REDUCING THE IMPACT OF WEIRS ON AQUATIC HABITAT

NSW DETAILED WEIR REVIEW

REPORT TO THE NEW SOUTH WALES ENVIRONMENTAL TRUST

LACHLAN CMA REGION

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Environmental TRUST

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The information contained in this publication is based on knowledge and understanding at the time of writing (July 2006). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check the currency of the information with the appropriate officer of NSW Department of Primary Industries or the user‘s independent adviser.

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Cover photos: Cob-o-corn Weir, Cob-o-corn Creek, Northern Rivers CMA (upper left); Stroud Weir, Karuah River, Hunter/Central Rivers CMA (upper right); Mollee Weir, Namoi River, Namoi CMA (lower left); and Hartwood Weir, Billabong Creek, Murray CMA (lower right).

EXECUTIVE SUMMARY

The highly modified nature of catchments in NSW presents many challenges in the way we protect the environment and manage its natural resources. In particular, setting goals and targets for aquatic habitat conservation in the region requires clear understanding of the extent of aquatic habitat degradation and where the best outcomes can be achieved.

Within lotic systems, native Australian fish have evolved to be reliant on a variety of habitat types to complete their life cycle, thus requiring free movement within rivers and streams and between estuarine and freshwater environments. Unfortunately, riverine connectivity has been severely disrupted within Australia through the installation of numerous instream structures that impede the natural flow regime and act as physical, hydrological, and behavioural barriers to fish movement. In NSW alone, several thousand weirs, dams and poorly designed road crossings exist on waterways, with the majority of these structures impeding fish passage and impacting on aquatic health.

In 1999, NSW Fisheries and the Department of Land and Water Conservation undertook the NSW Initial Weir Review (2002). The Initial Weir Review (2002) was commissioned by the State Weir Review Committee to provide a preliminary overview of the impact of weirs across the State. Due to the sheer number of weirs and dams in NSW, detailed assessments of each structure were not feasible. Therefore, the Initial Weir Review (2002) incorporated a rapid assessment of weirs in the State for the purpose of providing a 'snap shot' view of environmental considerations at each site, as well as to identify and shortlist priority structures that warranted further attention. It is under this premise that the Detailed Weir Review was conducted to provide a comprehensive assessment of the impacts and remediation options available for improving fish passage and waterway health at priority structures highlighted in the Initial Weir Review (2002).

A total of 109 weir structures within the 13 CMA regions of NSW were selected for Detailed Weir Reviews, with a thorough assessment of each structure undertaken. The individual detailed review reports presented in this project provide a comprehensive overview of each structure including operational details, system hydrology, ecological considerations, and the preferred remediation option of NSW DPI for improving fish passage at the weir.

As a primary recommendation, NSW DPI encourages the removal of redundant structures from waterways, with weir removal providing the greatest benefit to the health of the waterway by enabling unrestricted fish passage and reinstatement of natural sediment fluxes within a system. However, due to the requirement for regulation of flows and impoundment of water for irrigation purposes in many areas of NSW, removal of certain structures cannot be proposed as a primary remediation option. Recommendations put forth by NSW DPI to remediate or remove the weirs inspected throughout the NSW catchments as part of the Detailed Weir Review Project are supported by the NSW *State Weirs Policy*.

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This project was funded through the Environmental Trust Program and managed by the NSW Department of Primary Industries.

The NSW DPI Aquatic Habitat Rehabilitation Program Team managed the project including research, fieldwork, and report preparation. Personnel involved in data collection and report preparation were: Milly Hobson, Shaun Morris, Matthew Gordos, Charlotte Grove, Scott Nichols, Cameron Lay, Sharon Molloy, Sam Davis, Adam Vey, and Anthony Townsend, with maps produced by Ben Maddox. In addition, valuable assistance was provided by regional DPI Fisheries Conservation Mangers including Allan Lugg, David Ward, Trevor Daly, Scott Carter, and Pat Dwyer.

Representatives of all NSW Catchment Management Authorities, Department of Natural Resources, State Water, and local government authorities provided extensive advice and assistance toward the project for which we are grateful.

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1. INTRODUCTION

The following report outlines the results of the "*Impact of Weirs on Environmental Flows, Water Quality and Fish Passage*" (herein the "NSW Detailed Weir Review Project") for the catchments of NSW. The project was funded in November 2003 through the NSW Environmental Trust and was managed by the NSW Department of Primary Industries (now incorporating NSW Fisheries).

1.1 Project scope and setting

In 1999, NSW Fisheries[1] and the Department of Land and Water Conservation[2] undertook the NSW Initial Weir Review. The process aimed to make a provisional assessment of all licensed dams and weirs within NSW, evaluating their impact on fish passage for the purpose of identifying priority sites for remediation. Catchment-based summary reports were prepared (in accordance with the former Catchment Management Board boundaries) recommending remediation options for priority sites. Following the production of the initial weir reviews, the State Weir Review Committee acknowledged that more comprehensive weir reviews were required to assess additional social, cultural, ecological, and logistical issues pertaining to highlighted priority sites prior to the implementation of on-ground works. NSW DPI therefore initiated the NSW Detailed Weir Review project through funding provided by the NSW Environmental Trust that aimed to conduct thorough investigations into 80 high priority structures across NSW to better determine appropriate remediation actions.

1.2 Study aims and objectives

The current project builds on the outcomes of the NSW Initial Weir Review (NSW, Fisheries, 2002) by undertaking detailed reviews for high-priority structures within the thirteen catchments of NSW. The reviews aim to facilitate future on-ground works by addressing the social, ecological, cultural and logistical issues that surround the modification of existing barriers. This will provide a clear process towards mitigating a structure's environmental impact once funding is secured, with the Detailed Weir Review project also serving to identify those structures where remedial works can achieve the greatest ecological benefit. As a result, these reviews will allow external-funding bodies to have greater confidence in proposed works given that a comprehensive assessment and consultation process has already been undertaken.

The primary objectives of the project were to:

- Identify high priority weir structures within each CMA region that have a major impact on fish passage and aquatic habitat condition;
- Assess high priority weirs by reviewing social, ecological, cultural and logistical issues that are associated with each structure;
- Prioritise high priority weirs within each CMA region, and;
- Recommend remediation options to improve fish passage at each weir structure.

[1] Now NSW Department of Primary Industries
[2] Now NSW Department of Natural Resources

2. BACKGROUND

2.1 Fish passage in NSW

Stream connectivity and habitat diversity are critical components of healthy rivers. Within these systems, native fish have evolved to be reliant on a variety of habitat types to complete their life cycle, thus requiring free movement within rivers and streams and between estuarine and freshwater environments. In south-eastern Australia, approximately half of all freshwater fish species migrate as part of their life cycle (Fairfull and Witheridge 2003) including key species such as Murray cod, golden perch, silver perch, Australian bass, sea mullet, short finned and long-finned eels, freshwater mullet and freshwater herring. Migration distances can vary from a few metres during a fish's lifespan, to over a 1000km on an annual scale for species such as the iconic Murray cod and golden perch.

Impeding fish passage through the construction of dams, weirs, floodgates and waterway crossings can negatively impact native fish by:

- Interrupting spawning or seasonal migrations;
- Restricting access to preferred habitat, available food resources and breeding partners;
- Reducing genetic flow between populations;
- Increasing susceptibility to predation and disease through aggregation below barriers;
- Fragmenting previously continuous communities, and;
- Disrupting downstream movement of adults and impeding larval drift through the creation of still water (lentic) environments.

Natural flow regimes are essential in maintaining connectivity between upstream and downstream reaches (longitudinal connectivity), and adjacent riparian and floodplain habitats (lateral connectivity). Instream structures that span the whole channel (e.g. weirs and causeways) can impede natural flows, acting as physical and hydrological barriers to fish movement and isolating upstream and downstream habitats (Williams *et al.* 1996; Pethebridge *et al.* 1998; Thorncraft and Harris 2000; Fairfull and Witheridge 2003). Additionally, levees, floodgates and other off-stream structures (e.g. gross pollutant traps) can disrupt lateral connectivity by isolating seasonal or ephemeral habitats on floodplains and wetlands. For fish that have large-scale migrations in their life cycles, particularly anadromous (marine-to-freshwater) and catadromous (freshwater-to-marine) species, preventing passage can cause local extinctions above barriers and reduce population numbers downstream (Thorncraft and Harris 2000).

The installation and operation of in-stream structures and other mechanisms that alter natural flow regimes of rivers and streams has been listed as a *Key Threatening Process* under the *Fisheries Management Act 1994* and the *Threatened Species Conservation Act 1995*. Recommendations put forward by the Acts specifically note the impact of in-stream structures on the life histories of threatened freshwater fish species including silver perch (*Bidyanus bidyanus)*, Macquarie perch (*Macquaria australasica*), purple spotted gudgeon (*Mogurnda adspersa*), olive perchlet (*Ambassis agassizii)*, Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), Murray cod (*Maccullochella peelii peelii)*, and trout cod (*Maccullochella macquariensis*).

2.2 Barriers to fish passage

All native fish need to move between habitat areas at some stage in their life cycle to spawn, seek food, or find shelter; and for many species migrations over long extended distances are required to complete their life cycle (Thorncraft and Harris 1996; Smith and Pollard 1998). Man-made structures that span the width of the waterway can act as barriers to fish passage by creating a physical blockage, a hydrological barrier, or by forming artificial conditions that act as behavioural barriers to fish. The impact of such barriers on fish passage will vary depending on the design of the structure; the nature of flow, debris and sediment movement in the waterway; and the swimming capabilities of resident fish.

In NSW alone, there exist over 4,000 licensed weirs and dams on rivers and streams (NSW Weir Inventory database). Water impoundment structures are classified as being either fixed crest or adjustable release in design. Fixed crest weirs (also known as run-of-the river weirs) have a set height that water is impounded at, with water generally cascading over the crest of the weir at a natural flow rate barring extensive water extraction from the weir pool. As a result, fixed crest structures generally have only a minor impact on a the hydrological flow patterns of a waterway, with the main impact of such structures being the creation of a physical barrier to fish passage and the loss of upstream lotic habitat. Alternatively, adjustable release weirs and dams incorporate gates, valves, removable drop boards, and spillways that allow the flow of water in the system to be regulated to match stakeholder demands. Unlike fixed crest structures, adjustable release weirs can have much more far ranging effects on the ecology of a waterway including altered hydrological flow patterns and reduced water quality parameters (e.g. water temperature and dissolved oxygen). As with fixed crest weirs however, adjustable release structures also impinge upon fish migration either as physical (excessive headloss) or hydrological barriers (high flow velocity).

Until recently, management of fish passage barriers has centred on the effects of weirs and dams while little attention has been given to the extent of the impact of poorly designed road crossings. Similar to weirs: bridges, arch structures, culverts, causeways, and fords can impinge upon fish migration patterns by acting as physical, hydrological, and behavioural barriers. NSW DPI recently completed a detailed audit of road crossings in coastal catchments (NSW DPI 2006), which highlighted in excess of 1,700 barriers to migrating fish in the coastal waterways of NSW.

In tidal reaches, waterway crossings (especially those over irrigation/agricultural drains) commonly incorporate floodgates that restrict fish passage between flood events. Floodgates include hinge-flap, winch, sluice, and auto-tidal designs; with most of these structures acting as passive one-way valves that aid in draining water from low-lying land behind the gate while excluding tidal ingress. When water levels behind the floodgate are higher than the downstream levels, the gates open and the floodwaters discharge into the estuary. When water levels are elevated on the downstream side of the floodgate however, the structure is forced into the closed position, thus restricting the movement of water and fish into the drain.

The vertical walls of dams, weirs, causeways, and floodgates are the most commonly perceived barriers to migrating fish. However, hydrological barriers including excessive water velocity and turbulence that result from poorly designed fishways and culvert structures can further impede fish passage (Mallen-Cooper 1994). The degree to which a structure acts as a hydrological barrier will also be dependent upon the distance over which fish have to swim to negotiate the structure (Videler and Wardle 1991). Fish generally use two different swimming modes: fast burst

swimming for covering short distance and a cruising speed for longer journeys. Depending upon the design of the crossing, fish may be able to ascend part way up barriers or poorly designed fishways, only to be washed back downstream after their energy has been expended (subsequently predisposing them to predation or disease through fatigue).

Changes in habitat features associated with in-stream structures may also present behavioural barriers to migrating fish. Species that are able to pass into weir reservoirs may find the pooled lentic (still water) system unsuitable due to the loss of critical lotic (riverine) habitat features such as riparian vegetation cover, aquatic macrophytes, and large woody debris. Similarly, altered water temperature and aquatic dissolved oxygen regimes within and below weirs, in addition to lowered pH levels behind floodgates, can also deter migrating fish (Gehrke *et al.* 2001).

The location of instream structures within the catchment is another factor determining the impact of barriers on fish. Obstructions located lower in the catchment often drown out several times a year when rising water levels overcome headloss barriers (the difference in water level across the structure), thereby enabling fish to periodically pass (Harris *et al.* 1992). Alternatively, barriers located higher up the catchment generally drown out less frequently due to the steeper topography and comparatively smaller drainage areas present behind the structure.

2.3 Ecological impacts of weirs

The environmental impact of dams and weirs is widely recognised as one of the key contributors to riverine degradation. The impact from alterations to natural hydrology, changes to stream geomorphology, disruption of localised erosion and sedimentation processes, evaporative water loss, creation of still water environments, impediment of larval drift, and extractive water use have had a severe impact on the abundance and diversity of native fish populations and the quality of aquatic habitats throughout the world. They affect fish in a variety of ways, including: disrupting life-cycles, reducing gene pools, and creating conditions where fish become more susceptible to disease and predation. Moreover, exotic species such as carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), gambusia (*Gambusia holbrooki*), and redfin perch (*Perca fluviatilis*) that are considered habitat generalists, thrive in disturbed habitats compared to native fish, which are habitat specialists. As a consequence, flow-modified waterways possess reduced native fish fauna diversity, abundance, breeding success and ratio to introduced species when compared to unregulated streams (Gehrke and Harris 2001).

Water quality in reservoirs pose many problems not only for the supply of water to humans, but also to the survival of native flora and fauna within and along the watercourse. Larger weirs (> 10 metres) can alter temperature regimes within their impoundments through stratification where a warm surface layer forms over a colder, denser layer near the bottom of the reservoir. Given that most regulated weirs and dams release stored water from the bottom of the structure, cold-water pollution results, which can impact upon waterways kilometres downstream. Cold-water pollution significantly decreases an animal's growth rate while also delaying seasonal spawning runs of fish by depressing temperature sensitive metabolic rates. Thermal stratification in reservoirs also impacts upon aquatic oxygen levels by producing an anoxic bottom layer that forms when organic material settles on the bed and is broken down by oxygen-depleting bacteria. Diffusion of oxygen into these bottom layers is prevented by the existing thermal stratification, resulting in the release of hypoxic water below the weir, which can affect the distribution of oxygen-sensitive macroinvertebrates and fish species.

