings released into Sandy Creek.

Primary threatening processes in Zone 9 (South)

Barriers to fish passage

A total of 19 weir structures were identified in Zone 9 South during the NSW Initial Weir Review study, with seven of these sites recommended for further detailed investigation. These structures have the potential to interrupt natural flow regimes of waterways and impact upon the population of native fish, particularly through interrupting spawning or seasonal migrations, restricting access to preferred habitat and available food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of these structures on the major tributaries and creeks restricts fish passage to important habitats.

In addition to these weirs, other instream structures that may act as barriers to fish passage in the zone were assessed by NSW DPI as part of this project. The study examined eleven structures within the lower section of Zone 9 South including six bridges, three culverts, one causeway and one weir, and found that six of these structures, two bridges, two causeways and two culverts, acted as major barriers to fish passage.

Degradation of riparian zone

The riparian vegetation of Zone 9 South has been highly degraded, with the majority of the area in a very poor condition (Masse, 1998). The practice of clearing vegetation for agricultural purposes

has occurred extensively throughout the zone, reducing the presence of native vegetation and resulting in a narrow riparian zone.

Degradation of instream habitat

The majority of aquatic habitat in Zone 9 South was in a poor to very poor condition, with a high level of disturbance affecting the presence of debris and aquatic vegetation within the waterways (Massey, 1998). Large woody debris is absent at the majority of sites, being minimal at best, with a reduction in overhanging canopy and riparian vegetation contributing to this condition (Massey, 1998). Aquatic vegetation in this catchment was also highly degraded, with the majority of waterways in a very poor condition (Massey, 1998). There are no free floating forms of vegetation present, with only submergent and emergent forms of aquatic vegetation providing minimal coverage (Massey, 1998).

Salinity

Salinity is a major problem in the waterways of Zone 9 South, especially in Bogandillon Creek, which is located north of Lake Cowal. This system and its associated aquatic biota have experienced problems with salinity since the 1950s, which has resulted in the appearance of salt scalds, and a reduction in native riparian and aquatic vegetation (Driver *et al*, 2002).

Zone 9 (North): North eastern effluent/ephemeral channels

Habitat setting and aquatic species

Zone 9 North consists of unregulated ephemeral creeks and channels surrounded by semi arid rangelands. The landuse in this zone is dominated by agricultural practices, with grazing and irrigated crops occurring in the area. The zone takes in the Goobang catchment, which contains the tributaries of Goobang, Bumbuggan, Crooked and Gunningbland Creeks. The local vegetation types are dominated by eucalypt open woodland and eucalypt woodland.

Data from the NSW DPI Fishfiles database indicate that introduced fish species dominate the waterways of the zone, accounting for four of the five species present. Only one native species has been recorded in the zone, the gudgeon spp. This species however, dominated the fish abundance of the area. Fish stocking also occurs, including the release of native golden perch, Murray cod and silver perch fingerings.

Primary threatening processes in Zone 9 (North)

River regulation

The construction of weirs has had a significant impact on the waterways of Zone 9 North, especially Booberoi Creek. This system was originally a natural ephemeral anabranch of the Lachlan River, only receiving flows during high flow events (Terra Consulting, 2002). The construction of the Booberoi Weir and regulator has altered the natural flow regime of the creek, resulting in unseasonable flows and extensive siltation of the waterway. This siltation occurs downstream of the regulator where the flow is constricted and has resulted in the proliferation of cumbungi, which has increased the amount of trapped sediment. The accumulation of silt can impede flows and result in the loss of water that is released for stock and domestic purposes. This has resulted in the implementation of de-siltation works in Booberoi Creek to alleviate the problems associated with siltation.

Barriers to fish passage

A total of 14 licensed weirs were identified during the Initial Weir Review process for Zone 9 North, with four of these sites assessed during the review. These structures have the potential to interrupt natural flow regimes of waterways and impact upon the population of native fish, particularly through interrupting spawning or seasonal migrations, restricting access to preferred habitat and available food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of these structures on the smaller creeks restricts fish passage to important ephemeral habitats.

In addition to these weirs, other instream structures that may act as barriers to fish passage in the zone were assessed by NSW DPI as part of this project. The study examined three structures within the lower section of Zone 9 North including one bridge, one culvert and one weir, and found that only one of these structures, the weir, acted as a major barrier to fish passage.

Degradation of riparian zone

The riparian vegetation of Zone 9 North has been highly degraded with the majority of it in a poor condition (Massey, 1998). The majority of waterways have riparian zones that are narrow or absent, with native vegetation rare or absent and exotic species, such as willows, dominating. Floodplain based agricultural activities have had a significant impact on this condition, with farming practices and grazing evident at the top of the high bank.

Zone 10: Lake Brewster (10A), Lake Cargelligo (10B), Lake Cowal (10C), Nerang Cowal (10D)

Habitat setting and aquatic species

Lake Brewster (Zone 10A) and Lake Cargelligo (Zone 10B) are natural off-river lakes that have been modified to become the main water storages and flow regulating dams of the lower Lachlan catchment. Lake Cowal (Zone 10C) is an unregulated ephemeral waterway and the largest natural lake in the Lachlan catchment.

Zone 10A is a large off-river storage that is located midway between Lake Cargelligo and Hillston and is used to regulate upstream flows to the lower end of the river. Under current conditions, water is diverted by a fixed crest weir (Brewster Weir) along an inlet channel and into Lake Brewster, which has a maximum capacity of 153,000 ML, with an inlet channel capacity of 5,000 ML per day and an outlet capacity of 2,000 ML per day (Driver *et al*, 2002).

Lake Cargelligo (10B) was previously joined to the Lachlan River, however the construction of Lake Cargelligo Weir re-regulated flows from upstream reaches of the Lachlan River to the lower end of the river. The lake itself is a large off-river storage, which has a maximum capacity of 36,000 ML with an inflow capacity of 800 ML and an outflow capacity of 1,000 ML per day.

Lake Cowal is located within the Jemalong floodplain and contains both Lake Cowal (10C), which is the larger, deeper southern section, and Nerang Cowal (10D), the northern shallower portion (Diver *et al*, 2002). The lake receives water from local runoff from the Bland Creek catchment, as well as from overland flood flows from the Lachlan River. Receding water then flows back to the Lachlan River via Manna Creek and Nerang-Cowal.

Fish species expected to occur in the area include all of the 23 native species that are expected in the Lachlan catchment. Data from a study conducted by Kerezsy (2005) showed that native fish dominated the assemblage, accounting for nine out of the thirteen species present. The native western carp gudgeon dominated the abundance of all fish species present, whilst the introduced carp species had the second highest abundance (Kerezsy, 2005). Fish stocking has taken place in Lake Cargelligo (10B) and has included the native golden perch, Murray cod and silver perch.

Primary threatening processes in Zone 10

River regulation

Storing water in the lakes of management Zone 10 has the potential to reduce the water quality of the downstream waterways, including the Lachlan River. A study conducted by Thurtell *et al.* (2003) determined that discharged water from Lake Brewster (10A) had affected the water quality of downstream systems by increasing salinity, turbidity, nutrients and blue green algae.

Blue green algal blooms frequently occur in both Lake Brewster (10A) and Lake Cargelligo (10B), as well as their associated weir pools, particularly in summer drought conditions when temperatures are high and the lakes are shallow, turbid and eutrophic (Thurtell *et al*, 2003). These algal blooms have been known to be harmful to the health of the river ecosystems by reducing water quality and producing harmful toxins.

Barriers to fish passage

A total of three weir structures were identified in Zone 10 during the NSW Initial Weir Review study, with only one of these sites undergoing further investigation. These structures have the potential to interrupt natural flow regimes of waterways and impact upon the population of native fish, particularly through interrupting spawning or seasonal migrations, restricting access to preferred habitat and available food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of this structure on a major lake restricts fish passage to important ephemeral habitats.

Degradation of riparian zone

The riparian vegetation of Zone 10 is in a degraded condition, with the presence of Lippia causing a significant environmental problem along waterways and lakes, adding to the degradation of the riparian zone in the area (Earl, 2003). Lippia is widespread around Lake Cargelligo (10B) and Lake Cowal (10C), where its presence has increased soil erosion, leading to decreased bank stability, tree regeneration and an overall reduction in ecosystem diversity (Dellow *et al*, 2001; Earl, 2003).

Introduced fish species

Studies of the aquatic biota in Zone 10 indicate that introduced fish species are present in both the Lake Cargelligo and Lake Cowal systems. In these lakes, carp dominate the abundance of introduced fish species with their presence reflecting the poor condition of aquatic habitat in the area (Kerezsy, 2005). The establishment of introduced species reduces habitat and food resources available for native fishes, as well as impacts on native populations through predation, introduction of diseases, interference and disturbance of the instream environment.

Water pollution

Diffuse pollution has been recorded in Zone 10 during recent pesticide studies of the Lachlan catchment. During the study low level contamination of endosulfan, a pesticide used to control insect pests in cotton, fruit and vegetables, was detected in the waterways of Lake Brewster and Lake Cargelligo (Lloyd-Jones and Raisin, 2003). The presence of this chemical indicates that there is a risk to the health of the riverine environment, increasing the potential impact on aquatic biota (Lloyd-Jones, 1999; Lloyd-Jones and Raisin, 2003).

Salinity

Salinity is a major problem in the waterways upstream of Zone 10C, with extensive salt scalds appearing in Bogandillon Creek and the groundwater of this system moving south into Lake Cowal (Driver *et al*, 2002). Rising saline groundwater mounds from the Jemalong Plains Irrigation district are also a threat to the lake, with excess irrigation water from this district previously being channelled into Lake Cowal (Driver *et al*, 2002). This has reduced the condition of the aquatic environment, resulting in the reduction of riparian and aquatic vegetation (Driver *et al*, 2002).

Zone 11: Main channel Lachlan River from Hillston to Oxley

Habitat setting and aquatic species

Zone 11 is located in the lowland region of the Lachlan River and is characterised by flat plains with the occasional rocky outcrop. Landuse is dominated by grazing and broadacre crops, with the practice of these techniques affecting the environment. The local remnant vegetation types of the area are mainly comprised of eucalypt open woodland and eucalypt woodland, with grasslands, shrub lands, eucalypt open forest and river red gum forest also being present.

Information accessed from the NSW DPI Fishfiles database, which used data from studies conducted between 1994 and 2002, indicated that native fish dominate the assemblage present in the zone, accounting for four out of the seven species. The dominant species recorded was the native bony bream, comprising approximately 75% of the total fish species. Introduced fish, including carp and goldfish, were the next most abundant, however recreational fishing data suggests that the catch of carp in Zone 11 has decreased over the past four years (Park, unpublished). Fish stocking has occurred in the waterways, including the release of native golden perch and Murray cod fingerlings (Park, unpublished).

Primary threatening processes in Zone 11

River regulation

The cumulative impacts of river regulation are most evident in the lower reaches of the Lachlan, with waterways downstream of the dams and weir regulators receiving measured flows for irrigation purposes that are greatly altered from natural conditions. Regulation of the Lachlan River has resulted in a decrease in the duration of large spring floods (> 3,777 ML/day) and moderate floods (> 315 ML/day) at Booligal, whilst the occurrence of small floods (200 ML/day) has increased (Driver *et al*, 2002). The inundation of Booligal Swamp occurs approximately only half the time it did prior to river regulation and the condition of aquatic and riparian vegetation, as well as native fish populations that rely on seasonality, variability and frequency of high flows to complete their life cycles, has been significantly affected.

Barriers to fish passage

During the Initial Weir Review 15 licensed weirs structures were identified in Zone 11, with 12 of these sites assessed during the review. Three of these structures were further assessed during the Detailed Weir Review, demonstrating the significance of their potential impact on the catchment, which includes interrupting natural flow regimes of waterways and impacting upon the population of native fish (Fairfull and Witheridge, 2003). The location of these structures on the mainstem channel increases the impact on native fish by restricting fish passage to important seasonal and ephemeral habitats.

In addition to these weirs, other instream structures that may act as barriers to fish passage in the zone were assessed by NSW DPI as part of this project. The study examined 17 structures within Zone 11, which were dominated by bridges (13) and weirs (4), and found that all of the weir structures acted as major barriers to fish passage.

Degradation of riparian zone

The riparian vegetation of Zone 11 was in a degraded condition, with native vegetation cover being largely absent and the riparian zone dominated by the presence of exotic species such as willow and blackberry (Massey, 1998). The poor condition of the riparian zone has impacted on the aquatic vegetation in the area, which is also in a very poor condition. There are no submergent forms of vegetation present, and only limited numbers of both free floating and emergent species provide minimal coverage (Driver *et al*, 2002). Excess growth of cumbungi and lignum in Merrimajeel and Muggabah Creeks has substantially reduced the flows in these waterways, impeding stock and domestic water use (Driver *et al*, 2002).

Introduced fish species

Studies of the aquatic biota in Zone 11 indicate that introduced fish species are present in the waterways of the area, with carp and goldfish dominating the abundance of introduced fish present. The establishment of introduced species reduces habitat and food resources available for native fishes, as well as impacts on native populations through predation, introduction of diseases, interference and disturbance of the instream environment.

Water pollution

Diffuse pollution has been recorded in Zone 11 during recent pesticide studies of the Lachlan catchment. During the study low level contamination of endosulfan, a pesticide used to control insect pests in cotton, fruit and vegetables, was detected in the Lachlan River at Hillston (Lloyd-Jones and Raisin, 2003). The presence of this chemical indicates that there is a risk to the health of the riverine environment increasing the potential impact on aquatic biota (Lloyd-Jones, 1999; Lloyd-Jones and Raisin, 2003).

Zone 12: Great Cumbung Swamp (Oxley to Murrumbidgee junction)

Habitat setting and aquatic species

Zone 12 is marked by the Great Cumbung Swamp and includes the Baconian Swamp, as well as the terminal drainage swamp of the Lachlan River. The Great Cumbung Swamp is a large natural

wetland that developed where the river and its creeks terminate and spread out, covering an area of 50,000 ha (Roberts and Sainty, 1996; DLWC, 1998). The primary land use in the zone is grazing, however the region still remains in a relatively natural state (DLWC, 1998). The aquatic vegetation is dominated by common reed, with the surrounding floodplain area consisting of river red gum and black box. Large numbers of waterbirds, including the threatened Australian bittern (*Botaurus poiciloptilus*) and the freckled duck (*Stictonetta naevosa*), are supported by the Great Cumbung Swamp, with breeding occurring after flood events (DLWC, 1998).

Data from the NSW DPI Fishfiles database, which used information from studies conducted between 2000 and 2002, show that introduced fish species dominate the assemblage of fish found in Zone 12, accounting for three of the five species. These species were dominated by the presence of gambusia, which were the most abundant overall, whilst the native species present were dominated by gudgeons. There are no records of fish being stocked into Zone 12.

Primary threatening processes in Zone 12

River regulation

The construction of weirs and associated infrastructure has had a significant impact on the aquatic environment of Zone 12. Upstream weirs and regulators have altered the natural flow regime of the waterways that enter the Great Cumbung Swamp, resulting in unseasonable flows and inundation of the wetland. The IQQM model has determined that less water now enters the lower end of the Lachlan catchment (at Oxley) than in times prior to river regulation. This has resulted in reduced annual flow in the area, which is approximately 53% that of unregulated flows, and restricted the inundation of the area, with the wetland now being full only 62% of the time that it would have been before river regulation (DLWC, 1998; Driver *et al*, 2002).

Degradation of riparian zone

The riparian vegetation of Zone 12 is in a degraded condition, with a noticeable reduction in the abundance of native river red gums and common reed. The reduction in native vegetation has corresponded with an increase in the abundance of cumbungi, which can act as a weed species in high abundances and significantly impact on the natural condition of the aquatic habitat (Driver *et al*, 2002). The presence of this species can alter flow regimes of waterways and contribute to increased soil erosion, reduced bank stability and an overall reduction in ecosystem diversity within the zone (Dellow *et al*, 2001; Earl, 2003).

Introduced fish species

Studies of the fish assemblage in Zone 12 indicate that introduced fish species are present in the waterways of the area, with gambusia and carp dominating the abundance of introduced fish present. The establishment of introduced species reduces habitat and food resources available for native fishes, as well as impacts on native populations through predation, introduction of diseases, interference and disturbance of the instream environment. This impact is evident in Zone 12, with only two of the 23 native fish species expected to occur in the area recorded in recent years.

Zone 13: Western effluent Creeks (Willandra, Moolbang, and Merrowie)

Habitat setting and aquatic species

Zone 13 includes the three main effluent creeks of Willandra, Moolbang and Merrowie. These waterways transport flow away from the main channel of the Lachlan River, acting as a distributary network. The flow within these channels is reduced as the water moves in a downstream direction, and the creeks become largely ephemeral with infrequent flows. The land in this region is flat and consists of sparse vegetation dominated by grasslands, as well as eucalypt open woodland and cypress pine forest (DLWC, 1998). The vegetation in the area has been impacted on by the agricultural practices associated with grazing and broad acre cropping (DLWC, 1998).

Data from the NSW DPI Fishfiles database, which used information from studies conducted between 2001 and 2002, show that the fish assemblage in Zone 13 is dominated by introduced fish species, which represent four out of the seven species present. The introduced species are dominated by the presence of goldfish and gambusia, however the native bony bream species dominates the overall abundance of fish species located within Zone 13.

Primary threatening processes in Zone 13

Barriers to fish passage

A total of 32 weir structures were identified in Zone 13 during the NSW Initial Weir Review study, with 24 of these sites undergoing further investigation. These structures have the potential to interrupt natural flow regimes of waterways and impact upon the population of native fish, particularly through interrupting spawning or seasonal migrations, restricting access to preferred habitat and available food resources, and fragmenting previously continuous communities (Fairfull and Witheridge, 2003). The location of these structures on effluent waterways restricts fish passage to important seasonal and ephemeral habitats.

In addition to these weirs, other instream structures that may act as barriers to fish passage in the zone were assessed by NSW DPI as part of this project. The study examined seven structures within Zone 13, including four culverts, two bridges and one ford, and found that five of these structures acted as a barrier to fish passage. These barriers were dominated by culverts (4), with the ford also identified as a barrier to fish passage.

Degradation of riparian zone

The condition of riparian vegetation along the waterways of Zone 13 is reasonably degraded. Vegetation in this area exits along narrow riparian zones or does not exist at all, with a complete lack of riparian vegetation along both banks common in many areas (Driver *et al*, 2002). The poor condition of riparian vegetation is a result of increased agricultural and erosion pressures, which has been caused by an increase in flow, the feeding activities of carp and the dominance of aquatic weed species (Driver *et al*, 2002).

Degradation of instream habitat

The aquatic habitat of Zone 13 is in a degraded state, with the majority of habitat and vegetation present being in a poor condition (Massey, 1998). The majority of waterways in the area contain very little substrate material diversity, with organic debris including leaves, twigs, snags, tree roots and branches, predominantly absent in these areas (Massey, 1998). Aquatic vegetation in this region is significantly degraded, with only three species of submerged vegetation present at low number of sites within the zone (Massey, 1998).