The construction of weirs and dams also results in the inundation of streamside habitat. The drown-out of adjacent riparian zones detrimentally effects the survival of bank-side vegetation communities, resulting in the mortality of riparian flora. Deleterious impacts associated with vegetation dieback along reservoir banks include increased erosion and sedimentation, along with associated water quality reduction, proliferation of weed species, reduced macrophyte growth, especially within the littoral zone, and loss of vegetative shade cover. Additionally, the re-establishment of riparian communities at regulated reservoirs is problematic due to widely fluctuating water levels.

Weirs and floodgates can also alter the way a river channel interacts with its neighbouring floodplain. The design of such structures generally entails flood containment, which can isolate floodplains and wetlands while simultaneously reducing the carbon input entering from lowland rivers (and vice versa). Additionally, access to floodplains is essential to the reproduction of numerous species including silver perch and golden perch (*Macquaria ambigua*) that spawn in such habitats when food resources are abundant. Effective management of floodplain barriers is required to ensure that ecological functioning is maintained.

Weirs and dams also impact on channel geomorphology by trapping sediments from upstream and inadvertently storing them in the reservoir. Without a supply of sediment to replenish areas that have been eroded downstream by increased flow velocities and turbulence below the structure (otherwise known as clearwater erosion), the natural sediment balance is disrupted. Additionally, the manipulation of flows and the associated increased flow velocities below a weir or dam can result in the alteration of natural stream morphology by increasing erosion rates, which can result in the deepening and widening of rivers.

The sedimentation that occurs within weir pools further affects organisms within the stream by filling in fish habitat holes, smothering benthic organisms, and in some cases affecting fish respiration. The reduction in stream depth allows a greater surface area of the waterway to be subjected to sunlight penetration and evaporation, increasing water temperature particularly during the summer months. Turbid conditions resulting from sediments in the weir pool or increased erosion downstream can decrease light penetration into the water column and limit photosynthesis, thereby reducing the overall productivity of the system.

The significance of addressing the environmental impact of dams and weirs is reflected in the attention received across all levels of government and within Natural Resource Management forums. For the Murray Darling Basin Commission's Native Fish Management Strategy, over half of the objectives are directly related to mitigating the impact of weirs on fish habitat through structural modification or improved storage management. The Murray Darling Basin Commission is implementing the strategy by committing funds to improving fish passage along the length of the Murray River as part of the Living Murray Initiative. Additionally, the Commission is seeking ways to improve the management of available resources and maximise the delivery of water to the environment to restore critical variability in the flow regime for major inland rivers.

2.4 Policies and Legislation

The NSW Government recognises the significant impact that barriers present to aquatic biota within estuarine and riverine ecosystems. As part of this approach, the Government released the *State Weirs Policy* in 1997, which aims to mitigate or prevent the environmental impacts of weirs, road crossings, and floodgates in NSW. This goal is supported by the adoption of the following management principles:

1. *The construction of new weirs, or enlargement of existing weirs, shall be discouraged;*
2. *Weirs that are no longer providing significant benefits to the owner or user shall be removed, taking into consideration the environmental impact of removal;*
3. *Where retained, owners shall be encouraged to undertake structural changes to reduce their impact on the environment (e.g. installation of fishway);*
4. *Where retained, owners of weirs with regulatory works shall prepare and adhere to operational plans to reduce the environmental impact of weirs;*
5. *Where retained, gated off-take structures and fishways on all weirs shall be maintained in good working order;*
6. *Wetlands and riparian vegetation adjacent to weirs should be protected from permanent inundation;*
7. *Areas of environmental degradation caused by the impacts of weirs upstream and downstream of the weir pools, should where possible be rehabilitated; and*
8. *A respect for the environmental impact of weirs should be encouraged in all agencies and individuals that own, manage, or derive benefits from weirs.*

The *State Weirs Policy* is a component of the NSW water reforms initiated by the NSW Government in 1995. Implementation of the *State Weirs Policy* is a whole-of-government responsibility with the Department of Natural Resources (DNR) as the lead agency. DNR licences weirs under the *Water Management Act 2000* and *Water Management Amendment Bill 2005*. The Act aims to provide a mechanism for protecting and restoring water sources and their ecosystems, giving priority to environmental water, whilst still allowing improved access rights to watercourses and aiding in the arrangement of water management partnerships between local communities and the government. NSW DPI plays a significant role in the administration of the policy by protecting the interests and aquatic biodiversity of native fish.

In 1994, the *Fisheries Management Act* came into effect and specifically addressed the issue of fish passage. Under Sections 218-220 of *the Act* (1994), NSW DPI has the responsibility to ensure that the construction of any new weir or the modification of an existing structure does not deleteriously impact upon resident fish populations. Fairfull and Witheridge (2003) and NSW Fisheries (2003) provide a comprehensive overview of the legislative and policy requirements that must be observed during the planning, design, and construction of waterway crossings in NSW. Together these legislative tools, and associated NSW Government policies on fish passage, act to regulate the construction of structures that can impede fish passage. In addition, reinstating connectivity between upstream and downstream habitats and adjacent riparian and floodplain areas through the remediation of fish passage barriers has become an essential part of aquatic habitat management and rehabilitation programs in NSW.

3. PROJECT METHODOLOGY

3.1 Initial Weir Review

The Initial NSW Weir Review (2002) was commissioned by the State Weir Review Committee to provide a preliminary overview of the impact of weirs across the State, and to identify and shortlist priority structures that warranted further attention. The review consisted of a desktop database assessment followed by a subsequent field investigation of all identified weirs. The desktop assessment initially involved accessing the Licensing Administration Database System (LAS) created by the Department of Land and Water Conservation to identify the location and contact details for licensed weirs on named waterways. Adjacent landholders and structural owners were subsequently contacted and informed of the Weir Review Program, upon which permission was gained to inspect the structures. Where possible, meetings were arranged on-site with the relevant stakeholders to discuss the social, ecological, and hydrological issues associated with the weir/dam.

Following desktop and field data collection, weirs were prioritised and ranked on a catchment scale using criteria developed by Pethebridge *et al.* (1998) that included such factors as: river size, location in catchment, presence of threatened species, available upstream habitat, number of downstream obstructions, presence of a fishway, and whether anthropogenic impacts such as thermal pollution were present. It should be noted that the initial ranking of barriers was based only on fish passage considerations for the purpose of highlighting high priority weirs that have a significant, deleterious impact upon NSW native fish species. Although not included in the initial prioritisation process, socio-economic issues were investigated and reported upon in the initial weir review to provide guidance in future assessments. The outcomes of the prioritisation process were subsequently presented, reviewed, and accepted with comment by the relevant River Management Committees.

3.2 Selection of weirs for detailed review

Due to the sheer number of weirs and dams in NSW, detailed assessment of every structure was not feasible. As a result, the Initial Weir Review incorporated a rapid assessment of weirs in the State for the purpose of providing a ‘snap shot’ view of environmental considerations at each site relative to fish passage. The application of a rapid assessment technique was a simple and effective way of highlighting the extent of the problem and determining broad regional priorities to aid in informing future planning directives. However numerous environmental, social, cultural, and economic considerations need to be considered by natural resource managers when reviewing the operational status of water impoundment structures. It is under this premise that the Detailed Weir Review was conducted to provide a comprehensive assessment of the impacts and remediation options available for improving fish passage and waterway health at priority structures highlighted in the Initial Weir Review (2002).

A total of 1,163 weirs were inspected and assessed in the thirteen NSW catchments as part of the Initial Weir Review (2002), of which 355 were designated as structures requiring further investigation. Of these 355 identified weirs, 109 structures were selected for detailed reviews for this study. Information gathered during the initial reviews pertaining to environmental, social, cultural, and economic factors was considered in the selection of structures to incorporate into the Detailed Weir Review.

Additionally, consultation occurred with regional NSW DPI Conservation Managers, State Water representatives, and regional staff from the Department of Natural Resources, to further highlight regional issues that would influence the selection of priority structures.

Following the selection of structures, detailed assessments were performed on priority weirs to supplement and augment information previously obtained in the Initial Weir Review (2002). Detailed analysis involved field and desktop assessment, which required consultation with structure owners, local community members, adjacent landholders, and fishing groups that held a vested interest in the weir and adjoining reaches.

3.3 Desktop assessment and consultation

Prior to the site visit, a detailed desktop investigation was conducted to determine location information (e.g. section of the catchment), structural details (e.g. required uses and interested stakeholders, available upstream habitat), hydrological patterns, and further environmental considerations (ranges of threatened and protected species and archived water quality information). Structure owners, respective state government departments, fishing clubs, and community groups were consulted during this process to ascertain: construction dates, average flows, frequency of structural drown out[3] events, previous occurrence of blue-green algae in the weir pool, fish caught or observed in the vicinity of the weir, licensing information, and water extraction devices linked to the works of each weir. Where possible, volume of water discharged (ML/day) on the date of the field assessment, average yearly flows, and drown out event data were acquired from the nearest Department of Natural Resources river gauge.

3.4 Field assessment

Fieldwork in the region was conducted from April 2004 – May 2005. On-site visits were conducted where feasible with structure owners (e.g. State Water), which allowed queries to be answered and sites normally inaccessible to the public to be entered. A detailed assessment proforma (Appendix A) was completed for each structure, with location details and digital photographs also recorded.

Information obtained in addition to fields previously recorded during the Initial Weir Review included: extent of barrier impact (e.g. headloss); structural stability; position of the weir relative to upstream and downstream man-made barriers; hydrological information (including the length of the weir pool and depth behind the structure); evidence of siltation behind the structure; adjacent bank stability; occurrence of riparian fencing or stock access; riparian vegetation condition; presence of aquatic and riparian weeds; and class of waterway on which the weir was located (Table 3.1).

NSW DPI applies a ‘Class’ system to assign aquatic habitat values to waterways, as outlined in Table 3.1 (Fairfull and Witheridge 2003). Due to the previous prioritisation of weirs in the initial review the majority of structures assessed during this study were located on Class 1 waterways or high quality Class 2 systems.

[3] **Drown out** refers to when a structure is no longer having an impact on the passage of fish within a waterway. At this time, water levels are higher than the structure itself, allowing minimal disruption to water movement, and providing free passage of fish within a system. Compare with **over topped**, which refers to when a structure has water flowing over the top of the weir crest.

All data recorded in the Detailed Weir Review Project was downloaded into the NSW Department of Primary Industries Fish Habitat Database prior to comparative analysis to determine regional remediation priorities for each catchment.

Table 3.1. Classification of fish habitat in NSW waterways (Fairfull and Witheridge 2003).

Classification	Characteristics of Waterway Type
CLASS 1 Major fish habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek), habitat of a threatened fish species.
CLASS 2 Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.
CLASS 3 Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.
CLASS 4 Unlikely fish habitat	Named or unnamed waterway with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools after rain events (e.g. dry gullies or shallow floodplain depressions with no permanent aquatic flora present).

3.5 Prioritisation process

A weir prioritisation scheme was developed to assist in ranking priority structures requiring remediation in NSW (Appendix B). Although weirs included in the Detailed Weir Review Project had previously been assessed and prioritised as a component of the Initial Weir Review, it was deemed necessary to further rank these priority structures to incorporate the additional data collected, thereby providing regional CMAs with targeted, informed data when selecting structures for remediation. The prioritisation scheme was developed to determine regional priorities by ranking weirs based on the following categories: a) stream habitat value; b) structural impact; c) environmental criteria; and d) modification criteria.

An initial prioritisation was conducted based on stream habitat and structural impact criteria, which were viewed as the primary variables affecting fish passage. Stream habitat criteria were based on habitat class, location of the barrier in the catchment, number of downstream obstructions, and the amount of habitat (i.e. stream length in kilometres) opened to unimpeded fish passage. Table 3.1 outlines the characteristics of each waterway class that was used in the weir prioritisation scheme, with Class 1 systems receiving a high ranking while Class 4 systems recorded the lowest score. Location of the barrier in the catchment (e.g. tidal / lower / middle / upper) was determined by geomorphological and hydrological characteristics of the system, in addition to stream order and elevation. Barriers located within the tidal or lower reaches of the catchment with few-to-no obstructions downstream were ranked higher than weirs positioned in the upper headwaters. Moreover, a higher weighting was placed on weirs that, if remediated, would provide longer sections of unimpeded fish passage.

Structural impact criteria assessed whether the weir was a physical or hydrological barrier to migrating fish. Headloss over a structure, otherwise known as the ‘waterfall effect’, was the only major physical barrier recorded during the project. This parameter was measured under low flow conditions, with larger values representing a greater fish passage barrier and receiving a higher weighting. Hydrological barriers were categorised as displaying excessive water velocity and were assessed in association with the drown out occurrence of the structure.

Drown out values for structures were calculated from relevant time weighted flow duration data, with structures that rarely drowned out receiving a higher weighting than those structures that readily drowned out.

In association with the structural impacts assessed during the review, it was also noted if the weir was an undershot structure where the water is released from below the weir. These types of structures are known to have negative impacts on fish larvae (Marttin and Graaf 2002; Baumgartner 2005), and were given a higher weighting value during the prioritisation process.

Following the initial prioritisation, a secondary prioritisation incorporating environmental and structural modification criteria was conducted to further delineate rankings. Environmental criteria incorporated aquatic and riparian habitat condition (i.e. good / fair / poor), sedimentation in the weir pool, and threatened species habitat. Within the known ranges of species of conservation concern, priority rankings were determined by the quality of the surrounding aquatic habitat based on habitat class (Class 1-2: high ranking; Class 3: low ranking; Class 4: no ranking).