Water pollution

Diffuse pollution has been recorded in Zone 13 during recent pesticide studies of the Lachlan catchment. During the study, low level contamination of endosulfan, a pesticide used to control insect pests in cotton, fruit and vegetables, was detected in Willandra and Merrowie Creeks (Lloyd-Jones and Raisin, 2003). Chloropyrifos, an insecticide used to control insects in soil, was also detected in samples from Willandra Creek (Lloyd-Jones and Raisin, 2003). This chemical readily binds with soil particles and may reach the aquatic environment by spray drift or runoff. The presence of these chemicals indicates that there is a risk to the health of the riverine environment increasing the impact on aquatic biota (Lloyd-Jones, 1999; Lloyd-Jones and Raisin, 2003).

Appendix E – Habitat assessment sites in the lower Lachlan

Site Number	Site Name	Management Zone	Waterway	Map Name	Latitude	Longitude
1	Geramy	12	Lachlan River	Oxley	-34.2495	144.0735
2	Braebuck Woolshed	11	Lachlan River	Oxley	-34.2345	144.2444
3	Corrong	11	Lachlan River	Oxley	-34.2219	144.4532
4	Erin Station	11	Lachlan River	One Tree	-34.1644	144.5536
5	Ulonga	11	Lachlan River	One Tree	-34.0877	144.6393
6	Wheelba Bridge	11	Lachlan River	Muckerumba	-33.6525	145.2540
7	Hillston	11	Lachlan River	Hillston	-33.4838	145.5297
8	Moora Farm	8	Lachlan River	Hillston	-33.3707	145.6541
9	Kidman	8	Willandra Creek	Hillston	-33.3274	145.8310
10	Maryabba	8	Lachlan River	Cargelligo	-33.3448	146.0747
11	Gunniguldrie	8	Lachlan River	Cargelligo	-33.2639	146.1131
12	Poplars	8	Lachlan River	Cargelligo	-33.2206	146.4151
13	Euabalong	8	Lachlan River	Cargelligo	-33.1595	146.4670
14	Euabalong Bridge	8	Lachlan River	Cargelligo	-33.1108	146.4758
15	Marigold	8	Lachlan River	Tullibigeal	-33.0848	146.9282
16	Condobolin	8	Lachlan River	Condobolin	-33.0947	147.1521
17	Lake Waljeers	11	Lake Waljeers	One Tree	-34.0664	144.6594
18	Merrowie (Cobb Highway)	13	Merrowie Creek	Booligal	-33.6723	144.8162
19	Merrowie (Roeta Road)	13	Merrowie Creek	Willandra	-33.5600	145.1206
20	Mossgiel	13	Willandra Creek	Mossgiel	-33.1783	144.5653
21	Willandra National Park	13	Willandra Creek	Mossgiel	-33.1774	144.9686
22	Roto	13	Willandra Creek	Willandra	-33.2028	145.4818
23	Merrowie (Roto Road)	13	Merrowie Creek	Hillston	-33.3561	145.5544
24	Booberoi East Creek	8	Booberoi Creek	Tullibigeal	-33.0491	146.6251
25	Koobothery	8	Wallaroi Creek	Tullibigeal	-33.0956	146.8349
26	Wallamundary	9S	Wallamundary Creek	Condobolin	-33.1669	147.1383
27	Blue Range	9S	Wallaroi Creek	Condobolin	-33.2093	147.1008

Appendix F – Lower Lachlan fish passage barrier assessment form

LACHLAN WATERWAYS FISH PASSAGE - DESKTOP ASSESSMENT FORM

ASSESSOR: _____ **DATE:** _____ **CROSSING ID:** _____

CATCHMENT: _____ **WATERWAY:** _____

STREAM ORDER: _____ **ELEVATION:** _____ **LGA:** _____

1. LOCATION INFORMATION

1a Location

Nearest Town: _____ Road Name (or Nearest Road): _____

1b Section of Catchment *(please circle)***:** Upper Middle Lower

1c Approximate upstream catchment area (sqkm) _____

2. FISH BARRIER IMPACTS

2a. Fish Barrier Type *(circle)*

Bridge - single or multiple span or arched structure raised above channel bed.
Culvert - cell to convey water underneath roadway: **Pipe / Box**
Weir - instream structure designed to back water upstream: **Fixed Crest / Adjustable Release**
Causeway - low-level crossing designed to convey water over roadway surface
Ford - low level crossing formed directly on channel bed in a shallow section of a watercourse.
Floodgate - gated levee to regulate flow between floodplain and stream channel.
Other

2b If barrier blocks fish passage, approximately how much habitat upstream would become available if crossing was modified to allow for fish passage _____km

2c Approximate distance to the next potential obstruction to fish passage:

Upstream _____km Downstream _____km

Is it Natural / Man-made? **Is it Natural / Man-made?**

3. OWNERSHIP DETAILS

3a Ownership of this obstruction & land on which the structure lies *(circle)*:

Federal State Local Government Private Landholder

3b Owner of the next potential obstruction *(circle)*:

Upstream:	Federal	State	Local Government	Private Landholder
Downstream:	Federal	State	Local Government	Private Landholder

4. ENVIRONMENTAL CONSIDERATIONS

4a Threatened and protected aquatic species present *(circle)*:

Olive perchlet Eastern freshwater cod Purple spotted gudgeon Oxleyan pygmy perch

Macquarie perch Australian grayling Black cod Estuary cod

4b. Other key aquatic species present: _____

Also attach predicted species list for catchment from "Fishfiles" or "Freshwater Fish Database".

4c. Environmental status: _____

Consider terrestrial threatened species, critical habitat, conservation rating and protected area status.

Appendix F – Lower Lachlan fish passage barrier assessment form

LACHLAN WATERWAYS FISH PASSAGE - FIELD ASSESSMENT FORM

ASSESSOR: _____ **DATE:** _____ **CROSSING ID:** _____
GPS or GRID ref: _____ **PHOTO NUMBERS:** _____

1. LOCATION INFORMATION
1a Surrounding Land Uses *(please circle)***:**
Industrial Urban Park Forested Grazing Cropping
Description of land use _____

1b Structure Accessibility (Easement / Public Road / Other_____)

2. STRUCTURE DETAILS
2a Structure Description
Culvert type No. of cells Size of cells Width ____ m Breadth ____m Height ____m
Construction material *(circle)*: Concrete / Timber / Steel / Rock / Gravel / Sand-Fines

2b If a Road – Is it Sealed? *(circle)*: Sealed Unsealed N/A **Is it in Use?** Yes / No

3. FISH BARRIER IMPACTS
3a Is there a fishway? Yes / No **Type:** _____ **Working?** Yes / No

3b Fish Passage: Does the site potentially or actually block fish passage? Yes / No

3c If yes, what type of blockage *(circle)*:
Drop (>10cm) Increased Velocity Minimal Flow Depth (< 200mm) Lack of Light
Slope (>1:20) Increased Turbulence Debris (large woody / sediment)

3d If yes, is it *(circle)*: a complete barrier / major obstacle / moderate obstacle / minor obstacle

3e Does water exist upstream of the site: Yes / No **If yes, is it due to the structure?** Yes / No
If yes, what is the **average length** of pool _____m and **depth** of the pool _____m

3f Is there flow over/through the site: Yes / No

3g If yes, what is the water flow like? *(circle)*
Vertical Fall (**Height**____m) Steep Cascade High Velocity through Pipe Low flow
Gentle Incline Moderate Cascade Moderate Velocity through Pipe No flow

3h If location of the next obstruction is not the one identified in the desktop study please record the new location (GPS or road name): Upstream: _____
Downstream: _____ **Ownership:** _____

4. HABITAT DETAILS
4a Bank Height at crossing _____m **4b Channel Width at crossing** _____m

4c Habitat features: (substrate type: pools, riffles, gravel beds, macrophytes, snags, overhangs)

4d Condition of aquatic habitat *(circle)*: excellent good fair poor very poor

5. COMMENTS (EXTRA SITE / STRUCTURE INFO)

6. RECOMMENDATIONS

Appendix G – Fish passage prioritisation scheme (Lower Lachlan catchment)

CROSSING ID: _____ ___ZONE: _____ WATERWAY: _____TOWN: _____ASSESSOR:_____

A) STREAM HABITAT VALUE CRITERIA						
Primary Aquatic Habitat Rating						**SCORE**
Habitat Class		1	2	3	4	
Location in the System		Lower (< 300m)		Middle (300 – 700m)		
Secondary Aquatic Habitat Rating						
Downstream Obstructions		Few (< 5)	Moderate (5 –20)	Many (> 20)		
Distance to next Barrier Downstream		Greater than 40km	5 – 40km	Less than 5km		
Upstream Habitat		Abundant (> 40km)	Moderate (5 – 40km)	Limited (< 5km)		
Instream Habitat Condition		Good	Fair	Poor		
					SUBTOTAL	
B) STRUCTURE IMPACT CRITERIA						
Environmental Effect Rating						**SCORE**
Physical Barrier	Vertical Drop OR Slope	> 2500mm OR > 1:10	1500 – 2500mm OR 1:10 – 1:20	500 – 1500mm OR 1:10 – 1:20	200 – 500mm OR < 1:20	
	Debris	Present		Absent		
Hydrological Barrier	Velocity	High	Medium	Low		
	Flow Depth	< 100mm	100 – 200mm	> 200mm		
Light Penetration & Substrate Condition		High Behavioural Impact	Medium Behavioural Impact	Low Behavioural Impact		
					SUBTOTAL	
C) MODIFICATION CRITERIA						
Structure Use and Remediation Cost Rating						**SCORE**
Structure Use		Redundant		Essential		
Remediation Works Required		Minor changes (Maintenance)	Moderate changes (Retrofitting or Removal)	Major changes (Complete replacement of small structure)	Major changes (Complete replacement of large structure)	
					SUBTOTAL	
ID'D BY:	SECONDARY NAME:				**TOTAL**	

Appendix H – Raw data for the habitat assessment of the lower Lachlan

Zone	Site	Habitat Parameter IFV (%)								
		Fish Assemblage			Aquatic Vegetation	Riparian Vegetation				LWD
		LBN	SBN	Introduced		Full	Partial	None	Willow	
8	8*	2.08	43.75	54.17	4.37	96	4	0	0	45.34
	9	0	95.90	4.10	46.95	86.45	11.38	2.17	0	6.15
	10*	0.72	85.61	13.67	9.03	46	51	3	0	22.38
	11*	0.62	84.82	14.56	0	46	48	6	0	19.42
	12*	1.01	93.94	5.05	22.36	93	7	0	0	29.89
	13*	0	75.86	24.14	8.84	90	9	1	0	16.50
	14*	2.03	82.60	15.37	2.96	60	34	6	0	24.89
	15*	14.29	45.24	40.48	2.26	77	21	0	2	9.59
	16*	0	16.67	83.33	0.36	16	59	10	15	7.05
	24	0	16.67	83.33	92.67	93	3	4	0	3.18
	25	0	0	100	7.25	45	43	12	0	15.09
9 South	26	0	0	100	32.93	45	43	12	0	49.51
	27	0.97	0.97	98.06	96.44	45	43	12	0	2.82
11	2*	1.86	59.63	38.51	2.44	100	0	0	0	65.61
	3*	0	63	37	40.6	79	11	10	0	9.30
	4	-	-	-	-	-	-	-	-	-
	5*	0	65.19	34.81	12.03	85	13	2	0	19.44
	6*	3.19	45.10	51.71	8.79	69	29	2	0	33.68
	7*	0	98.20	1.80	8.94	61	38	1	0	18.02
	17	0	0	100	0	92	8	0	0	0
12	1*	0	2.45	97.55	65.05	23.14	31.90	44.96	0	0.12
13	18	0	0	0	22.18	44	51	5	0	10.57
	19	0	0	0	36.05	100	0	0	0	11.29
	20	0	0	100	45.54	14.84	51.80	33.36	0	0.04
	21	0	5.08	94.92	49.99	97	3	0	0	3.20
	22	0	93.18	6.82	86.04	83	11	6	0	0.07
	23	0	0	100	1.84	82	15	3	0	3.87

Note: * denotes site located on mainstem of Lachlan River.

Appendix H – Raw data for the habitat assessment of the lower Lachlan

Zone	Site	Aquatic Vegetation Species													
		Cumbungi	Noogoora Burr	Phragmites	Water Milfoil	Lignum	Pondweed	Pale Knotweed	Spike Rush	Water Primrose	Sand	Ribbon Weed	Canegrass	Sedge	Ranunculus
8	8*	0.199	0.150	0.000	0.000	0.000	0.000	1.862	0.667	0.000	1.496	0.000	0.000	0.000	0.000
	9	0.00	6.86	0.00	0.00	0.00	0.00	37.00	0.00	0.00	0.00	0.00	0.00	1.19	1.90
	10*	0.000	1.232	0.000	4.275	0.000	0.000	2.494	1.028	0.000	0.000	0.000	0.000	0.000	0.000
	11*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	12*	0.000	0.000	0.000	22.361	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	13*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.842	0.000	0.000	0.000	0.000	0.000	0.000
	14*	0.000	0.635	0.000	0.000	0.000	0.000	0.000	1.481	0.000	0.845	0.000	0.000	0.000	0.000
	15*	0.000	0.000	1.053	0.000	0.000	0.000	0.000	0.367	0.000	0.556	0.286	0.000	0.000	0.000
	16*	0.355	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	24	20.264	6.507	15.437	6.426	1.837	7.918	21.894	3.385	0.000	0.332	0.000	0.000	8.668	0.000
	25	5.025	0.000	0.000	0.000	0.000	0.000	0.601	0.000	0.000	0.000	0.000	0.000	1.623	0.000
9 South	26	28.135	0.00	0.00	0.00	0.00	0.00	0.00	1.985	1.790	0.00	0.00	0.00	1.019	
	27	91.300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.136	0.00	0.00	0.00	0.00	0.00
11	2*	0.00	0.00	0.00	0.00	0.982	0.00	1.455	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3*	25.953	0.00	0.00	0.00	0.00	0.00	2.338	4.674	7.602	0.00	0.00	0.00	0.00	0.00
	4*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	5*	0.00	0.00	0.00	0.00	9.487	0.00	1.231	1.093	0.221	0.00	0.00	0.00	0.00	0.00
	6*	0.00	1.337	0.00	0.00	0.00	0.00	6.850	0.00	0.605	0.00	0.00	0.00	0.00	0.00
	7*	2.195	0.00	0.646	0.617	0.00	0.00	0.00	3.343	1.496	0.00	0.00	0.647	0.00	0.00
	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	1*	7.67	0.76	56.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	18	0.00	0.00	0.00	0.00	22.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	19	0.00	0.00	0.00	0.00	36.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20	0.00	0.00	0.00	0.00	45.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	21	32.71	0.18	0.09	0.00	2.09	0.00	0.00	14.92	0.00	0.00	0.00	0.00	0.00	0.00
	22	57.70	26.58	0.00	0.00	0.00	0.00	0.00	1.76	0.00	0.00	0.00	0.00	0.00	0.00
	23	0.00	0.00	0.00	0.00	1.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Note: * denotes site located on mainstem of Lachlan River.															

Appendix I – Habitat assessment of the lower Lachlan

Zone 8: Main channel Lachlan River from Bedgerebong to Hillston

Site 8: Lachlan River at Moora Farm

Site 8 contained a large number of snags and sedimentation deposits, with restricted water flow during the time of sampling. Riparian vegetation was in good condition with an intact understorey, whilst the instream habitat had minimal aquatic vegetation.

Habitat mapping results consisted of good riparian vegetation cover, with 96% being full and 4% being partial vegetation. Instream habitat covered 50% of the area, and consisted of 45% large woody debris. Fish survey results consisted of 54% introduced fish species, dominated by carp and redfin, 44% small bodied natives, including Australian smelt and bony bream, and 2% large bodied natives, dominated by golden perch.

Site 8 appeared to be in a reasonable condition, consisting of good riparian vegetation and instream habitat that covered a significant proportion of the reach area and consisted of numerous snags. Native fish were present at the site, but introduced species were dominant.

Site 9: Willandra Creek at Kidman

Observations for Site 9 included the presence of some snags and reasonable riparian cover, although the understorey was in a severely depleted condition. The water was shallow and infested with weeds that were dominated by noogoora burr and slender knotweed.

Results of habitat mapping showed that 87% of the riparian zone had full cover, 11% had partial cover and 2% possessed no riparian vegetation. Instream habitat covered 53% of the area and consisted of 37% pale knotweed, 6.8% noogoora burr, 1.9% Ranunculus and 1.2% sedge, as well as 6.1% woody debris. Fish survey results for the site showed that 96% of the fish assemblage was dominated by small bodied natives (Australian smelt, bony bream and gudgeons), with 4% accounted for by introduced fish species (carp, goldfish and redfin). No large bodied native species were recorded.

Site 9 appeared to be in a reasonable condition, with good riparian vegetation and instream habitat, although the presence of noogoora burr at this site could be detrimental to the aquatic environment. The results of fish surveys showed a dominance of native species, although no large bodied native fish were present.

Site 10: Lachlan River at Maryabba

Site 10 possessed reasonable riparian vegetation, with young acacias and some understorey present. There was little water flow in the Lachlan River at the time of sampling and the instream habitat possessed deep holes, with lots of snags and some aquatic vegetation.

Habitat mapping results showed that the riparian vegetation consisted of 51% partial cover, 46% full cover and 3% no vegetation. Instream habitat covered 31% of the reach area and consisted of 22.4% woody debris, as well as water milfoil (4.3%), pale knotweed (2.5%), noogoora burr (1.23%), and common spike rush (1.03%). Fish surveys were dominated by natives, consisting of 85% small bodied (Australian smelt, bony bream and gudgeons), 14% introduced species (carp, goldfish and redfin) and 1% large natives (Murray cod).

Site 10 appeared to be in a reasonable condition, with riparian vegetation possessing a reasonably intact understorey, and instream habitat containing a good proportion of snags and aquatic vegetation. There was also a dominance of native fish species, including the presence of Murray cod.

Site 11: Lachlan River at Gunniguldrie-Horseshoe Bend

Habitat mapping results for Site 11 indicated that the riparian vegetation was in a moderate condition, with 48% partial cover, 46% full cover and 6% no riparian vegetation. Instream habitat comprised 19% coverage of woody debris, with aquatic vegetation absent at this site.

Fish survey results were dominated by the presence of native species, comprised of 85% small bodied natives (Australian smelt and bony bream), 14% introduced fish species (carp and redfin) and 1% large bodied natives (golden perch).

Site 11 appeared to be in a moderate to poor condition, with the presence of a sand slug, moderate riparian cover, no understorey and no aquatic vegetation affecting the aquatic environment. Instream habitat contained a good proportion of woody debris and the fish survey results possessed larger abundances of natives, enhancing the health of the reach.

Site 12: Lachlan River at Poplars

Site 12 was observed to contain a large abundance of milfoil and a significant number of snags. There was no visible water flow in the Lachlan River during sampling and the riparian vegetation was in a reasonable condition, however, there was virtually no understorey with the banks of the river being mostly bare.

Habitat mapping of the reach showed that the riparian zone consisted of 93% full cover and 7% partial vegetation. Instream habitat covered 52% of the reach area, comprising 30% woody debris and 22% milfoil. Fish survey results were dominated by native species, with small bodied natives comprising 94% (Australian smelt, bony bream and gudgeons), 5% introduced species (carp and gambusia) and 1% large bodied natives (golden perch).