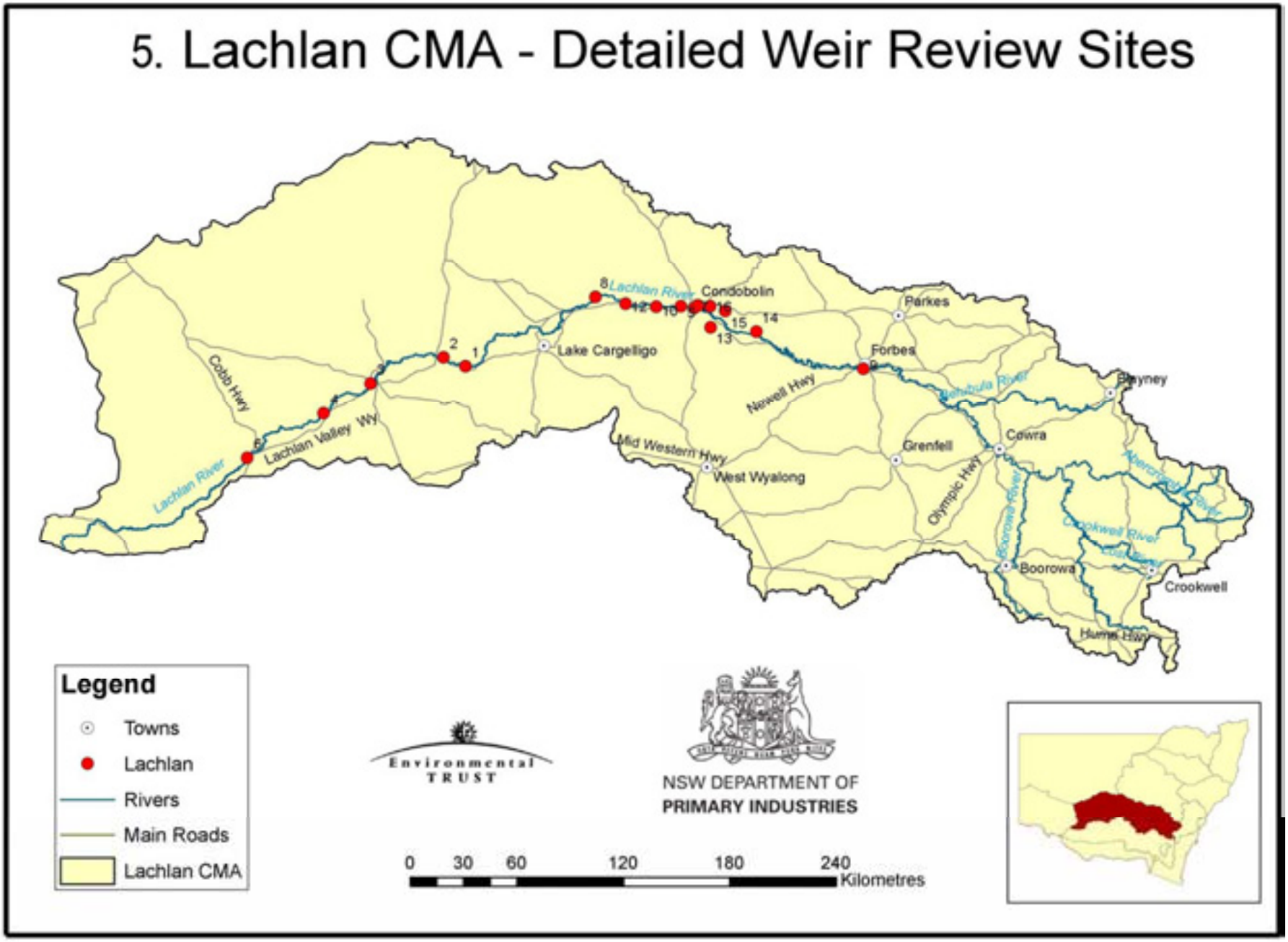
Modification criteria assessed structural use and the ease of remediating the weir. Occasionally structures were recorded during the Detailed Weir Review that were no longer used by the licensee or adjacent property owners. These obsolete weirs received a higher priority score due to the ease (e.g. low costs and short timescales) associated with remediation. Additionally, weir inspections noted that a number of structures required immediate maintenance that would enact the *Fisheries Management Act* 1994, which stipulates for the remediation of fish passage if repair works are undertaken. Weirs that were noted as candidates for removal received a higher ranking than weirs requiring fishways or structural modification to remediate fish passage due to the reduced costs and short timescales associated with the former option.

The weir prioritisation scheme was applied to all structures investigated, with results for each catchment displayed in their respective summary tables. Included in the summary tables are details of priority structures where remediation works have been completed or commenced. These structures have not been reviewed in this report, however information has been included in the tables to highlight the number of priority structures within each catchment. It should also be noted that the prioritisation of barriers carried out in this investigation is provisional in nature. Although social, cultural, and economic issues were considered during the Detailed Weir Reviews in order to provide an objective outcome, a degree of subjectivity is still required when assessing structures prior to the allocation of funding for remediation.

4. INDIVIDUAL DETAILED WEIR REVIEW REPORTS

Information used to prioritise each weir is detailed in the Individual Detail Weir Review reports for each catchment that appear in the following sections. Individual weir reports provide comprehensive accounts of the structures operational details, system hydrology, ecological considerations, proposed remediation options (along with projected costs), and preferred NSW DPI option for improving fish passage at the weir. A complete data set for each weir is stored in the NSW Department of Primary Industries Fish Habitat Database – this data can be accessed by contacting NSW DPI staff.

5. Lachlan CMA - Detailed Weir Review Sites



Lachlan CMA Summary Table

Rank	Barrier Name	Latitude	Longitude	Structure Type	Watercourse	Ownership	Operational Fishway	Recommendation	Estimated Cost of preferred option ($)	Estimated Cost of alternative option ($)	Potential Increase in Habitat Area (km)
1	Lake Brewster Weir	-33.396231	145.984762	Fixed crest (concrete and rock fill)	Lachlan River	State Water	No	Fishlock	>1M	N/A	130
2	Willandra Weir	-33.349710	145.872957	Fixed crest (sheet piling and rock fill)	Lachlan River	State Water	No	Vertical Slot Fishway	>1M	250 - 500K	110
3	Hillston Weir	-33.486971	145.503860	Fixed crest (sheet metal, wooden piling and rock fill)	Lachlan River	State Water	No	Full Width Rock Ramp Fishway	250 - 500K	500K - 1M	146
4	Tallawanta Weir	-33.640566	145.266166	Fixed crest (concrete and rock fill)	Lachlan River	Private	No	Full Width Rock Ramp Fishway	150 - 250K	<50K	135
5	West Condobolin Weir	-33.085925	147.076468	Adjustable crest (dropboards)	Lachlan River	Private Water Trust	No	Removal	<50K	150 - 250K	30
6	Booligal Weir	-33.874000	144.879200	Fixed crest (wooden piling, rock fill and concrete)	Lachlan River	State Water	No	Vertical Slot Fishway	500K - 1M	150 - 250K	186
7	Condobolin Weir	-33.094337	147.142958	Fixed crest (concrete)	Lachlan River	State Water	No	Vertical Slot Fishway	250 - 500K	150 - 250K	97
8	Booberoi Weir	-33.037800	146.643400	Fixed crest (concrete)	Lachlan River	State Water	No	Vertical Slot Fishway	500K - 1M	150 - 250K	80
9	Cottons Weir	-33.410495	148.000608	Fixed crest (concrete)	Lachlan River	State Water	No	Vertical Slot Fishway	500K - 1M	150 - 250K	170
10	Micabil Weir	-33.087226	146.950312	Fixed crest (concrete)	Lachlan River	Private Water Trust	No	Vertical Slot Fishway	250 - 500K	150 - 250K	45
11	Lachlan Shire Council Weir	-33.082134	147.163725	Fixed crest (rock fill)	Goobang Creek	State Water	No	Vertical Slot Fishway	500K - 1M	250 - 500K	13
12	Kiactoo Weir	-33.072205	146.795590	Fixed crest (concrete)	Lachlan River	State Water	No	Vertical Slot Fishway	250 - 500K	150 - 250K	45
13	Burrawang West Weir	-33.100006	142.225522	Fixed crest (rock fill)	Bumbuggan Creek	Private	No	Low flow fishway channel	50 - 150K	150 - 250K	20
14	TSR Weir	-33.216098	147.457628	Fixed crest (wooden piling and rock fill)	Bumbuggan Creek	RLPP	No	Removal	<50K	150 - 250K	8
15	Kennedy's Weir	-33.110310	147.300766	Fixed crest (steel gates, wooden piling, concrete and rock fill)	Goobang Creek	Private	No	Full Width Rock Ramp Fishway	50 - 150K	<50K	19
16	Brady's Weir	-33.085161	147.224228	Fixed crest (wooden piling and concrete)	Goobang Creek	Private	No	Full Width Rock Ramp Fishway	150 - 250K	<50K	14
N/A	Bumbuggan Creek Weir	-33.225559	147.460371	Gated weir	Bumbuggan Creek	State Water	Yes	Vertical Slot Fishway (completed 2004)	>1M	N/A	N/A
N/A	Gonowlia Weir	-33.082134	145.596341	Adjustable crest (dropboards)	Lachlan River	State Water	No	Dropboards be removed when not in use (not a priority site)	N/A	N/A	N/A
N/A	Jemalong Weir	-33.399755	147.776047	Adjustable crest (vertical lift gates)	Lachlan River	State Water	No (investigations for fishway commenced)	Vertical Slot Fishway	>1.5M	N/A	N/A
N/A	Lake Cargelligo Weir	-33.201153	152.453119	Adjustable crest	Lachlan River	State Water	No (fishway construction to commence soon)	Vertical Slot Fishway	>1M	N/A	N/A

LAKE BREWSTER WEIR, LACHLAN RIVER

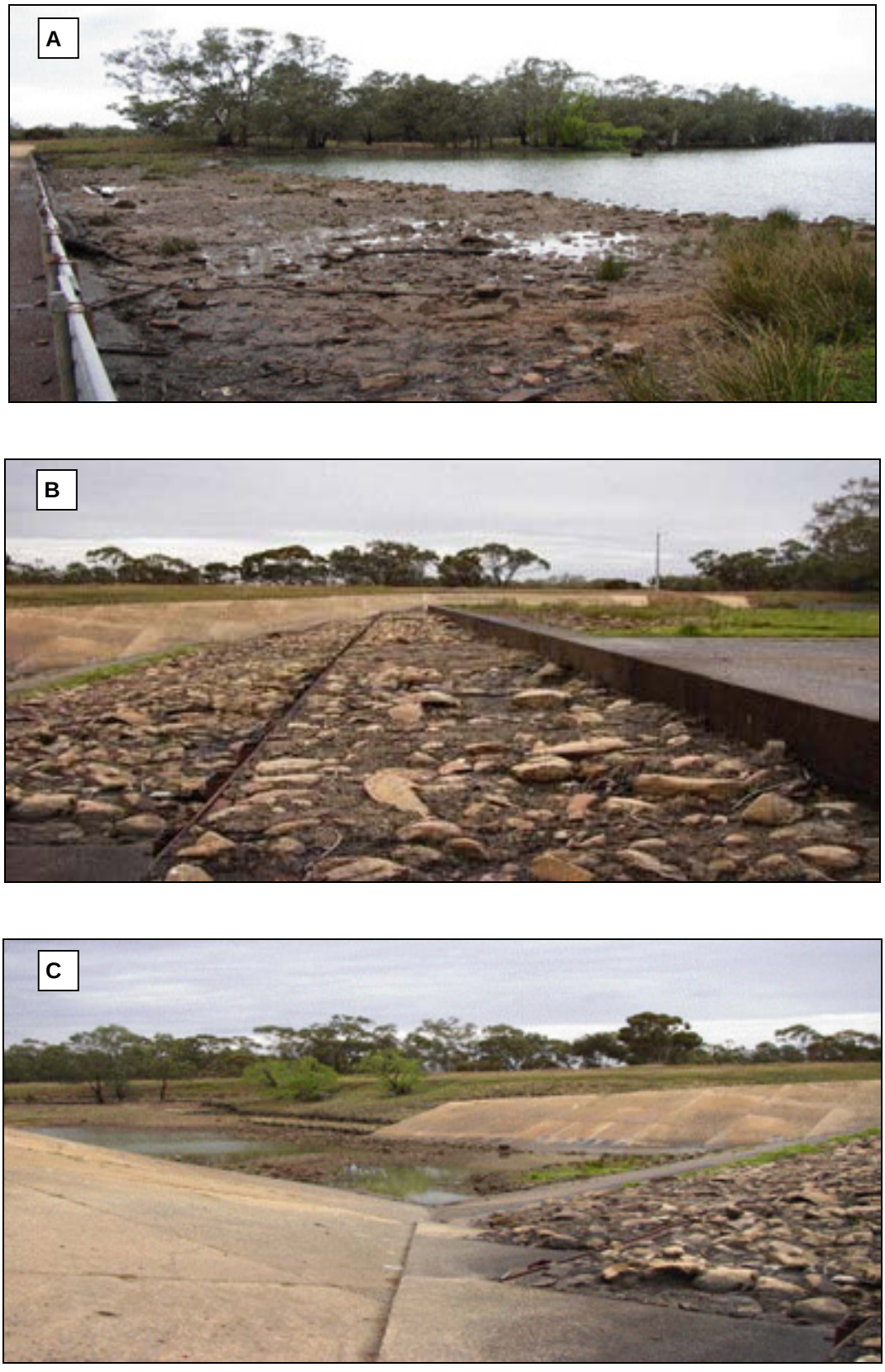


Figure 1. A) upstream side, B) structure crest, C) downstream side, Lake Brewster Weir, Lachlan River (30.09.2003, 25ML/day).

Description and Setting

Lake Brewster Weir (Figure 1) is located on the Lachlan River, approximately 42km West of Lake Cargelligo within the Lower Lachlan River catchment. The weir is approximately 9 metres high and approximately 90 metres across the length of the crest. The weir is a fixed crest structure with no regulating infrastructure, and is constructed of concrete and rock fill.

Lake Brewster Weir acts as a barrier to fish passage at all flow conditions and has not been recorded as drowning out. During the floods of September 1990, which were the highest flows ever recorded at 26,300ML/day, the weir continued to remain operable, indicating that drown out of the structure will be greater than 26,300ML/day. Lake Brewster Weir restricts fish passage due to excessive head loss, a slope steeper than 1:20, increased velocity, and increased turbulence across the face of the structure.

Lake Brewster Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation need due to the higher prevalence of fish spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Good instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to fish is Lake Cargelligo Weir located on the Lachlan River approximately 112km away; the next barrier downstream is Willandra Weir on the Lachlan River 18km away. Both structures are owned and operated by State Water, who is currently undertaking investigations to construct a vertical slot fishway at Lake Cargelligo, with on ground works expected to commence in the 06/07 financial year; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Lachlan River are regulated by Wyangala Dam, which is located in the upper limits of the Lachlan River catchment. There are eight major barriers to fish passage upstream of the Lake Brewster Weir on the Lachlan River: Lake Cargelligo, Booberoi, Kiacatoo, Micabil, West Condobolin, Condobolin, Jemalong, and Cottons Weirs.

The closest DNR river gauge is located at the Benson Drop Weir downstream of Lake Brewster outlet on the Lachlan River (station 412047). Information with regard to flows within the Lachlan River referred to in this review was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and staff from State Water, DNR, and NSW DPI, and uses data acquired between 17.04.1996 – 07.04.2005.