Site 12 appeared to be in reasonable condition, possessing good riparian vegetation and reasonable instream habitat with a substantial amount of woody debris and aquatic vegetation. Fish species in the reach were dominated by small bodied natives.

Site 13: Lachlan River at Euabalong Station

Site 13 displayed very limited aquatic vegetation and moderate riparian vegetation with no understorey. Feral goats were observed at the site, which may have contributed to the reduction in riparian diversity within the understorey.

Habitat mapping results included riparian vegetation with 90% full cover, 9% partial cover and 1% no riparian vegetation. Instream habitat covered 25% of the reach area and was comprised of 16% woody debris and 9% common spikerush. The fish survey results showed that small bodied natives, dominated by Australian smelt, bony bream and gudgeons, had the largest abundance (76%), whilst introduced species such as carp and gambusia contributed 24%, with no large bodied natives recorded.

Site 13 appeared to be in a reasonable condition, possessing good riparian vegetation and a reasonable coverage of snags, however there was a lack of aquatic vegetation at this site. Small bodied native fish dominated the abundance of fish this reach during the study.

Site 14: Lachlan River at Euabalong Bridge

Habitat mapping results for Site 14 indicate that the riparian vegetation was in a good condition, with 60% full cover, 34% partial cover and 6% no vegetation. Instream habitat covered 28% of the reach and was comprised of 25% woody debris, 1.5% common spikerush, 0.8% sand and 0.6% noogoora burr. The fish survey results showed that native fish dominated the abundance of fish species present, with small bodied natives such as Australian smelt and bony bream accounting for 83%, whilst 15% were introduced species (carp and redfin) and 2% were large bodied natives (Murray cod and golden perch).

Site 14 appeared to be in a reasonable condition, with riparian vegetation dominated by full or partial coverage and aquatic habitat possessing a large proportion of woody debris. Small bodied native fish dominated the fish assemblage, with large bodied natives also present.

Site 15: Lachlan River at Marigold

Results from habitat mapping indicated that the riparian vegetation was in a good condition, with 77% of the area comprising full vegetation, 21% containing partial vegetation and 2% made up of willows. The instream habitat of Site 15 covered 12% of the reach, consisting of

9.6% woody debris, 1.05% phragmites, 0.6% sand, 0.4% common spike rush, and 0.3% ribbon weed. The fish survey results showed that 45% of the abundance consisted of small bodied natives (Australian smelt), 40.5% introduced species (carp and goldfish) and 14% large bodied natives (Murray cod and golden perch).

Site 15 appeared to be in a reasonable condition, containing good riparian vegetation and a reasonable proportion of aquatic habitat. The aquatic habitat contained three plant species, including a small proportion of ribbon weed, which was not found at other sites. Site 15 was dominated by small bodied natives and also contained the largest proportion of large bodied natives, with three Murray cod and one golden perch recorded during one sampling occasion.

Site 16: Lachlan River at Condobolin

Site 16 was observed to be very degraded, with poor riparian vegetation dominated by willows and consisting of no understorey. There was very little aquatic vegetation, with only a few small snags and the flow was very slow with only a few deep pools observed.
Results from habitat mapping indicated that the riparian zone possessed 59% partial cover, 16% full, 15% willows and 10% no vegetation. Instream habitat covered 7.4% of the reach and comprised 7.05% woody debris and 0.35% cumbungi. Fish survey results showed that introduced species (carp and goldfish) dominated the site, accounting for 83% of species within the reach, whilst only 17% of small bodied natives (Australian smelt) were recorded.

Site 16 appeared to be in a highly degraded condition, possessing small proportions of full riparian vegetation and instream habitat. The reach had a fish species composition and abundance that was dominated by introduced species, with no large bodied natives present.

Site 24: Booberoi Creek East

Site 24 was observed as having good riparian vegetation, with little understorey. Minimal flow was also observed during the study, with significant amounts of aquatic vegetation present, including the exotic noogoora burr and slender knotweed.

The habitat mapping results for the site showed that the riparian vegetation was dominated by 93% full cover, 4% no riparian vegetation and 3% partial cover. Aquatic habitat at Site 24 covered 96% of the reach area and was comprised of nine aquatic vegetation species including pale knotweed (21.9%), cumbungi (20.3%), phragmites (15.4%), sedge (8.7%), pondweed (7.9%), noogoora burr (6.5%), water milfoil (6.4%), common spikerush (3.4%) and lignum (1.8%), as well as 3.2% woody debris and 0.33% sand. Fish survey results showed that 83% of the fish species present were introduced (carp, goldfish and gambusia) and 17% were small bodied natives (gudgeons).

Site 24 appeared to be in a reasonable condition with a significant cover of riparian vegetation and a variety of aquatic plants. However, the plant species comprised a significant proportion of phragmites and cumbungi, which can act as pest species when present in large dense stands by choking streams (Sainty and Jacobs, 1981; Massey, 1998). The dominance of introduced fish species at this site also indicates that aquatic conditions are poor for native fish, particularly large bodied species that were completely absent.

Site 25: Wallaroi Creek at Koobothery

Site 25 was observed to be dry during the study, possessing limited aquatic vegetation and woody debris, as well as no understorey in the riparian vegetation.

Habitat mapping results showed that the riparian zone had 45% full cover, 43% partial cover and 12% no vegetation. Aquatic habitat in Site 25 covered 22% of the area and was comprised of 15.1% woody debris, 5% cumbungi, 1.6% sedge and 0.6% pale knotweed. Fish survey results indicated that the assemblage of fish at this site was dominated by introduced species, including carp, goldfish and redfin, which comprised 100% of the species.

Site 25 appeared to be in a very poor condition, possessing less than 50% full riparian vegetation and minimal aquatic vegetation. The reduced quality of habitat at the site is reflected in fish survey results, which has a complete absence of natives.

Zone 9 (South): South eastern effluent/ephemeral channels

Site 26: Wallamundary Creek at Condobolin

Site 26 contained two weirs (412/80175/B0093), the first of which was a fixed crest structure that is 15 m across the crest length and 1.5 m in vertical height. The second weir (412/80175/B0095), downstream of the first, was broken and unused and did not appear to have major adverse affects on water flow or aquatic health. Above the first weir the flow was very low and cumbungi dominated the aquatic habitat, significantly affecting the flow. The large stands of cumbungi were not seen in the faster flowing areas below the weir.

Habitat mapping results for Site 26 showed that the riparian vegetation was dominated by 45% full cover, 43% partial cover and 12% without vegetation. Aquatic habitat covered 82% of the reach area and was comprised of 49.5% woody debris, 28% cumbungi, 2% common spikerush and water primrose, and 1% sedge. Fish survey results for the site showed that the area was completely dominated by introduced fish, with the fish assemblage represented by 100% of these species, including carp and goldfish.
Site 26 was in a poor condition, with the presence of weirs and subsequent impediment to water flow contributing significantly to this condition. This environment promoted the growth of cumbungi, which has reduced the quality of aquatic habitat and is reflected by the dominance of introduced species in the assemblage of fish at the site.

Site 27: Wallaroi Creek at Blue Range

Site 27 included a low road crossing (LL01), which had stopped flows within Wallaroi Creek at the site and created conditions suitable for significant abundances of cumbungi.

Habitat mapping results for the site indicated that the riparian zone consisted of 45% full vegetation, 43% partial vegetation and 12% no vegetation. The aquatic habitat in the reach covered 99% of the area and was comprised of 91% cumbungi, 5% water primrose and 3% woody debris. The fish survey results showed that the site is dominated by introduced fish species including carp, goldfish, gambusia and redfin (98%), with only 1% of small bodied natives (flathead gudgeon) and 1% of large bodied natives (freshwater catfish) recorded in the fish assemblage at Site 27.

Site 27 was in a poor condition, with the riparian zone possessing less than 50% full riparian vegetation and aquatic vegetation dominated by large dense stands of cumbungi. This condition is reflected in the dominance of introduced fish species, with only 2% of the fish present being native.

Zone 11: Main channel Lachlan River from Hillston to Oxley

Site 2: Lachlan River at Braebuck Woolshed

It was noted that a weir was present at Site 2, with water pooling downstream from it. The site contained riparian vegetation in good condition but with no understorey, and a significant number of snags were present, with limited aquatic vegetation.

Habitat mapping results for the reach showed that 100% of the area had riparian vegetation in full cover. Instream habitat covered 68% of the reach area and was comprised of 66% woody debris, 1.5% pale knotweed and 1% lignum. The fish survey results showed the area was dominated by small bodied natives (Australian smelt and bony bream), which accounted for 59.6% of the fish assemblage. Introduced fish species (carp, goldfish and redfin) were also present, with 38.5% of the assemblage, and large bodied natives (golden perch) were recorded at the site, contributing 2% to the fish assemblage.

Site 2 appeared to be in a healthy condition, possessing good riparian cover, a high proportion of large woody debris and a greater proportion of native fish species than introduced species, including one large bodied native species.

Site 3: Lachlan River at Corrong

The channel of Site 3 was very narrow and contained shallow depths of approximately 0.5 m, with deeper pools present around woody debris. The waterway contained significant amounts of aquatic vegetation and also had riparian vegetation that was in good condition, however the understorey was reduced due to stock grazing.

Habitat mapping results for the reach showed that the area had good riparian vegetation with 79% full cover, 11% partial cover and 10% without vegetation. The instream habitat covered 50% of the reach area and comprised a variety of vegetation including 26% cumbungi, 8% water primrose, 5% common spikerush and 2% pale knotweed, with woody debris also present and accounting for 9% of the habitat. Fish species composition was dominated by 63% small bodied natives (Australian smelt and bony bream), with introduced species (carp, goldfish and redfin) contributing 37% to the assemblage. There were no large bodied native species recorded at the site.

Site 3 appeared to be in a reasonable condition, possessing significant stands of riparian vegetation, as well as instream habitat, although there were large amounts of cumbungi present, which can form dense stands and reduce water flow (Sainty and Jacobs, 1981; Massey, 1998). The proportion of native fishes was higher than introduced species, however there was a lack of large bodied natives at the site.

Site 5: Lachlan River at Ulonga

Site 5 was observed to be in a moderate condition, possessing good aquatic vegetation with significant amounts of large woody debris. A large pump for water extraction was located at this site, impacting on the aquatic environment of the reach.

Results from habitat mapping indicated that Site 5 had good riparian vegetation, with 85% full cover, 13% partial cover and 2% with no vegetation. Instream habitat covered 32% of the area, with 19% of this cover provided by large woody debris, 9.5% lignum, 1% common spikerush, 1% pale knotweed and 0.2% water primrose. Fish species at the site were dominated by 65% small bodied natives (Australian smelt and bony bream), with 35% introduced fish species (carp, goldfish and redfin perch) also recorded. No large bodied native fishes were recorded at this site.

Site 5 appeared to be in a reasonable condition with respect to riparian vegetation and instream habitat. This condition is reflected in the proportion of small bodied native fishes to introduced fishes, however no large bodied native fish species were recorded.

Site 6: Lachlan River at Wheelba Bridge

Site 6, which was located downstream of Tallawanta Weir, had restricted flow, with a large number of carp evident during fieldwork. The riparian vegetation of the reach contained no understorey and the instream habitat had a low number of pools.

Results of habitat mapping showed that riparian vegetation of the reach was in a good condition, with 69% of the riparian zone containing full cover, 29% partial cover and 2% without vegetation. Instream habitat covered 42.5% of the reach area and was comprised of 34% large woody debris, 7% pale knotweed, 1.3% noogoora burr and 0.6% water primrose. Introduced fish species (carp, goldfish and redfin perch) dominated the fish assemblage at the site, contributing 52% to the assemblage, whilst small bodied natives (Australian smelt, bony bream and gudgeon) entailed 45% and large bodied natives (golden perch) contributed 3%.

Site 6 appeared to be in reasonable condition, with moderate riparian vegetation, moderate instream habitat and a reasonable proportion of native fishes, including the presence of one large bodied native species. Potential threats to the site include the presence of the exotic noogoora burr, as well as the dominance of the introduced carp species.

Site 7: Lachlan River at Hillston Weir

Site 7 was observed to contain a large weir pool and possessed a significant number of willows. The riparian vegetation also had a reasonable understorey, whilst the instream habitat possessed a moderate coverage of aquatic vegetation and large woody debris.

Habitat mapping results indicated that the riparian vegetation was in a reasonable condition, with 61% full cover, 38% partial cover and 1% without vegetation. Instream habitat covered 27% of the reach area and was comprised of 18% woody debris, common spike rush (3.3%), cumbungi (2.2%), water primrose (1.5%), cane grass (0.6%), phragmites (0.6%) and water milfoil (0.6%). Fish survey results showed that the majority of fish present at the site were small bodied natives (Australian smelt and bony bream), which accounted for 98% of the assemblage, with only 2% being introduced species (carp and goldfish). No large bodied native fishes were recorded at the site.

Site 7 appeared to be in a reasonable condition, with riparian vegetation being in a moderate condition and instream habitat comprising a good proportion of woody debris and a variety of aquatic plant species. Native fish species dominated the assemblage of fish at the site, although no large bodied natives were found. The presence of Hillston Weir at this site could restrict downstream water flow and impede fish passage.

Site 17: Lachlan River at Lake Waljeers

Lake Waljeers was observed to be completely dry at the time of sampling, with a limited number of snags and moderate riparian vegetation with no understorey located at Site 17.

Habitat mapping results showed that the riparian zone contained 92% full cover and 8% partially covered vegetation. There was no instream habitat and results of fish surveys showed a species composition of 100% carp. Lake Waljeers is the terminal lake for Muggabah Creek, which is an effluent creek below Booligal (Driver *et al.* 2002). The fact that this lake was dry at the time of the survey was largely due to the ongoing drought, resulting in the lack of instream habitat. Fish survey results used for the study were taken in 2000, during conditions of low water levels. The dominance of carp indicates that the habitat for native fish would be poor during times of flow.

<u>Zone 12</u>: Great Cumbung Swamp (Oxley to Murrumbidgee junction)

Site 1: Lachlan River at Geramy

Site 1 was contained minimal woody debris and aquatic vegetation, however anecdotal evidence indicated that there was a significant amount of ribbon weed previously recorded at the site. The lack of flow resulted in the dominance of phragmites, cumbungi and spike rush.

Results from habitat mapping showed that the riparian vegetation was in a poor condition with a total of 45% of the riparian area comprised of no vegetation, 32% containing partial cover and 23% full cover. Instream habitat covered 65% of the reach area and was comprised of 57% phragmites, 8% cumbungi and 0.8% noogoora burr, as well as 0.12% woody debris. Fish survey results showed that introduced fish species (carp, goldfish and gambusia) dominated the site, with 97.5% of the fish assemblage, whilst small bodied natives (gudgeons and bony bream) only accounted for 2.5% of the fish assemblage. No large bodied natives were recorded at Site 1.

Site 1 appeared to be in a highly degraded condition, possessing a dominance of introduced fish species, a limited cover of woody debris, large areas without riparian vegetation and instream vegetation that was dominated by phragmites and cumbungi. In addition to this, noogoora burr was also present at the site, with this exotic species having the potential to spread through the area easily and rapidly (Lamp and Collett, 1979).

Zone 13: Western effluent Creeks (Willandra, Moolbang, and Merrowie)

Site 18: Merrowie Creek at Cobb Highway

Site 18 was dominated by the presence of lignum, with no flow during the time of sampling. The site also possessed a reduced presence of aquatic vegetation and woody debris.
The results from habitat mapping indicated that the riparian zone was in a moderate condition, with 44% possessing full cover, 51% partial cover and 5% no vegetation. Instream habitat covered 33% of the reach area and was comprised of 22% lignum and 11% woody debris. No fish data was available for this site as this was an additional site and surveys had not been conducted.

The lack of water at Site 18 was predominantly a result of the drought conditions experienced during sampling and the practice of water extraction in the main channel and upper reaches. Riparian vegetation was in a poor condition, with less than 50% full vegetation occurring along the reach. There was also a lack of aquatic habitat diversity at the site, and the dominance of lignum, predominantly found in low flowing ephemeral creeks, is indicative of a dry area (Sainty and Jacobs, 1981).

Site 19: Merrowie Creek at Roeta Road

Observations at Site 19 indicated that the reach had good riparian vegetation, however due to the drought, stock had grazed much of the available understorey vegetation. Aquatic habitat contained a significant proportion of lignum and a limited number of snags, with evidence of pooling behind the snags. There was no water present during the time of sampling.

Habitat mapping results showed that the riparian zone was dominated by full cover, which accounted for 100% of the site. Instream habitat contained 47% coverage of the reach area, and was comprised of 36% lignum and 11% woody debris. No fish data was available for this site as this was an additional site and surveys had not been conducted.

The lack of water at Site 19 was a result of the drought conditions experienced during sampling and the practice of water extraction in the main channel and upper reaches. Riparian vegetation was in a good condition, and although there was a lack of aquatic habitat diversity at the site, there was evidence of pooling behind snags.

Reach 20: Willandra Creek at Mossgiel

Observations at Reach 20 indicated that the reach possessed poor riparian vegetation, with no water present during the time of sampling and no aquatic vegetation. Anecdotal evidence suggested that the site previously possessed significant amounts of cumbungi, however this had all been grazed by stock.

Results from habitat mapping showed that the riparian vegetation was in a poor condition with 52% classified as having partial cover, 33% no cover, and only 15% possessing full cover. Instream habitat covered 45.6% of the area, and was comprised of 45.5% lignum and 0.04% woody debris. Fish survey results showed that the site was dominated by introduced fish (carp, goldfish and gambusia), which accounted for 100% of the fish assemblage at the site.

Site 20 was in a very degraded condition, containing only a small proportion of full riparian vegetation cover, a lack of aquatic habitat diversity and a full dominance of introduced fish species, with no native species recorded.

Site 21: Willandra Creek at Willandra National Park

Site 21 was observed as having very good riparian vegetation and aquatic vegetation that was comprised predominantly of cumbungi, lignum, phragmites, and small patches of milfoil. Stock had eaten patches of cumbungi present at the site.

Habitat mapping results indicated that the riparian vegetation possessed 97% full cover and 3% partial vegetation cover. Instream habitat at the site covered 53.2% of the reach area and comprised 33% cumbungi, 15% common spike rush, 3% woody debris, 2% lignum, 0.2%

noogoora burr and 0.1% phragmites. Fish survey results showed that 95% of the fish assemblage was dominated by introduced species (carp and goldfish), with only 5% represented by small bodied natives (bony bream). No large bodied natives were recorded.

Site 21 appeared to be in a reasonable condition, possessing good riparian vegetation and instream habitat. The site was however dominated by introduced fish species, with the exotic noogoora burr also being present.

Site 22: Willandra Creek at Roto

Habitat mapping results for Site 22 showed that the riparian vegetation contained 83% full cover, 11% partial cover and 6% no riparian vegetation. Aquatic habitat covered 88% of the reach area, and was comprised of 58% cumbungi, 27% noogoora burr, 2% common spikerush and 1% woody debris. Fish survey results were dominated by the presence of small bodied natives (Australian smelt and bony bream), which accounted for 93% of the fish assemblage, as well as the presence of introduced species (carp and goldfish), which possessed 7% of the fish species recorded at Site 22.