The weir is preventing fish passage under all flow conditions, and it has been suggested that the weir in its current condition would not drown out - even during extreme flooding conditions. It is predicted that drown out of the weir would theoretically occur at flows well in excess of 26,300ML/day, although the State Water Assets Manager has confirmed that flows greater than 26,300ML/day have not been recorded for this site.

There are currently seven licensed water extractors who utilise the water in the upstream weir pool for varying uses including stock, domestic and irrigation purposes, to a maximum annual allocation of 10,040ML (high and low security licenses).

Operational Details

Lake Brewster Weir is owned and operated by State Water. The weir was built in 1950 and is currently used to conserve "surplus" water from the Lachlan River for re-regulation. Water from Lake Brewster is later released to the Lower Lachlan River catchment primarily for irrigation in the summer months. The upstream weir pool is used for stock, domestic and irrigation purposes in addition to local residents' recreational pursuits such as fishing, boating and camping.

Ecological Considerations

The movement of migratory fish populations within the Lachlan River are greatly impacted due to the presence of several barriers throughout the system. However, unlike all other barriers in the Lower Lachlan River catchment, Lake Brewster Weir is the largest barrier to fish passage, and remains a barrier to fish passage over all flow conditions. The reinstatement of fish passage at this site is therefore extremely important to maintain connectivity throughout the entire catchment, especially at higher flows when all other structures are drowned out, but Lake Brewster Weir remains a barrier.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden and silver perch and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River at the Lake Cargelligo and Lake Brewster area: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon, and the threatened silver perch. Introduced species including redfin, common carp, and gambusia are also likely to be present.

At the time of inspection, the Lachlan River either side of the weir had minimal understorey (Figures 2 and 3) due to prevailing drought conditions. The dominant overstorey vegetation present was river red gums, with some willows present downstream.

The Lachlan River at this location possesses some important fish habitat including instream large woody debris, which provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and the growth of algae (thereby creating a food source for macroinvertebrates). The rehabilitation of the riparian zone, including willow removal and riparian fencing, should be undertaken in conjunction with any fish passage remediation works at this site to benefit not only fish passage, but also fish habitat.

Figure 2. Lachlan River downstream of Lake Brewster Weir (01.10.2003, 25ML/day).

Figure 3. Lachlan River upstream of Lake Brewster Weir (01.10.2003, 25ML/day).

Proposed Remediation Actions

State Water is in the process of reviewing their entire existing infrastructure within the Lachlan catchment. Recommendations made as a result of this report will be further discussed with State Water to determine a solution that will improve fish passage at this site.

As Lake Brewster Weir has a crest height in excess of nine vertical metres, many fishway designs are not suitable as they have not been tested to such heights in Australia, and they are not economically viable. A fishlock provides an alternative option for higher structures, and is the only realistic option available for Lake Brewster Weir.

- **Option 1 –** Fishlock

The only lock fishway built in NSW to date is at Yarrawonga Weir on the River Murray. This fishlock has been shown to be effective in transporting fish over the 12 metre high weir, although several operating and exit arrangements require modification (Thorncraft and Harris 2000).

A fishlock operates in a similar manner to a boat lock. The fishlock works by attracting fish through an entrance similar to that of a pool type fishway, but instead of swimming up a channel the fish accumulate in a holding area at the base of the lock (Thorncraft and Harris 2000). The holding area where the fish accumulate is sealed and water is directed into the chamber until water levels are equal to the upstream weir pool. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

An issue for consideration is the maintenance requirements at remote or unstaffed sites. Routine inspections of automated mechanisms, and fishway operation would need to be incorporated into the works schedule of the managing authority. This is the preferred option for Lake Brewster Weir, as it is the largest barrier to fish migration in the Lachlan River.

Projected Remediation Cost

Projected cost	**< $50K**	**$50K - $250K**	**$250K - $500K**	**$500K - $1M**	**> $1M**
Option 1					✔

Recommendation

It is recommended that a fishlock (Option 1) be further investigated at Lake Brewster Weir.

Benefits Associated with Remediation

The Lachlan River possesses some important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment.

By reinstating fish passage at Lake Brewster Weir unimpeded access to in excess of 130km of potential habitat would be provided to fish and other aquatic organisms.

Following construction of a vertical slot fishway at Lake Cargelligo in 2006/07, any works undertaken at Lake Brewster Weir will further rise in priority within the Lachlan catchment. In addition, should fish passage remediation works be undertaken at Lake Brewster following the works at Lake Cargelligo, in excess of 235km of potential habitat would be opened to fish and other aquatic fauna.

WILLANDRA WEIR, LACHLAN RIVER

Figure 1. Willandra Weir, Lachlan River (30.09.2003, 80ML/day).

Description and Setting

Willandra Weir (Figure 1) is located on the Lachlan River, within the Lower Lachlan River catchment, approximately 42km north east of the township of Hillston. The weir is approximately 4 metres high and is 30 metres across the length of the crest. Willandra Weir is a fixed crest structure with no associated regulating infrastructure, and is constructed of sheet piling and rock fill. The weir acts as a barrier to fish passage when flows are less than 8,500ML/day due to excessive head loss, increased turbulence, and increased velocity across the face of the structure.

Willandra Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation need due to the higher prevalence of fish spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Significant instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to fish is Brewster Weir located on the Lachlan River approximately 18km away; the next weir downstream is Gonowlia Weir on the Lachlan River 55km away. Both structures are owned and operated by State Water. Gonowlia Weir is only a barrier to fish passage from May – June each year when it is in operation,

State Water have advised that at all other times the boards are removed to below water level (zero head loss), and the structure is therefore not considered a high priority for fish passage within the Lachlan CMA. The next major barrier is Hillston Weir located a further 38km downstream near Hillston township, which is owned and managed by State Water.

- Low frequency of drown out (flow at which fish passage is possible, where headloss and velocity are minimal).

Hydrology

Flows within the Lower Lachlan River are regulated at Lake Brewster, with water supplies for the entire catchment sourced from Wyangala Dam, in the upper limits of the Lachlan catchment when stores are inadequate at Lake Brewster. There are nine major barriers to fish passage upstream of the Willandra Weir on the Lachlan River: Lake Brewster, Lake Cargelligo, Booberoi, Kiacatoo, Micabil, West Condobolin, Condobolin, Jemalong, and Cottons Weirs.

The closest DNR river gauge is located upstream of Willandra Weir on the Lachlan River (station 412038). Information with regard to flows within the Lachlan River referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and uses data acquired between 09.10.1970 – 06.04.2005.

Willandra Weir prevents fish passage over most flow conditions, although it has been suggested that the weir in its current condition would drown out with flows in excess of 8,500ML/day. The time weighted flow duration curve for the Lachlan River shows that flows would exceed 8,500ML/day less than 4% of the time.

There are currently seven licensed water extractors who utilise the water in the upstream weir pool for varying uses including stock, domestic and irrigation supply, with total annual allocation exceeding 9,026ML (high and low security licenses).

Operational Details

Willandra Weir was built in 1896 and was used in conjunction with a regulator to divert flows down Willandra Creek. Willandra Weir is owned and operated by State Water. There are at least seven other groups who utilise water being pooled upstream for varying purposes, and another five riparian stock and domestic diverters. The site is also used by the local residents for recreational pursuits including fishing, boating and camping.

At the time of the inspection the structure required some maintenance work including the replacement of some sheet piling and protection of eroding banks downstream.

Ecological Considerations

Fish passage may be possible less than 4% of the time when the structure drowns out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Lachlan River. Furthermore if the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels.

If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir.

Figure 2. Lachlan River downstream of Willandra Weir (30.09.2003, 80ML/day).

Figure 3. Lachlan River upstream of Willandra Weir (30.09.2003, 80ML/day).

At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden perch, silver perch, and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River in the Hillston/Booligal area: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon, and the threatened silver perch. Introduced species including redfin, common carp, and gambusia are also likely to be present.

At the time of inspection the riparian zone downstream of the weir was moderately vegetated with some erosion present (Figure 2), whilst the riverbank was well vegetated (including several willows) upstream of the weir, and had no active erosion present (Figure 3).

There is large woody debris present either side of the weir that would be playing an integral role as fish habitat, and could also be playing a role in the protection and stabilisation of the riverbank at some locations (Figure 2). Instream woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and the growth of algae (thereby creating a food source for macroinvertebrates).

Proposed Remediation Actions

State Water is in the process of reviewing their entire existing infrastructure within the Lachlan catchment. Recommendations made as a result of this report will be further discussed with State Water to determine options for improving fish passage at this site.

Removal of this structure is not an option at this stage as the structure is still required for provision of stock, domestic and irrigation water supply.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present or when located on a major waterway (class 1 fish habitat). With varying head loss the vertical slot fishway would is likely to be more effective in passing a greater range of fish size classes than other fishway designs.

The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location/ access, and various structural and hydrological constraints. This option is the preferred option for fish passage remediation at the Willandra Weir, however this option will only be feasible when major modifications (upgrade) of the structure is undertaken to ensure the vertical slot fishway can be secured adequately.

- **Option 2 –** Partial width rock ramp fishway

Willandra Weir only drowns out approximately 4% of the time, meaning that fish passage is not possible for the majority of the time except during high flow (flooding) conditions. The construction of a partial width rock ramp fishway would therefore make a significant contribution to improving the passage of native fish prior to structure drown out.

Modifications required to the structure would involve extending the existing spillway by strategically placing several rock ridges to create a series of resting pools that are connected by small steps or "riffles", so that an overall gradient of 1:20 was created. The rock ramp could be constructed perpendicular with the weir on the left hand bank with a "dog-leg" return back toward the weir base to ensure the greatest chance of fish finding the fishway entrance, and to take advantage of created attraction flows (Figure 1). This modification could provide passage to a greater range of fish species and size classes over a greater range of flows, and is considered the most cost effective solution to this site.

- **Option 3 –** Full width rock ramp fishway

The construction of a full width rock ramp fishway would provide similar benefits, to the partial width rock ramp fishway (Option 1), although it would operate over a wider range of flows. A considerable amount of rock would need to be imported to the site to create a full width rock ramp fishway with a gradient of 1:20 (as the weir currently sits at 4 metres in height, the fishway would be required to extend more than 80 metres downstream). A full width rock ramp fishway would therefore be an expensive option for this site.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K	>$1M
Option 1						✔
Option 2				✔		
Option 3					✔	

Recommendation

Ideally it should be recommended that a vertical slot fishway (Option 1) be constructed at Willandra Weir, as this will provide fish passage for a greater number of fish species and size classes over a wider range of flows than is currently possible. However due to the costs associated with this design, and the requirement for the structure itself to be stabilised, it may be necessary to investigate the other fishways designs as described in Options 1 and 2.

Benefits Associated with Remediation

The Lachlan River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment.

By reinstating fish passage at Willandra Weir, in excess of 110km of potential habitat would be provided to fish and other aquatic organisms upstream and downstream of this site.

HILLSTON WEIR, LACHLAN RIVER

Figure 1. Looking upstream to Hillston Weir, Lachlan River (30.09.2003, 82ML/day).

Figure 2. Looking downstream from crest of Hillston Weir, Lachlan River (30.09.2003, 82ML/day).

Description and Setting

Hillston Weir (Figure 1 and 2) is located on the Lachlan River approximately 2km south west of Hillston on a dry weather road within the Lower Lachlan catchment. The weir is approximately 4 metres in high and approximately 25 metres across the length of the crest. The weir is a constructed of sheet metal, wooden piling, and rock fill, and is a fixed crest structure with no regulating infrastructure. The weir acts as a barrier to fish passage when flows are less than 4,750ML/day due to excessive head loss and increased turbulence across the face of the structure.

Hillston Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation requirement due to the higher prevalence of fish spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Good instream and riparian habitat condition;
- Improved stream connectivity: the next major barrier upstream is Willandra Weir, approximately 93km away. There is a minor barrier between Hillston Weir and Willandra Weir – Gonowlia Weir – approximately 38km upstream. Gonowlia Weir is owned and operated by State Water, although is only considered a barrier to fish passage from May – June each year when regulating boards are in place. At all other times, State Water has advised that the regulating boards are removed to below water level (no head loss). Gonowlia Weir is therefore not considered a high priority for fish passage within the Lachlan CMA. The next barrier downstream is a privately owned weir on the property “Tallawanta”, on the Lachlan River approximately 50km away; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Lower Lachlan River are regulated by Lake Brewster. When water supplies from Lake Brewster are inadequate, water for the entire catchment is sourced from Wyangala Dam, located in the upper limits of the Lachlan River catchment. There are ten major barriers to fish passage upstream of the Hillston Weir on the Lachlan River: Willandra, Lake Brewster, Lake Cargelligo, Booberoi, Kiacatoo, Micabil, West Condobolin, Condobolin, Jemalong, and Cottons Weirs.

The closest DNR river gauge is located upstream of Hillston Weir on the Lachlan River (Station 412039). Information with regard to flows within the Lachlan River referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from State Water, DNR and NSW DPI, and uses data acquired between 10.10.1970 to 16.06.2005.

Hillston Weir prevents fish passage during most flow conditions. It has been suggested that the weir in its current condition would drown out with flows in excess

of 4,750ML/day. The time weighted flow duration curve for the Lachlan River indicates that flows would exceed 4,750ML/day approximately 7% of the time.

There are currently 22 licensed water extractors who utilise the water in the upstream weir pool, for varying purposes including town water, stock, domestic and irrigation, with total annual allocation exceeding 9,765ML (high and low security licenses).

Operational Details

Hillston Weir was originally built in 1946 and was later replaced with the existing structure in 1955. The weir is owned and operated by State Water. The original use of the weir was for town water, stock, domestic, and irrigation supply, which it continues to be used for today.

At the time of the inspection the structure required some maintenance works including the replacement of some sheet piling and protection of eroding banks downstream.

Ecological Considerations

Fish passage may only be possible at 7% of the time when the structure drowns out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Lachlan River. If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden perch, silver perch, and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River in the Hillston and Booligal area: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon, and the threatened silver perch. Introduced species including redfin, common carp, and gambusia are also likely to be present.

The Lachlan River upstream and downstream of this site has a significant amount of instream woody debris (Figure 4) - an important component of fish habitat. Riparian vegetation at the time of the inspection was sparse due to a lack of riparian fencing allowing stock to have direct access to the river. The dominant over storey plant species was river red gum and some *Wilga* sp., with little or no understorey vegetation present. Extensive erosion was also present downstream of the weir (Figure 3).

Figure 3. Lachlan River downstream of Hillston Weir (30.09.2003, 82ML/day).

Figure 4. Lachlan River upstream of Hillston Weir (30.09.2003, 82ML/day).