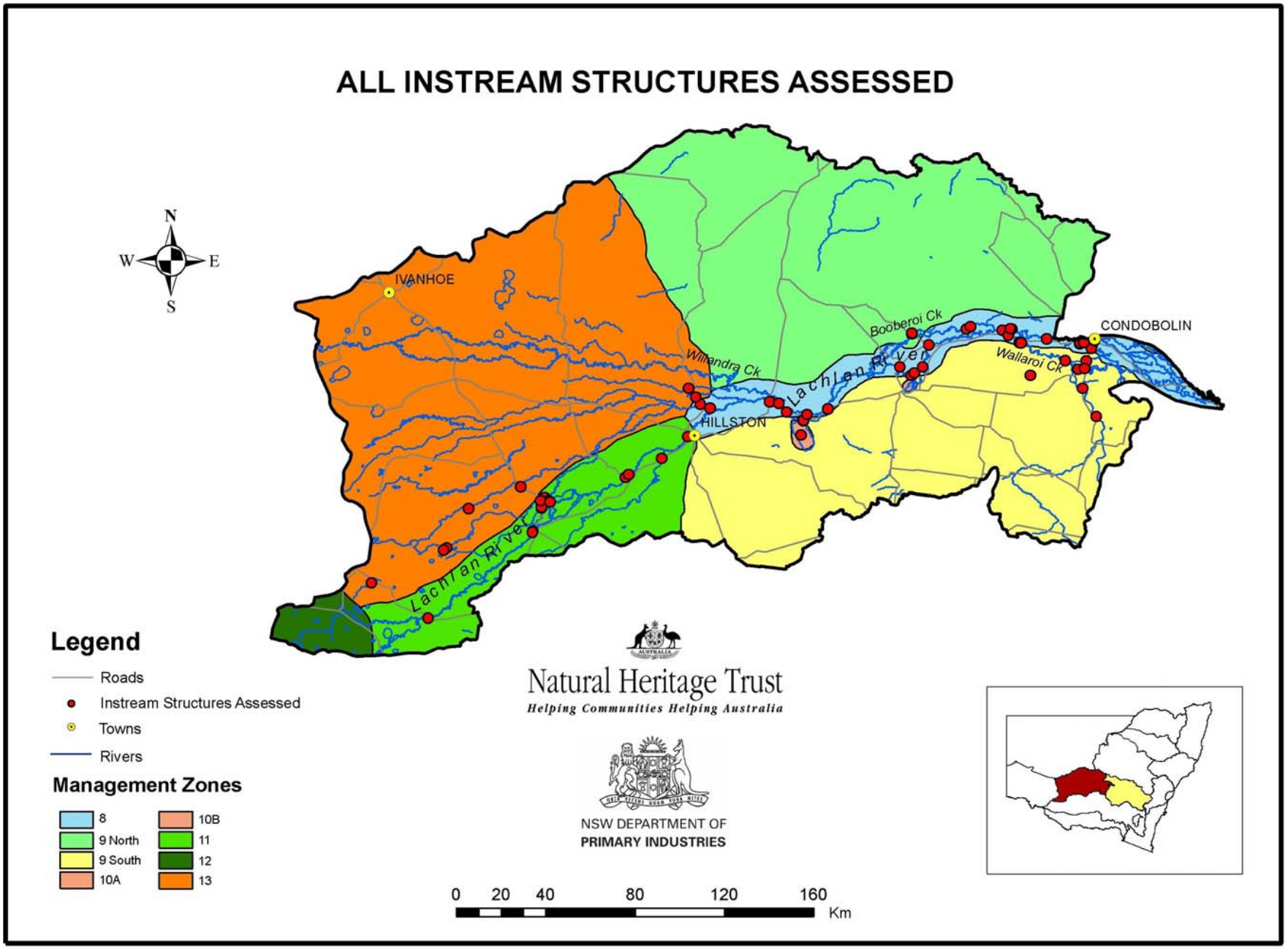
Site 22 had a good coverage of riparian vegetation, however the aquatic vegetation comprised a high proportion of cumbungi and a significant proportion of noogoora burr. It is likely that large dense stands of cumbungi would reduce water flow at the site and the presence of noogoora burr would compete with native and pasture plants (Sainty and Jacobs, 1981; Parsons and Cuthbertson, 1982). Native fish dominated the fish recorded at Site 22, however no large bodied natives were present.

Site 23: Merrowie Creek at Roto Road

Observations at Site 23 indicated that the riparian zone was in a poor condition, possessing no understorey vegetation. The aquatic environment contained no water and no aquatic vegetation, however there were a reasonable number of snags present with evidence of associated deep holes.

Habitat mapping results showed that riparian zone consisted of 82% full vegetation cover, 15% partial vegetation cover and 3% without riparian vegetation. The aquatic habitat of Site 23 covered 6% of the reach area, and consisted of 4% woody debris and 2% lignum. Fish survey results showed that introduced fish species (carp and goldfish) dominated the assemblage at the site, contributing 100% to the fish species present.

Site 23 contained good riparian vegetation, however the aquatic habitat was in a very poor condition, lacking in diversity and abundance. The effects of drought and upstream water usage would have contributed to the lack of water at Site 23, resulting in the poor condition of instream habitat, which is further reflected by the dominance of introduced fish species.

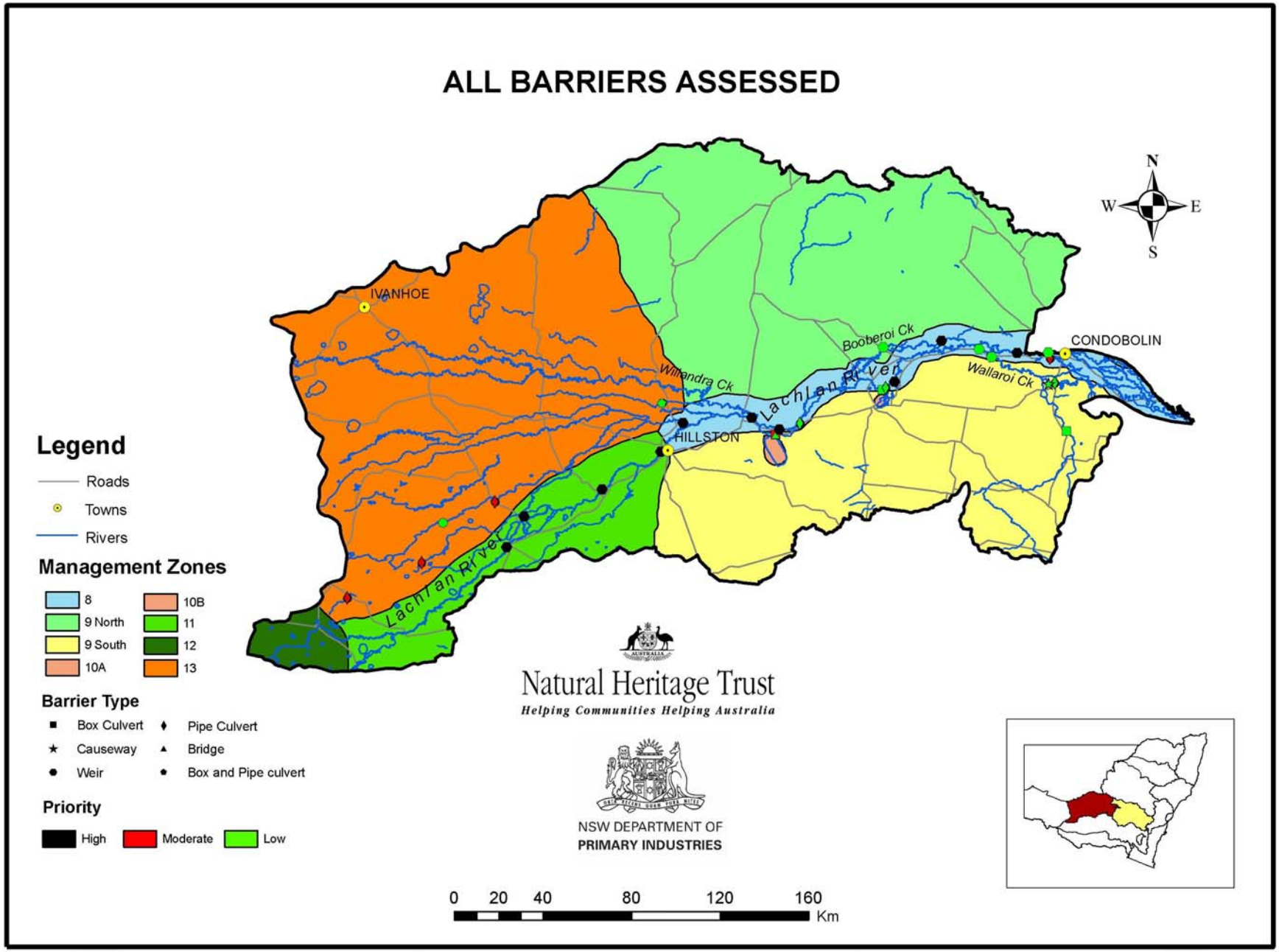


Appendix J – All instream structures assessed in the lower Lachlan

Appendix K – Instream structures recommended for remediation

Summary of fish barrier types assessed in the lower Lachlan and their associated priority level.