Proposed Remediation Actions

Hillston Weir is still required, with removal not an option at this stage. State Water is in the process of reviewing their entire existing infrastructure within the Lachlan catchment, with recommendations made within this report being discussed further with State Water to develop a solution that will improve fish passage at this site. Two different fishway designs are presented below as alternative options to provide fish passage at this site.

The general premise behind rock ramp and vertical slot fishways is to create a series of pools separated by short steps that allow fish to traverse a structure on an overall slope of 1:20.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present or when located on a major waterway (class 1 fish habitat). With varying head loss the vertical slot fishway would is likely to be more effective in passing a greater range of fish size classes than other fishway designs. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location/ access, and various structural and hydrological conditions constraints. This option is the preferred option for fish passage remediation at Hillston Weir, however it may not be feasible unless major modifications to the structure also occur.

- **Option 2 –** Full width rock ramp fishway

Hillston Weir only drowns out 7% of the time, meaning fish passage is not possible for the majority of the time, except during high flow (flooding) conditions.

The construction of a full width rock ramp fishway would make a significant contribution to improving the passage of native fish prior to drown out of the structure. The modifications required would involve extending the existing spillway through strategic placement of several transverse rock ridges, and formation of resting pools that are connected by small riffles so that an overall gradient of 1:20 was created.

As the structure is only 25 metres across, the rock ramp fishway could be constructed across the entire width of the weir, making use of the existing low flow channel positioned in the centre of the weir. This modification could provide passage to a greater range of fish species and size classes during a greater range of flows prior to drown out.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1					✔
Option 2				✔	

Recommendation

Unless major modifications are scheduled for this structure, it is recommended that a full width rock ramp fishway (Option 2) be constructed at Hillston Weir.

Benefits Associated with Remediation

The Lachlan River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits for the ecology of the catchment. By reinstating fish passage at Hillston Weir, unimpeded access to in excess of 146km of potential habitat would be provided to fish and other aquatic organisms.

TALLAWANTA WEIR, LACHLAN RIVER

Figure 1. Tallawanta Weir, Lachlan River (28.04.2005, 31.5ML/day).

Description and Setting

Tallawanta Weir (Figure 1) is located on the Lachlan River approximately 30km south west of Hillston on the Booligal Road, within the Lower Lachlan catchment. The weir is approximately 1.8 metres high and is approximately 22 metres across the length of the crest. The weir is a fixed crest structure with no regulating infrastructure and is constructed rock fill and concrete pillars. The weir acts as a barrier to fish passage when flows are less than 3,000ML/day due to excessive head loss, increased turbulence, and increased velocity across the face of structure.

Tallawanta Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation need due to the higher prevalence of fish spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Significant instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier is Hillston Weir approximately 55km away; the next barrier downstream is Booligal Weir, approximately 80km away. Both structures are owned and operated by State Water; and

- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Lower Lachlan River are regulated at Lake Brewster, with water supplies for the entire catchment sourced from Wyangala Dam, in the upper limits of the Lachlan catchment when stores are inadequate at Lake Brewster. There are 11 major barriers to fish passage upstream of Tallawanta Weir on the Lachlan River which include: Hillston, Willandra, Lake Brewster, Lake Cargelligo, Booberoi, Kiacatoo, Micabil, West Condobolin, Condobolin, Jemalong, and Cottons Weirs.

The closest DNR river gauge is located upstream of Hillston Weir on the Lachlan River (station 412039). Information with regard to flows within the Lachlan River referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and NSW DPI, and uses data acquired between 10.10.1970 to 16.06.2005.

Tallawanta Weir prevents fish passage over most flow conditions. It has been estimated that the weir in its current condition would drown out with flows in excess of 3,000ML/day. The time weighted flow duration curve for the Lachlan River shows that flows would exceed 3,000ML/day approximately 12% of the time.

There is currently only one licensed extractor (the owner of Tallawanta Weir), who utilises the upstream weir pool, however there are as many as 16 other license holders who extract water in the reach from Wheabalah Bridge, upstream to Hillston. The total allocation for high and low security licenses is 60,686ML per annum.

Operational Details

Tallawanta Weir is privately owned and is located on the property “Tallawanta”. The weir was originally built in 1992, primarily for irrigation and some stock and domestic use. The weir backs water up into an irrigation off-take channel located directly upstream on the right hand bank.

During a previous site inspection in 2003 it was noted that the weir had been partially washed away on the left hand bank. At the time of the current inspection (2005), it was noted that the structure had undergone some repair work on the left hand bank, and had been returned to its original height. The landholder advised that the works had taken place after the replacement of an RTA bridge located just downstream. The *Fisheries Management Act 1994* states “the Minister may require a person who constructs, alters or modifies a dam or weir to provide fish passage”.

Because of the location of this structure in the catchment, and the presence of remnant populations of migratory native fish including golden perch, Murray cod, and the threatened silver perch, it is highly likely that fish passage remediation works at this site will greatly benefit these remnant fish communities and other aquatic organisms.

Ecological Considerations

Fish passage may only be possible at 12% of the time when the structure drowns out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Lachlan River.

Figure 2. Lachlan River downstream of Tallawanta Weir (28.04.05, 31.5ML/day).

Figure 3. Lachlan River upstream of Tallawanta Weir (28.04.05, 31.5ML/day).

Furthermore if the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden perch, silver perch, and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River in the Hillston and Booligal area: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon, and the threatened silver perch. Introduced species including redfin, common carp, and gambusia are also likely to be present.

The Lachlan River at this site is moderately vegetated, with some minor erosion present downstream of the weir (Figures 2 and 3). There is large woody debris present along this stretch of the river that would be playing an integral role as fish habitat, and could also be playing a role in the protection and stabilisation of the riverbank. Instream woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and the growth of algae (thereby creating a food source for macroinvertebrates).

There is some aquatic vegetation downstream of the weir (including *Typha* spp.). Bank stabilisation works would complement any fish passage remediation carried out at this site.

Proposed Remediation Actions

As the structural condition of this weir is likely to deteriorate over time, any investment of a fishway at this site would need to be protected. This may require undertaking structural works on the weir to reinforce it. This cost has not been calculated into the fish passage options below.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present or when on class 1 fish habitat such as the Lachlan River. With varying head loss the vertical slot fishway would is likely to be more effective in passing a greater range of fish size classes than other fishway designs.

The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location, access, and various structural and hydrological constraints. This option is the preferred option for fish passage remediation at Tallawanta Weir, however the cost associated with the installation of a vertical slot fishway at this site would increase, as the weir would need to undergo considerable modifications, if not be rebuilt entirely.

- **Option 2 –** Full width rock ramp fishway

Potentially Tallawanta Weir only drowns out approximately 12% of the time, meaning fish passage is not possible for the majority of the time, other than during high flow conditions. The construction of a full width rock ramp fishway designed to pass fish prior to the drown out of the structure would make a significant contribution to improving the passage of native fish, and provide a significant benefit to the ecology of the Lachlan River.
Modifications would involve extending the existing spillway so that a gradient of 1:20 was created by strategically placing several transverse rock ridges to create resting pools that are connected by small steps or "riffles". This modification could provide passage to a greater range of fish species and size classes over a greater range of flows than is currently possible. The weir is only 18 metres across and 1.8 metres high, enabling a suitable design to be developed following some engineering input. Detailed specifications for the construction of rock ramp fishways can be obtained from NSW DPI and must be incorporated into any engineering designs developed.

A potential restriction that may be encountered with this option is access to suitable rock. As the structure is 1.8 metres high, the fishway would extend nearly 40 metres downstream (to create a fall of 1:20), thus requiring a large amount of rock for its construction. If this rock cannot be sourced, alternative options should be investigated (such as a partial width rock ramp fishway, or removal).

- **Option 3 –** Removal

At present the landholder would like to retain the weir and the associated license so that water can continue to be extracted for irrigation, domestic and stock supply. It has previously been suggested that this landholder may continue to extract water if the weir is removed by excavating a sump in the side of the riverbank from which water may be pumped. This option should be considered by the landholder, as it is the most cost effective solution for this site, and would provide the greatest benefits to migrating fish species in this section of the Lachlan River. A hydrological survey may be required to determine the feasibility of this option (to determine river bed levels and corresponding water levels following weir removal). The estimated cost of removing the weir structure and undertaking necessary surveys is less than $10,000.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1				✔	
Option 2			✔		
Option 3	✔				

Recommendation

It is recommended that in the first instance the needs of the landholder be determined with respect to Option 3 (i.e. determine whether the structure can be removed or not). Alternatively if the weir is to be retained, then a full width rock ramp fishway (Option 2) should be constructed.

Benefits Associated with Remediation

The Lachlan River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment including reinstating more natural nutrient and sediment transport processes.

By reinstating fish passage at Tallawanta Weir, in excess of 135km of potential habitat either side of the structure would be provided to fish and other aquatic organisms.

WEST CONDOBOLIN WEIR, LACHLAN RIVER

Figure 1. West Condobolin Weir, Lachlan River (28.10.2004, 207ML/day).

Description and Setting

West Condobolin Weir (Figure 1) is located on the Lachlan River in the Lower Lachlan River catchment, approximately 10km downstream of Condobolin and can be accessed from Kiacatoo Road. The weir is approximately 1.5 metres high and 25 metres across the length of the crest and is constructed entirely of concrete with eight dropboard bays.

Advice from DNR is that the West Condobolin Weir is not licensed, with State Water confirming that the weir has not been managed for some time. The weir acts as a barrier to fish passage when flows are less than approximately 3,800ML/day due to excessive head loss, increased turbulence, and increased velocity across the face of the structure.

West Condobolin Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the mid – lower end of the catchment has a higher conservation requirement due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Significant instream and riparian habitat condition;

- Improved stream connectivity: the next upstream barrier to fish is Condobolin Weir 10km away, which is owned and operated by State Water; the next barrier downstream is Micabil Weir on the Lachlan River 20km away, which is owned by a Private Water Trust; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Wyangla Dam regulates flows within the Lachlan River, and is located in the upper limits of the Lachlan River catchment. There are four major barriers to fish passage upstream of West Condobolin Weir on the Lachlan River: Condobolin, Jemalong, Cottons, and Apex Weirs.

The closest DNR river gauge is located upstream near Williams Street bridge, within the Condobolin Weir pool on the Lachlan River (station 412006). Information with regard to flows within the Lachlan River referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and NSW DPI, and uses data acquired between 01.09.1973 – 23.06.2005.

It has been estimated that the weir in its current condition would drown out with flows in excess of 3,800ML/day. The time weighted flow duration curve for the Lachlan River at the Condobolin Bridge shows that flows would exceed 3,800ML/day less than approximately 17% of the time.

The weir backs water up into Nerathong Creek. There are currently four licensed water extractors who utilise the water in the upstream weir pool for varying uses including stock, domestic, and irrigation, with total annual allocation of 644ML/day (high and low security licenses).

Operational Details

A Private Water Trust owns West Condobolin Weir. The weir was built in 1926 for the supply of water for irrigation, stock, and domestic purposes – it is now used for recreation, with some riparian users likely to be associated with it. As advised by DNR, the weir is no longer licensed, is not currently being maintained, and its drop boards have remained inactive for many years. Currently there is a head loss in excess of 600mm, which exceeds the swimming capabilities of native fish within the Lachlan River catchment.

Ecological Considerations

Fish passage may be possible up to 17% of the time when the structure drowns out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Lachlan River. Furthermore if the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Figure 2. Lachlan River downstream of West Condobolin Weir (28.10.2004, 207ML/day).

Figure 3. Lachlan River upstream of West Condobolin Weir (28.10.2004, 207ML/day).

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden perch, silver perch, and Murray cod occur in the area and have recently been caught. The HCV database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon, and the threatened silver perch. Introduced species including redfin, common carp, goldfish, and gambusia are also likely to be present.

The Lachlan River at this site is moderately vegetated (dominant overstorey species being river red gum), with some minor erosion either side of the weir (Figures 2 and 3). There is some large woody debris along this stretch of the river that would be playing an integral role in the development of fish habitat and could also play a role in the protection and stabilisation of the riverbank (Figure 3). Instream woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and the growth of algae (thereby creating a food source for macroinvertebrates). At the time of the inspection there was limited ground cover on the banks, potentially as a result of prevailing drought conditions.

Proposed Remediation Actions

Despite the fact that the weir may drown out several times during the year, there remain significant periods of time where the passage of all fish will be affected. If these periods coincide with spawning migrations for particular species, the weir will continue to have a significant impact on the migratory fish community within the Lachlan River.

- **Option 1 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of the Lachlan River and provide significant improvements in the availability of aquatic and riparian habitat to fish and other aquatic organisms. The weir is currently not being maintained and therefore the removal of this structure should be considered a viable option following further consultation with DNR, State Water, and nearby landholders.

Removal of the weir structure has a much greater cost benefit than other remediation options. Access to the site is possible with an excavator via Kiacatoo Road, with structure debris requiring removal to a dumpsite above the floodplain. Estimated total cost for complete removal of this structure is less than $10,000).

- **Option 2 –** Structure modification and full width rock ramp fishway

Currently the majority of flow passes down the centre of the weir through the vacant dropboard bays. By rendering the other dropboard bays inoperable and reducing the height of the weir, flows could be permanently directed down the centre of the channel and into a low flow section of a full width rock ramp fishway. The alteration to the existing structure to include a rock ramp fishway below the fixed crest would make a significant contribution to improving the passage of native fish at this site at all flows prior to drown out for a relatively small investment.

The fishway would need to be constructed to the specifications as recommended by NSW DPI, including to an overall gradient of 1:20.

The fishway would possess a central low flow channel that is formed by strategically placing transverse rock ridges to create resting pools that are connected by small steps or “riffles”. The remainder of the structure would also be on a 1:20 slope, both upstream-downstream, and laterally (toward the river bank), so that water would move out from the central low flow channel as river flows increased. Detailed specifications for the construction of rock ramp fishways can be obtained from NSW DPI and should be incorporated into the initial planning stage of the project.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1	✔				
Option 2			✔		

Recommendation

Complete removal of this structure is the preferred remediation option for this site (Option 1), as the weir is no longer licensed and it is regarded as an illegal structure. Further consultation is required between the landowner and DNR, however, if it is determined that removal of the structure would disadvantage upstream license holders and riparian users, then modification of the structure and installation of a full width rock ramp fishway (Option 2) is the next best option.

Benefits Associated with Remediation

The Lachlan River contains some important fish habitat that should be protected, with the reinstatement of fish passage along the entire system is likely to generate substantial benefits to the ecology of the catchment.

By reinstating fish passage at West Condobolin Weir in excess of 30km of potential habitat either side of the weir would be provided to fish and other aquatic organisms.