Barrier Type	Zone 8	Zone 9S	Zone 9N	Zone 10	Zone 11	Zone 12	Zone 13	Total
High Priority								
Bridge	0	0	0	0	0	0	0	**0**
Causeway	0	0	0	0	0	0	0	**0**
Culvert	1	0	0	0	0	0	0	**1**
Ford	0	0	0	0	0	0	0	**0**
Weir	6	0	0	0	4	0	0	**10**
Subtotal	7	0	0	0	4	0	0	**11**
Medium Priority								
Bridge	0	0	0	0	0	0	0	**0**
Causeway	0	0	0	0	0	0	0	**0**
Culvert	1	1	0	0	0	0	4	**6**
Ford	0	0	0	0	0	0	0	**0**
Weir	4	0	1	0	0	0	0	**5**
Subtotal	5	1	1	0	0	0	4	**11**
Low Priority								
Bridge	0	2	0	0	0	0	0	**2**
Causeway	0	1	0	0	0	0	0	**1**
Culvert	3	2	0	0	0	0	0	**5**
Ford	0	0	0	0	0	0	1	**1**
Weir	0	0	0	0	0	0	0	**0**
Subtotal	3	5	0	0	0	0	1	**9**
Total	**15**	**6**	**1**	**0**	**4**	**0**	**5**	**31**



Appendix L – Fish passage barriers in the lower Lachlan

Appendix M – Details of fishways employed in Australia

Rock ramp fishways

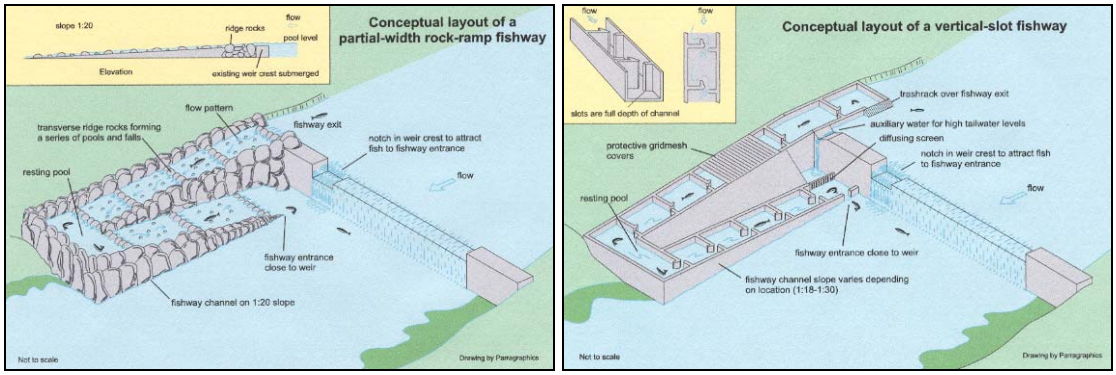
Rock ramp fishways were developed as a simple and relatively low-cost alternative to more formally engineered fishway designs. This design is particularly effective in overcoming low barriers and may be subsequently constructed in association with stream erosion control works. This type of fishway is particularly valuable for providing fish passage at low weirs.

Rock ramp fishways are generally built on slopes that attempt to match the surrounding geomorphic features within the waterway (although these are typically between 1:20 and 1:30 slope). In this design, large rocks are placed to form a series of small pools and falls at about 2 m intervals. Fish ascend rock ramp fishways by darting through sections of high water velocity that occur between large rocks, and resting in the pools created by the rock ridges. Fish alternate between these movements, continuing through until they exit.

Vertical slot fishways

Vertical slot fishways comprise a more engineered and controlled version of a rock ramp fishway. In this design resting pools are essentially concrete cells, with the entrance/exit to/from each of the pools being a vertical slot at either end. The maximum water velocity occurs as water falls through each slot, with the downstream pool acting to dissipate hydraulic energy as well as providing resting areas for ascending fish. The slope of the channel and the interval between slots controls the water velocity allowing the fishway to be designed to suit the swimming ability of particular ascending fish.

Vertical slot fishways have flexibility of operation over varying headwater and tailwater levels, as well as allowing fish to pass through the fishway at any depth. This type of fishway is more expensive than a rock ramp fishway, and requires larger volumes of water to operate.



Reference:
Thorncraft, G. and Harris, J.H. (2000) *Fish passage and fishways in NSW: A Status Report.* Cooperative Research Centre for Freshwater Ecology Technical Report 1/2000.

Appendix N – Rehabilitation site prioritisation scheme (Lower Lachlan catchment)

A) HABITAT VALUE					
Native Fish Assemblage	**Category (and Value)**				**SCORE**
Diversity	High 3-4 (2)	Medium 1-2 (1)	Low 0 (0)		
Large Body Abundance	Medium >10% (3)	Low 0%-10% (2)	None (1)		
Small Body Abundance	High >50% (3)	Medium 20%-50% (2)	Low 0%-20% (1)	None (0)	
Riparian Vegetation					
Overall Cover	Full (4)	Full/Partial (3)	Partial/Full (2)	Partial/None (1)	
Understorey Condition	None (3)	Yes but minimal (2)	Yes and intact (1)		
Large Woody Debris					
Coverage of LWD	High >15% (2)	Medium <15% (1)	None (0)		
				SUBTOTAL	

B) ADDITIONAL CRITERIA				
Fish Passage Barriers	**Category (and Value)**			**SCORE**
Barrier in reach proximity	Yes (2)	No (0)		
Socio/Econ Value				
Public Profile and Stakeholder Interest	High - good profile/landowners known and interested (3)	Medium – moderate profile/landowners known (2)	Low – remote area/landowners unknown or not interested (1)	
			SUBTOTAL	
			TOTAL	

Appendix O – Rehabilitation site prioritisation data

Rank	Site	Zone	Native Fish Assemblage			Riparian Vegetation		LWD Cover	Fish Passage Barrier	Socio/Econ
			Diversity	LBN Abundance	SBN Abundance	Cover	Understorey Condition			
1	13*	8	3 species	None	75.86%	Full	None	16.50%	Lk Cargelligo Weir (11km d/s)	Low Profile
2	12*	8	4 species	1.01%	93.94%	Full	None	29.89%	Lk Cargelligo Weir (9km u/s)	Low Profile
3	6*	11	4 species	3.19%	45.10%	Full/Partial	None	33.68%	Tallawanta Weir (3.5km u/s)	Medium Profile
4	14*	8	4 species	2.03%	82.60%	Full/Partial	Yes (minimal)	24.89%	No	Rec Area
4	15*	8	3 species	14.29%	45.24%	Full (willow)	Yes	9.59%	Micabil Weir (4km u/s)	Rec Area
6	8*	8	3 species	2.08%	43.75%	Full	Yes (intact)	45.34%	Gonowlia Weir (14.5km d/s)	Low Profile
6	2*	11	3 species	1.86%	59.63%	Full	None	65.61%	No	Low Profile
6	7*	11	2 species	None	98.20%	Full/Partial	Yes	18.02%	Hillston Weir (3.5km d/s)	Rec Area
9	10*	8	4 species	0.72%	85.61%	Partial/Full	Yes (intact)	22.38%	Lk Brewster Weir (17km d/s)	Low Profile
9	11*	8	4 species	0.62%	84.82%	Partial/Full	None	19.42%	No	Low Profile
9	25	8	0 species	None	None	Full/Partial	None	15.09%	LL05 (1km u/s) & Worrongorra Weir (2km u/s)	Medium Profile
9	3*	11	2 species	None	63%	Full	Yes (minimal)	9.30%	No	Medium Profile
13	9	8	3 species	None	95.90%	Full	Yes (minimal)	6.15%	No	Medium Profile
13	16*	8	1 species	None	16.67%	Partial (willow)	None	7.05%	Condobolin Weir (1km d/s)	Rec Area
13	24	8	-	None	16.67%	Full	Yes (minimal)	3.18%	Booberoi Weir (2km u/s)	Medium Profile
16	23	13	0 species	None	None	Full	None	3.87%	Gonowlia Weir (7km u/s)	Medium Profile
17	27	9S	2 species	0.97%	0.97%	Full/Partial	-	2.82%	LL01 (0km) and LL02 (4.5km d/s)	Medium Profile
17	5*	11	2 species	None	65.19%	Full	-	19.44%	No	Low Profile
17	22	13	2 species	None	93.18%	Full	-	0.07%	No	Medium Profile
20	19	13	-	None	None	Full	Yes (minimal)	11.29%	No	Medium Profile
21	17	11	0 species	None	None	Full	None	No	No	Medium Profile
21	18	13	-	None	None	Partial/Full	None	10.57%	No	Medium Profile
21	21	13	1 species	None	5.08%	Full	-	3.20%	No	Remote Site
24	1*	12	2 species	None	2.45%	None/Partial/Full	Yes (minimal)	0.12%	No	Remote Site
24	20	13	0 species	None	None	Partial/None	None	0.04%	No	Medium Profile
26	26	9S	0 species	None	None	Full/Partial	-	49.51%	No	Remote Site

Appendix P – Maps of the aquatic habitat assessment sites for the lower Lachlan

Zone 8

Site 8 – Map 3
Site 9 – Map 4
Site 10 – Map 5
Site 11 – Map 6
Site 12 – Map 7
Site 13 – Map 8
Site 14 – Map 9
Site 15 – Map 10
Site 16 – Map 11
Site 24 – Map 12
Site 25 – Map 13

Zone 9 South

Site 26 – Map 14
Site 27 – Map 15

Zone 11

Site 2 – Map 16
Site 3 – Map 17
Site 5 – Map 18
Site 6 – Map 19
Site 7 – Map 20
Site 17 – Map 21

Zone 12

Site 1 – Map 22

Zone13

Site 18 – Map 23
Site 19 – Map 24
Site 20 – Map 25
Site 21 – Map 26
Site 22 – Map 27
Site 23 – Map 28


aquatic habitat
rehabilitation
making more fish ...naturally