BOOLIGAL WEIR, LACHLAN RIVER

Figure 1. Booligal Weir, Lachlan River (01.10.2003, 18ML/day).

Description and Setting

Booligal Weir (Figure 1) is located within the township of Booligal on the Lachlan River in the Lower Lachlan catchment. The weir is approximately 1.8 metres in height and is approximately 30 metres across the length of the crest. Booligal Weir is a fixed crest structure constructed of sheet/ wooden piling and rock fill with a concrete cap, and has no regulating infrastructure associated with it. The weir acts as a barrier to fish passage during flows less than 1,710ML/day due to excessive head loss and increased turbulence across the face of the structure.

Booligal Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the mid – lower end of the catchment has a higher conservation need due to the higher prevalence of fish spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Good instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier is a privately owned weir on the property “Tallawanta” located on the Lachlan River approximately 86km away. Downstream there are three privately owned drop board weirs located in the next 100km. These barriers are approximately 1 metre high and may only drown out during flooding events (although drown out frequencies for these structures were not available). These weirs are used

primarily for stock and domestic water supply. Landholders in this section of the river have advised that very little water reaches them due to the high level of extractions that occur upstream; and

- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Lower Lachlan River are regulated at Lake Brewster and when water supplies are inadequate here, water for the entire catchment is sourced from Wyangala Dam, which is located in the upper limits of the Lachlan catchment. There are 12 major barriers to fish passage upstream of the Booligal Weir on the Lachlan River, which include Tallawanta, Hillston, Willandra, Lake Brewster, Lake Cargelligo, Booberoi, Kiacatoo, Micabil, West Condobolin, Condobolin, Jemalong, and Cottons Weirs.

There is a DNR river gauge associated with Booligal Weir on the Lachlan River (station 412005). Information with regard to flows within the Lachlan River referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and NSW DPI, and uses data acquired between 13/10/1970 to 15/06/2005.

The weir is preventing fish passage over most flow conditions. It has been estimated that the weir in its current condition would drown out when flows are in excess of 1,710ML/day. The time weighted flow duration curve for the Lachlan River shows that flows would exceed 1,710ML/day approximately 13 % of the time.

There are currently six licensed water extractors who utilise the water in the upstream weir pool for varying uses including town water, stock, domestic, and irrigation, to a total annual allocation of 8,090ML (high and low security licenses).

Operational Details

Booligal Weir was originally built in 1906 and was later replaced with the existing structure in 1945. The weir is owned and operated by State Water. The weir continues to be used for its original purpose of supplying town, stock, domestic, and irrigation water to the surrounding area.

Ecological Considerations

Fish passage may only be possible when the weir drowns out (approximately 13% of the time), with the timing of these flows not necessarily coinciding with spawning migrations of all or any of the resident fish species within the Lachlan River. If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focussing on the traditional iconic adult recreational species.

Figure 2. Erosion downstream of Booligal Weir, Lachlan River (01.10.2003, 18ML/day).

Figure 3. Lachlan River downstream of Booligal Weir (01.10.2003, 18ML/day).

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden and silver perch and Murray cod occur in the area and have recently been caught.

The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River in the Booligal area: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon and the threatened silver perch. Introduced species including redfin, common carp, and gambusia are also likely to be present.

With regard to the three privately owned weirs downstream of Booligal Weir, further landholder consultation and a hydrological assessment would need to be undertaken before any further decisions were made with regard to these weirs. As all three are located in the Lower Lachlan catchment, they are also considered priority sites for fish passage remediation. Harris (2004) identified lowland river reaches ("downstream of Condobolin") as integral habitats for fish recruitment for many migratory species including golden perch, Murray cod and silver perch - all of which are known to be present in the Lachlan River below Booligal Weir.

Landholders have raised their concerns regarding the large numbers of carp located at this end of the system. In particular, the adjacent landholder identified "Reed Bed Swamp" (downstream of one of these weirs), as a breeding ground for carp. As a result this landholder was hesitant about supporting a fishway at their weir, which may lead to greater dispersal of this introduced species.

It is important to realise that the area downstream of Booligal Weir would be classed as 'core habitat' critical for the recruitment of native fish (Harris 2004). A project could be developed with the Murray Darling Basin Commission (MDBC) to not only address fish passage at these sites, but also carp control. The MDBC are heavily involved in strategies to address carp control across the entire basin. A coordinated effort could be made to control carp by investigating targeted fishing campaigns, screening wetlands, carp separation cages, and river rehabilitation in this area in conjunction with fish passage remediation options.

The Lachlan River upstream and downstream of the weir (Figures 1, 2 and 3) was moderately vegetated at the time of the inspection and was predominantly dominated by river red gum. There was some bank erosion present downstream, with several stands of willows also occurring in this area. The rehabilitation of this site through erosion protection works, riparian fencing, revegetation, and willow control would complement any fish passage remediation works being undertaken at this site by improving fish habitat.

Proposed Remediation Actions

As this structure is still required, and because the condition of this weir is likely to deteriorate over time, reinstatement of the structure would need to occur to protect any investment in a fishway at this site. This may require undertaking structural works to reinforce the weir, which have not been calculated into the fish passage options below.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present. With varying head loss the vertical slot fishway is likely to be more effective in passing a greater range of fish size classes than other fishway designs. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location, access, and various structural and hydrological constraints.

This is the preferred option for fish passage remediation at the Booligal Weir, however the cost associated with the installation of a vertical slot fishway would increase, as a result of the weir requiring considerable structural modifications in addition to the construction of the fishway itself. It is recommended that the installation of a fishway at this site be undertaken as part of any future weir upgrade.

- **Option 2–** Full width rock ramp fishway

As the weir only drowns out approximately 13% of the time, fish passage is not possible for the majority of the time except during high flow (flooding) conditions (see *Hydrology* section). The construction of a full width rock ramp fishway would make a significant contribution to improving the passage of native fish as it would enable fish to pass prior to drown out of the structure, and therefore over a wider range of flows. Modifications to the structure would involve extending the existing spillway so that a gradient of 1:20 was created and strategically placing several rock ridges to create resting pools that are connected by small riffles. The rock ramp could be constructed across the entire width of the weir (30 metres) and include a low flow section in the centre of the weir. This modification could provide passage to a greater range of fish species and size classes over a greater range of flows and would provide additional support to the structure during high flow events.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1					✔
Option 2			✔		

Recommendation

It is recommended that a vertical slot fishway (Option 1) be investigated in the event that any major modifications to this weir take place. A full width rock ramp fishway (Option 2) could also be considered at Booligal Weir after further assessment of the site constraints. State Water is in the process of reviewing their entire existing infrastructure within the Lachlan catchment. Recommendations made as a result of this report will be discussed with State Water to improve fish passage at this site.

Further investigations should be undertaken to address fish passage and carp control at the three privately owned weirs further downstream on the Lachlan River as discussed in *Ecological Considerations*.

Benefits Associated with Remediation

The Lachlan River contains important fish habitat that should be protected, with reinstatement of fish passage along the entire system generating substantial benefits to the ecology of the catchment. By reinstating fish passage at Booligal Weir unimpeded access to in excess of 186km of potential habitat would be allowed for fish and other aquatic organisms.

CONDOBOLIN WEIR, LACHLAN RIVER

Figure 1. Condobolin Weir, Lachlan River (29.04.05, 148.5ML/day).

Description and Setting

Condobolin Weir (Figure 1) is located within the town limits of Condobolin, 300 metres downstream of the Williams Street Bridge on the southern edge of Condobolin, on the Lachlan River (Lower Lachlan River catchment). The weir is approximately 2.1 metres high and 24 metres across the length of the crest and is constructed entirely of concrete. Condobolin Weir is a fixed crest structure, with no gates or culverts associated with it, and acts as a barrier to fish passage when flows are less than approximately 4,100ML/day due to excessive head loss and increased turbulence across the face of the structure.

Condobolin Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (the site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the mid – lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to fish is a privately owned weir on “Waroo Stud” 40km away, with the next barrier being Jemalong Weir (another 47km upstream). The next barrier downstream is West Condobolin Weir on the Lachlan River approximately 10km away, which is currently by a private Water Trust; and

- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Lachlan River are regulated by Wyangla Dam, which is located in the upper limits of the Lachlan River catchment. In addition to the small privately owned structure, there are two major barriers to fish passage upstream of the Condobolin Weir on the Lachlan River, Jemalong Weir and Cottons Weir.

Upstream, the privately owned weir at "Waroo Stud" is drowned out most of the time and is not considered a significant barrier to fish except during extremely low flow conditions. Currently this weir is also breached on the left hand bank which allows fish passage during these low flow conditions. The landholder has been advised that if the weir were to be reinstated, approval would need to be sought from NSW DPI (Fisheries Management) before any instream works commenced.

Jemalong Weir is situated another 47km upstream from the weir at "Waroo Stud". This weir is currently owned and operated by State Water and is one of the highest priority weirs for fish passage in the Lachlan catchment. Jemalong Weir is an undershot weir that, due to its size, does not drown out. Negotiations are currently underway to address fish passage at this site as a result of an environmental offset to a local development.

The closest DNR river gauge is located upstream near the Williams Street Bridge within the Condobolin weir pool on the Lachlan River (station 412006). Information with regard to flows within the Lachlan River referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from State Water, DNR and NSW DPI, and uses data acquired between 01.09.1973 – 23.06.2005.

Condobolin Weir is preventing fish passage during most flow conditions. It has been estimate that the weir in its current condition would drown out with flows in of approximately 4,100ML/day. The time weighted flow duration curve for The Lachlan River at the Condobolin Bridge shows that flows would exceed 4,100ML/day less than 16% of the time. It was noted in the Initial Weir Review that water flow over the summer months could be minimal if irrigation water for the Lower Lachlan is being provided by Lake Brewster. If Lake Brewster is empty and water for the entire catchment is being sourced from the Wyangla Dam upstream, Condobolin Weir has been known to drown out for several months at a time.

There are currently 29 licensed water extractors who utilise the water in the upstream weir pool for varying uses including stock, domestic and irrigation, with total annual allocation exceeding 7,329ML/day (high and low security licenses).

Operational Details

Condobolin Weir is owned and operated by State Water. The weir was built in 1925 for supply of water to the town of Condobolin and for stock and domestic use. Presently the weir is used for recreation, stock, domestic and irrigation supply for upstream water users, but not for providing a town water supply. Water is extracted for the town supply from Goobang Weir located approximately 3km upstream on Goobang Creek.

Ecological Considerations

Fish passage may be possible less than 16% of the time when the structure drowns out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Lachlan River.

Figure 2. Lachlan River downstream of Condobolin Weir (29.04.2005, 145.8ML/day).

Figure 3. Lachlan River upstream of Condobolin Weir (29.04.2005, 145.8ML/day).

If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden and silver perch and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River in the Hillston and Booligal area: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon and the threatened silver perch. Introduced species including redfin, common carp and gambusia are also likely to be present.

This site has some instream woody debris, which is an important component of fish habitat. The site is dominated by river red gum, although there are several stands of willows (Figures 2 and 3) that should be removed in conjunction with any fish passage remediation works carried out at this site.

Proposed Remediation Actions

Despite the fact that the weir may drown out several times during the year, there remain significant periods of time where the passage of all fish will be affected. If these periods coincide with spawning migrations for particular species, the weir will continue to have a significant impact on the migratory fish community within the river.

Condobolin Weir is still required and its removal is not considered a viable option at this point. State Water is in the process of reviewing their entire existing infrastructure within the Lachlan catchment. Recommendations made as a result of this report will be discussed further with State Water to determine a solution that will improve fish passage at this site.

The general premise behind rock ramp and vertical slot fishways is to create a series of pools separated by short steps that allow fish to traverse a structure on an overall slope of 1:20. Two different fishway designs are described below to provide alternative fish passage options for this site.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present. With varying head loss the vertical slot fishway is likely to be more effective in passing a greater range of fish size classes than other fishway designs. The construction of the weir with concrete makes it an ideal anchor for securing the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location/access, and various structural and hydrological constraints. This option is the preferred option for fish passage remediation at Condobolin Weir.

- **Option 2 –** Full width rock ramp fishway

A full width rock ramp fishway would also provide fish passage for a greater range of fish species and size classes over a greater range of flows than is currently possible.

The premise behind a rock ramp fishway is to provide a gradual slope of 1:20 by strategically placing rock ridges placed parallel to the weir to create resting pools that are connected by small riffles (or steps), enabling fish to traverse the structure. Flows would be directed down a central "low flow" channel in the full width rock ramp fishway, enabling fish passage to occur for the majority of the time. As flows increased, water would move laterally out from the low flow channel, where lower velocities would be encountered and fish passage encouraged.

However, unlike a vertical slot fishway, it is more difficult to secure a rock ramp fishway to a structure such as Condobolin Weir unless a considerable amount of concrete and steel pylons are used.

Projected Remediation Costs

Projected cost	**< $50K**	**$50K - $150K**	**$150K - $250K**	**$250K - $500K**	**> $500K**
Option 1				✔	
Option 2			✔		

Recommendation

Due to the greater range of flows under which it is operational, the construction of a vertical slot fishway (Option 1) is the preferred remediation action for this site.

Benefits Associated with Remediation

The Lachlan River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Condobolin Weir, unimpeded access to in excess of 97km of potential habitat would be provided to fish and other aquatic organisms.

BOOBEROI WEIR, LACHLAN RIVER

Figure 1. Booberoi Weir, Lachlan River (>200ML/day).

Figure 2. Booberoi Weir spillway during low flow, Lachlan River (20ML/day).

Description and Setting

Booberoi Weir (Figures 1 and 2) is located approximately 18km north-east of Eubalong on the Booberoi Road in the Lower Lachlan River catchment. Booberoi Weir approximately 3.5 metres high and 85 metres across the length of the crest and is constructed entirely of concrete. The weir is a fixed crest structure, and has no regulating gates or culverts associated with it. Booberoi Weir acts as a barrier to fish passage when flows are less than approximately 12,000ML/day due to excessive head loss, and increased turbulence across the face of the structure.

The Booberoi Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Good instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to fish is a Kiacatoo Weir, approximately 23km away, the next barrier downstream is Lake Cargelligo Weir on the Lachlan River 57km away. Both structures are owned and operated by State Water. Lake Cargelligo Weir is currently undergoing investigations by State Water for the construction of a vertical slot fishway with construction expected to commence in the 06/07 financial year; and
- Low frequency of drown out (flow at which fish passage is possible, where headloss and velocity are minimal).

Hydrology

Flows within the Lachlan River are regulated by Wyangala Dam, which is located in the upper limits of the Lachlan River catchment. There are six major barriers to fish passage upstream of Booberoi Weir on the Lachlan River and include: Kiacatoo, Micabil, West Condobolin, Condobolin, Jemalong and Cottons Weirs.

The closest DNR river gauge is located downstream at Lake Cargelligo Weir on the Lachlan River (station 412011). Information with regard to flows within the Lachlan River referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and NSW DPI, and uses data acquired between 18.09.1970 – 05.04.2005.

Booberoi Weir is preventing fish passage over most flow conditions. It is predicted that the weir in its current condition would drown out with flows in excess of 12,000ML/day. The time weighted flow duration curve for the Lachlan River at Lake Cargelligo Weir indicates that flows would exceed 12,000ML/day less than 1% of the time.

There are currently 12 licensed water extractors who utilise the upstream weir pool, with varying uses including stock, domestic, and irrigation, with total annual allocation exceeding 7,271ML (high and low security licenses).

Operational Details

The Booberoi Weir was built in 1902 to divert flows down Booberoi Creek for stock, domestic use and some irrigation flows and to supply water to the railway line to Broken Hill. The structure is owned and operated by State Water.

On the right hand bank there exists a natural rock bar, which in high flow conditions has the potential to pass some fish upstream and downstream past the weir.

Ecological Considerations

Fish passage may be possible less than 1% of the time, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Lachlan River.

Figure 3. Lachlan River upstream of Booberoi Weir (25.09.2003, 20ML/day).

Figure 4. Lachlan River downstream of Booberoi Weir (25.09.2003, 20ML/day).

If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focussing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicate that fish species including freshwater catfish, golden and silver perch and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River near Booberoi Weir: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon and the threatened silver perch. Introduced species including: redfin, common carp and gambusia are also likely to be present.

The Lachlan River either side of Booberoi Weir is well vegetated (Figures 3 and 4), with stands of willows present in the upstream weir pool. There is a public reserve on the right hand bank where the groundcover is often slashed. There is no bank erosion either side of the site and the riverbed at this location is very stable as a result of the exposed bedrock, which is acting as a natural bed control.

Proposed Remediation Actions

Booberoi Weir is still needed and its removal is not considered a viable option. State Water is in the process of reviewing their entire existing infrastructure within the Lachlan catchment. Recommendations made as a result of this report will be further discussed with State Water to come up with a solution that will improve fish passage at this site.

- **Option 1 -** Construction of a partial width rock ramp fishway

As the Booberoi Weir drowns out infrequently (<1% of the time), there remain significant periods of time where the passage of all fish will be affected. The addition of a partial width rock ramp fishway to the existing structure that allows fish passage prior to structure drown out would make a significant contribution to improving the passage of native fish at this site for a relatively small investment.

A natural rock spillway (Figure 1) exists on the right hand bank. This natural spillway has the potential to pass fish in high flow conditions, although by making some simple modifications to the spillway and structure, fish passage may be possible over a greater range of flows. Modifications would include cutting a low flow channel in the concrete weir wall (notching) on the right hand side to increase the flow over the spillway. The partial width rock ramp fishway could then be constructed perpendicular to the weir itself on the right hand bank with a return “dog-leg” bringing the downstream entrance back toward the weir base to take advantage of an attraction flows. By extending this existing natural rock spillway to achieve a gradient of 1:20, and by strategically placing several rock ridges to create resting pools that are connected by riffles (small steps), this modification would provide passage to a greater range of fish species and size classes during adequate flow periods.

- **Option 2 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present. With varying head loss the vertical slot fishway would be more effective in passing a greater range of fish size classes.

The construction of a vertical slot fishway at this site would be the most effective, but highest cost option for fish passage the concrete weir wall providing a suitable anchor for the fishway and its associated infrastructure. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location/access, and various structural and hydrological constraints.

A vertical slot fishway is the preferred option at this site, as it would allow fish passage over the greatest range of flows, including low flow periods when the basic partial width rock ramp fishway design would not. As Booberoi Weir is one of the largest barriers to fish migration in at least 100km stretch of river, it is important to maximise fish passage over a wide range of flows.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1			✔		
Option 2					✔

Recommendation

The construction of a vertical slot fishway (Option 2) is the preferred remediation action for this site.

Benefits Associated with Remediation

The Lachlan River contains important fish habitat that should be protected, and the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Booberoi Weir fish and other aquatic organisms would be allowed unimpeded access to over 80km of potential habitat. A willow eradication program undertaken in conjunction with fish passage works at this site would also be advantageous.

COTTONS WEIR, LACHLAN RIVER

Figure 1. Cottons Weir, Lachlan River (05.04.2006, 754ML/day).

Figure 2. Apex Weir located approximately 3km upstream from Cottons Weir on the Lachlan River at Forbes (05.04.2006, 754ML/day).

Description and Setting

Cottons Weir (Figure 1) is located on the Lachlan River approximately 8km downstream of Forbes on the West Wyalong Road in the Mid - Upper Lachlan River catchment. The weir is approximately 2 metres high and 35 metres across the length of the crest. The weir is a concrete fixed crest structure, with no gates or culverts associated with it, and acts as a fish passage barrier when flows are less than approximately 5,000ML/day due to excessive head loss and increased turbulence across the face of the structure.

Cottons Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus,* and anecdotal sightings of Macquarie perch, *Macquaria australasica*);
- Diverse range of native fish (High Conservation Value);
- Significant instream and riparian habitat condition, one side of the river is protected by a reserve;
- Improved stream connectivity: the next major barrier to fish upstream is the State Water owned Wyangala Dam, approximately 130km upstream in the upper reaches of the Lachlan catchment. The next major downstream fish passage barrier is Jemalong Weir approximately 40km away. Although this is the location of major fish passage barriers, smaller barriers do occur upstream (Apex Weir located approximately 3km away), and downstream (two privately owned weirs on the Lachlan River between Forbes and Jemalong Weir located on the property “Borambil Park”). These weirs are considered a low priority for fish passage as they are drowned out more often then not. However, if it was determined that these weirs were no longer needed, they should be removed to minimise the potential for debris accumulation behind the weirs and further restriction to flows and fish passage does not occur during low flow conditions; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Lachlan River are regulated by Wyangla Dam, which is located in the upper limits of the Lachlan River catchment. Cottons Weir is the only major barrier to fish passage between Forbes and Wyangla Dam.

As mentioned above, there is a small unlicensed rock weir “Apex Weir” (Figure 2) located approximately 3km upstream of Cottons Weir on the Lachlan River within the town limits of Forbes. This weir drowns out more frequently than Cottons Weir but still acts as a barrier to fish passage during low flow periods. Apex Weir is approximately 1.2 metres high and drowns out during flows in excess of 1,000ML/day, which is estimated to occur approximately 70% of the time. The Forbes town water supply intake is located just upstream from this weir. Despite this, it is possible that modifications to the intake pipe could be undertaken enabling the weir to be removed. The future management of Apex Weir should be addressed, with discussions between Council and NSW DPI currently underway.

The closest DNR river gauge is located within Cottons Weir pool on the Lachlan River (station 412004). Information with regard to flows within the Lachlan River referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from State Water, DNR and NSW DPI, and uses data acquired between 30.07.1970 – 27.04.2005.

Cottons Weir is preventing fish passage during most flow conditions. It has been estimated that the weir in its current condition would drown out when flows are in excess of 5,000ML/day. The time weighted flow duration curve for the Lachlan River at Cottons Weir shows that flows would exceed 5,000ML/day less than 13% of the time.

Operational Details

Cottons Weir is owned and operated by State Water. The original structure was built in 1915 and was later replaced with the existing weir in 1929 for supply of water to the town of Forbes. The weir is currently also used for recreation, stock, domestic and irrigation supply for upstream water users. Town water is extracted further upstream near Apex Weir.

Ecological Considerations

Fish passage may be possible less than 13% of the time when the structure drowns out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Lachlan River. If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including river blackfish, Macquarie perch, freshwater catfish, golden and silver perch and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River in the Forbes area: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon and the threatened silver perch. Introduced species including redfin, common carp and gambusia are also likely to be present.

It has been suggested that the structures located on the main stem of the Lachlan River between Forbes and Wyangala are not as high priority for fish passage as others further down the catchment because of the effects of cold water pollution from Wyangala Dam. Wyangala Dam has been classified as having “high” severity for cold water pollution (Preece 2003), and it is known that cold water pollution from this storage may extend anywhere from 170km – 400km downstream (Lugg 1999).

Cold water pollution can impact on the natural migration and spawning of our native fish species, the availability of food sources such as zooplankton, and the growth of instream aquatic vegetation (NSW Fisheries 2001).

Figure 3. Lachlan River downstream of Cottons Weir (05.04.2006 754ML/day).

Figure 4. Lachlan River upstream of Cottons Weir (05.04.2006 754ML/day).

NSW DPI still considers Cottons Weir as a priority for fish passage, and believes that the issue of cold water pollution should be addressed in conjunction with the assessment of all barriers within the Upper Lachlan catchment.

The reinstatement of fish passage at Cottons Weir may be further realised if fish passage works take place at Jemalong Weir.

Jemalong Weir is the next major barrier to fish passage downstream and is currently being investigated for a fishway as an environmental offset as part of the conditions for DNR Ministerial consent to a major development in the Lachlan catchment. A vertical slot fishway is the preferred option for Jemalong Weir, with a cost estimate of in excess of $1.5M.

Jemalong Weir is a high priority site in the Lachlan catchment, as it is an undershot weir with vertical steel gates that does not drown out. Undershot weirs are known to have a negative impact on fish larvae (up to 40% mortality of larvae passing through an undershot weir, compared to only 16% in an overshot weir) (Marttin and Graaf 2002, Baumgartner 2005). It is therefore important that we understand the effect of weirs on fish communities so that they can be better managed to assist in the protection of native fish and their habitats in the entire Lachlan catchment.

This site surrounding Cottons Weir has some important fish habitat components including instream woody debris and well vegetated banks dominated by river red gum (Figures 3 and 4). These key features contribute to the river ecology by providing food and shelter to the aquatic organisms. Upstream and downstream from the weir there are several stands of willows (Figures 2 - 4). Management of the surrounding willows should be addressed in conjunction with fish passage works at this site.

Proposed Remediation Actions

Despite the fact that the weir may drown out several times during the year, there remain significant periods of time where the passage of all fish will be affected. If these periods coincide with spawning migrations for particular species, the weir will continue to have a significant impact on the migratory fish community within the catchment.

Cottons Weir is still required, with its removal not considered a viable option at this stage. State Water is in the process of reviewing their entire instream infrastructure within the Lachlan catchment. Recommendations made as a result of this report will be further discussed with State Water to determine a solution that will improve fish passage at this site.

The general premise behind rock ramp and vertical slot fishways is to create a series of pools separated by short steps that allow fish to traverse a structure on an overall slope of 1:20. Two different fishway designs are described below to provide alternative fish passage options for this site.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present. With varying head loss the vertical slot fishway would be more effective in passing a greater range of fish size classes at this site than other fishway designs.

The concrete composition of the weir makes it an ideal anchor for securing the vertical slot fishway and its associated infrastructure. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location/access and various structural and hydrological constraints. Installation of a vertical slot fishway is the preferred option for fish passage remediation at Cottons Weir.

- **Option 2 –** Partial width rock ramp fishway

This type of fishway is constructed using strategically placed rock ridges to create resting pools that are connected by small riffles or steps to provide passage to a greater range of fish species and size classes during adequate flow periods.

A low flow channel is located on the left hand bank (Figure 1), which may lend itself to modification and allow for construction of a partial width rock ramp fishway. If this were to occur, small modifications to the weir structure may be required to direct flow down the fishway and create attraction flow on this side of the weir.

Under the variable headloss conditions encountered on the mainstem of the Lachlan River, a vertical slot fishway would be able to operate better than a partial width rock ramp fishway.

- **Option 3 –** Removal of Apex Weir (Figure 2)

Any fish passage remediation works that are carried out at Cottons Weir would be benefited if Apex Weir (upstream within the township of Forbes) were partially or completely removed.

The removal of Apex Weir may be achieved following further consultation with Forbes Shire Council to determine alternate options for supply of water to the town (such as the extension of off-take pipes). Works would involve the removal of the concrete rubble to an offsite location, and could be achieved over a two day period with an estimated cost of <$10,000.

In addition to the removal of the weir, a coordinated habitat rehabilitation project could be undertaken at this site to remove several stands of willows either side of the weir and revegetate the site. This would provide considerable benefits to the aquatic habitat and aquatic communities, and enhance the aesthetic qualities for the adjacent caravan park.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1					✔
Option 2			✔		
Option 3		✔			

Recommendation

The construction of a vertical slot fishway (Option 1) is the preferred remediation action for this site. In addition to works at Cottons Weir, if Apex Weir (3km upstream) is no longer required, then it should be removed or modified to allow for fish passage under all flow conditions (Option 3: complete removal estimated at <$10,000).

Benefits Associated with Remediation

The Lachlan River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Cottons Weir unimpeded access to in excess of 170km of potential habitat will be provided to fish and other aquatic organisms.

MICABIL WEIR, LACHLAN RIVER

Figure 1. Micabil Weir, Lachlan River (04.05.2005, 133ML/day).

Figure 2. Natural rock spillway on right hand bank - Micabil Weir, Lachlan River (04.05.2005, 133ML/day).

Description and Setting

Micabil Weir (Figures 1 and 2) is located on the Lachlan River within the Lower Lachlan River catchment, approximately 30km west of Condobolin on the Lake Cargelligo Road. The weir is constructed entirely of concrete and is approximately 1.6 metres high and 29 metres across the length of the crest. Micabil Weir is a fixed crest structure with no gates or culverts associated with it, and acts as a barrier to fish passage when flows are less than approximately 4,500ML/day due to excessive head loss, increased turbulence, and increased velocity across the face of the structure.

Micabil Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Significant instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to fish is the West Condobolin Weir 21km away, the next barrier downstream is Kiacatoo Weir on the Lachlan River 24km away. Both of these structures are owned and operated by State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where headloss and velocity are minimal).

Hydrology

Flows within the Lachlan River are regulated by Wyangla Dam, which is located in the upper limits of the Lachlan River catchment. There are five major barriers to fish passage upstream of Micabil Weir on the Lachlan River: West Condobolin, Condobolin, Jemalong, Cottons, and Apex Weirs.

The closest DNR river gauge is located upstream near Condobolin Bridge within the Condobolin weir pool on the Lachlan River (station 412006). Information with regard to flows within the Lachlan River referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and DPI, and uses data acquired between 01.09.1973 – 23.06.2005.

Micabil Weir prevents fish passage during most flow conditions. It has been estimated that the weir in its current condition would drown out when flows are in excess of 4,500ML/day. The time weighted flow duration curve for the Lachlan River at Condobolin Bridge shows that flows would exceed 4,500ML/day less approximately 15% of the time.

There are currently ten licensed water extractors who utilise the water in the upstream weir pool for varying uses including stock, domestic and irrigation, with total annual allocation of 22,618ML (high and low security licenses).

Operational Details

The Micabil Water Trust owns Micabil Weir. The weir was built in 1926 for supply of water for irrigation. The weir is currently used for recreation, stock, domestic, and irrigation supply for upstream water users including “Kiarghathur Station”. The weir is a fixed crest, non-regulating structure.

Figure 3. Lachlan River downstream of Micabil Weir (25.09.2003, 230ML/day).

Figure 4. Lachlan River upstream of Micabil Weir (25.09.2003, 230ML/day).

Ecological Considerations

Fish passage may be possible at 15% of the time when the structure drowns out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Lachlan River. Furthermore, if the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden perch, silver perch, and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River, Lake Brewster and Lake Cargelligo area: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon, and the threatened silver perch. Introduced species including redfin, common carp, goldfish, and gambusia are also likely to be present.

The Lachlan River at this site is moderately vegetated with some minor erosion either side of the weir (Figures 3 and 4). There is large woody debris present along this stretch of the river that would be playing an integral role as fish habitat, and could also be playing a role in the protection and stabilisation of the riverbank. Instream woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and the growth of algae (thereby creating a food source for macroinvertebrates).

There is some aquatic vegetation in the upstream weir pool, with several stands of willows present upstream also. Willow eradication at this site would complement any fish passage remediation works that are undertaken at Micabil Weir.

Proposed Remediation Actions

Despite the fact that the Micabil Weir may drown out several times during the year, there remain significant periods of time when the passage of all fish will be affected. If these periods coincide with spawning migrations for particular species, the weir will continue to have a significant impact on the migratory fish community within the Lachlan River. Removal of Micabil Weir is not considered a viable option at this time, as the structure is still required for recreation, stock, domestic, and irrigation water supply.

- **Option 1 -** Partial width rock ramp fishway

A natural rock spillway exists on the right hand bank (Figure 2). This rock ramp has the potential to pass fish in high flow conditions, however by carrying out some simple modifications, fish passage may be possible over a greater range of flows.

The alteration of the existing structure to include a partial width rock ramp with a low flow channel designed to pass fish prior to the drown out of the structure would improve fish passage past the structure, and provide a significant benefit for a relatively small investment. Modifications would include cutting a low flow channel in the concrete weir wall on the right hand side to increase the flow over the spillway.

The existing spillway could be extended so that a gradient of 1:20 was created. The fishway itself would comprise a series of strategically placed rock ridges that create resting pools connected by small steps or riffles. Over a slope of 1:20, this series of steps and pools would allow fish passage to be provided for a greater range of fish species and size classes when flows are adequate prior to drown out.

The downstream entrance to the fishway could be brought back toward the weir wall in a "dog-leg" design to take advantage of attraction flows, or alternatively the fishway could run parallel to the weir wall, thereby catering for a greater range of flows (as the fishway entrance will always be adjacent the weir regardless of flows, enabling fish to locate it under various flow conditions. This option is considered the most cost effective solution for this site.

- **Option 2 –** Full width rock ramp fishway

The construction of a full width rock ramp fishway (at a slope of 1:20) would provide similar benefits to a partial width rock ramp fishway design, but be operable at a greater range of flows. A drawback of this design is its greater expense due to the considerable amount of rock requiring importation to the site. This option is therefore not considered viable for Micabil Weir.

- **Option 3 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present. With varying head loss the vertical slot fishway are considered more effective in passing a greater range of fish size classes than other fishway designs. The cost of a vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location, access, and various structural and hydrological constraints. The concrete wall of the weir would provide a suitable anchor for the vertical slot fishway and its associated infrastructure.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1		✔			
Option 2			✔		
Option 3				✔	

Recommendation

The construction of a vertical slot fishway (Option 3) is the preferred option for fish passage remediation at this site, as the weir is located on the main stem of the Lachlan River and is located within the range of a threatened species. Depending on hydrological and site constraints the partial width rock ramp could be considered as an alternative option if fish passage could be achieved over 95% of flows.

Benefits Associated with Remediation

The Lachlan River contains some important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment.

By reinstating fish passage at Micabil Weir, in excess of 45km of potential habitat either side of the structure would be provided to fish and other aquatic organisms within the Lachlan River.

LACHLAN COUNCIL WEIR, GOOBANG CREEK

Figure 1. Lachlan Council Weir, Goobang Creek (28.04.2005, 95ML/day).

Figure 2. Town water supply off-take, upstream of Lachlan Council Weir, Goobang Creek (29.04.2005, 95ML/day).

Description and Setting

The Lachlan Council Weir (Figure 1) is located on Goobang Creek in the Mid Lachlan River catchment, just within the township of Condobolin. The weir is located upstream of Goobang Creek's junction with the Lachlan River, and is easily accessible via the public reserve on the right hand bank and the Travelling Stock Route on the left hand bank. Goobang Creek flows back into the Lachlan River approximately 1km downstream. The weir is fixed crest structure with no regulating infrastructure associated with it, approximately 4 metres high and approximately 35 metres across the length of the crest. The weir acts as a barrier to fish passage when flows are less than approximately 4,500ML/day due to excessive head loss, inadequate pool depth, increased turbulence, and increased velocity across the face of the structure.

The Lachlan Council Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*, and olive perchlet, *Ambassis agassizii*);
- Location within the catchment (fish habitat located in the mid – lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Good instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to fish is Brady's Weir located on the Goobang Creek approximately 10km away. The next barrier downstream is the State Water owned Condobolin Weir which is on the Lachlan River approximately 3km away; and
- Low frequency of drown out (flow at which fish passage is possible, where headloss and velocity are minimal).

Hydrology

The flows within Goobang and Bumbuggan Creeks are controlled by the State Water owned regulating structure, Bumbuggan Weir, located approximately 52km upstream from this site. There are four other barriers to fish passage located upstream from this weir on the Goobang and Bumbuggan Creeks including: Brady's, Kennedy's, Burrawang West, and the TSR Weirs - all located within the Goobang and Bumbuggan Creek system.

The closest DNR river gauge is on Goobang Creek (station 412014) located within Lachlan Council Weir pool. Information with regard to flows within Goobang Creek referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and NSW DPI, and uses data acquired between 01.01.1985 – 05.04.2005.

It has been suggested that the weir would drown out when flows exceed 4,500ML/day. Although daily flows are highly variable, and may range from 25-5,000ML/day, the time weighted flow duration curve for Goobang Creek shows that flows would only exceed 4,500ML/day approximately 1% of the time.

There are currently several licensed water extractors who utilise the water in the upstream weir pool, with Lachlan Shire Council alone possessing a license to extract 15,000ML per annum for town water supply.

Operational Details

The Lachlan Council Weir was built in the 1890's to provide a town water supply. Today the weir is still owned and utilised by Lachlan Shire Council for town water supply, with several other private landholders also extracting water from the weir pool for stock, domestic, and irrigation purposes.

The weir is constructed of concrete and rock fill, which creates the downstream spillway. At the time of the inspection the structure had minor structural leaks, which Lachlan Shire Council were negotiating with NSW DPI to repair. The *NSW Fisheries Management Act 1994* states "the Minister may require a person who constructs, alters or modifies a dam or weir to provide fish passage".

Ecological Considerations

Due to structure drown out, fish passage may only be possible 1% of the time, with the timing of these flows not necessarily coinciding with the spawning migrations of all or any of the resident fish species within the Goobang Creek system. If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden perch, silver perch, and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following species native species are expected to occur within Goobang Creek: freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon, and the threatened silver perch. Introduced species including redfin, common carp, and gambusia are also likely to be present.

The Lachlan River either side of the weir (Figures 2 and 3) was moderately vegetated at the time of the inspection, and was largely dominated by river red gums. At the time of inspection there was some bank erosion present downstream of the weir, and there were several stands of willows both upstream and downstream of the weir. Riparian rehabilitation of this site, including erosion protection works, riparian fencing, revegetation, and willow control would complement any fish passage remediation works being undertaken at this site.

Figure 3. Goobang Creek downstream of Lachlan Council Weir (29.04.2005, 95ML/day).

Proposed Remediation Actions

As this weir is the highest on the entire Goobang and Bumbuggan system, it does not drown out regularly. It is therefore recommended that fish passage options be further investigated at this site. By creating fish passage past this weir it will enable the upstream movement of fish from the Lachlan River into the Goobang Creek and downstream movement from Goobang Creek back into the Lachlan River.

- **Option 1 –** Vertical slot fishway

With varying head loss the vertical slot fishway would be more effective in passing a greater range of fish size classes. Vertical slot fishways are considered one of the most effective fishway designs and is the preferred design where threatened species are present (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*). The concrete weir wall makes a suitable anchor for securing a vertical slot fishway and its associated infrastructure. The weir could be constructed on the left hand bank. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location, access, and various structural and hydrological constraints.

- **Option 2 –** Partial width rock ramp fishway

As the weir only drowns out at 1% of the time, fish passage is not possible for the majority of the time, other than during high flow (flooding) conditions (see *Hydrology* section). The construction of a partial width rock ramp fishway would make a significant contribution to improving the passage of native fish in Goobang Creek.

Modifications to the structure would involve extending the existing spillway so that a gradient of 1:20 was created by strategically placing several transverse rock ridges to create resting pools that are connected by short "riffles". The partial width rock ramp fishway could be constructed perpendicular to the weir on the left hand bank, with a "dog-leg" return bringing the downstream entrance closer to the base of the weir to take advantage of attraction flows. This modification could provide passage to a greater range of fish species and size classes over a greater range of flows than is currently possible, and is considered the most cost effective option available for this site. Detailed specifications for the construction of rock ramp fishways can be obtained from NSW DPI and should be incorporated into the initial planning stage of the project.

- **Option 3 –** Full width rock ramp fishway

The construction of a full width rock ramp fishway would provide similar benefits as the installation of a partial width rock ramp fishway (Option 1), although the costs incurred would be much greater due to a considerable amount of rock needing to be imported to the site. The weir currently sits at 4 metres high, and as such both the partial and full width rock ramp fishways would be required to extend more than 80 metres downstream (to create a 1:20 gradient). Whilst this is possible for a partial width rock ramp fishway, which can "dog-leg" back toward the weir, it may not be realistic for a full width rock ramp fishway at this site.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1					✔
Option 2			✔		
Option 3				✔	

Recommendation

The construction of a vertical slot fishway (Option 1) is the preferred remediation action for this site, however it would also be the most costly option. If the vertical slot fishway was not considered feasible after a more detailed options study, the partial width rock ramp fishway (option 2) should be considered.

Benefits Associated with Remediation

The Goobang and Bumbuggan Creeks contain important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment.

Reinstating fish passage past Lachlan Council Weir would open up an additional 10km of fish habitat upstream to Brady's Weir, and an additional 3km downstream to Condobolin Weir (on the Lachlan River). Addressing fish passage along the entire Goobang and Bumbuggan Creek system would provide an enormous benefit to the resident fish species. The cumulative proposed fish passage remediation works at all five weirs could be implemented as part of a demonstration reach for this system, and incorporate other riparian rehabilitation activities including fencing, weed removal and revegetation.

KIACATOO WEIR, LACHLAN RIVER

Figure 1. Kiacatoo Weir, Lachlan River (25.09.2003, 200ML/day).

Description and Setting

Kiacatoo Weir (Figure 1) is located on the Lachlan River approximately 36km west of Condobolin on the Lake Cargelligo Road, within the Lower Lachlan River catchment. The concrete, fixed crest structure is approximately 1.5 metres high and 18 metres across the length of the crest, and has no gates or culverts associated with it. The weir acts as a barrier to fish passage when flows are less than approximately 4,000ML/day due to excessive head loss and increased turbulence across the face of the structure.

Kiacatoo Weir is ranked as a high remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Diverse range of native fish (High Conservation Value);
- Good instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to fish on the Lachlan River is Micabil Weir, located approximately 22km away; the next barrier downstream is Booberoi Weir on the Lachlan River 23km away. Both of these structures are owned and operated by State Water; and

- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Lachlan River are regulated by Wyangla Dam, located in the upper limits of the Lachlan River catchment. There are six major barriers to fish passage upstream of Kiacatoo Weir on the Lachlan River and include Micabil, West Condobolin, Condobolin, Jemalong, Cottons, and Apex Weirs.

The closest DNR river gauge is located upstream near the Williams Street bridge within the Condobolin weir pool on the Lachlan River (station 412006). Information with regard to flows within the Lachlan River at Kiacatoo Weir was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from State Water, DNR, and NSW DPI, and uses data acquired between 01.09.1973 – 23.06.2005.

The weir is preventing fish passage over most flow conditions. It is predicted that the weir in its current condition would drown out when flows are in excess of 4,000ML/day. The time weighted flow duration curve for the Lachlan River at Condobolin Weir indicates that flows would exceed 4,000ML/day less than 16% of the time.

There are currently two licensed water extractors who utilise the water in the upstream weir pool with a total annual allocation exceeding 19,972ML (high and low security licenses).

Operational Details

Kiacatoo Weir is owned and operated by State Water. The Weir was built in 1935 to conserve water upstream for irrigation. Currently the weir is used for stock, domestic, and irrigation purposes.

Ecological Considerations

Fish passage may be possible less than 16% of the time when the structure drowns out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Lachlan River. If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden perch, silver perch, and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following native species are expected to occur within the Lachlan River near Kiacatoo Weir: bony herring, freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon, and the threatened silver perch. Introduced species including redfin, common carp, and gambusia are also likely to be present.

Figure 2. Lachlan River downstream of Kiacatoo Weir (25.09.2003, 200ML/day).

Figure 3. Lachlan River upstream of Kiacatoo Weir (25.09.2003, 200ML/day).

The banks of the Lachlan River either side of Kiacatoo Weir (Figures 2 and 3) were moderately vegetated at the time of inspection, and were mainly dominated by river red gums. Some minor bank erosion was noted downstream of the weir, and there were several stands of willows upstream and downstream of the structure. The rehabilitation of the riparian zone, including erosion protection works, riparian fencing, revegetation, and willow control, would complement any fish passage remediation being undertaken at this site.

Proposed Remediation Actions

Kiacatoo Weir is still required and its removal is not considered a viable option at this time. State Water is in the process of reviewing their entire existing infrastructure within the Lachlan catchment. Recommendations made from this report will be further discussed with State Water to improve fish passage at this site.

- **Option 1 –** Full width rock ramp fishway

As Kiacatoo Weir only drowns out at 16% of the time, fish passage is not possible for the majority of the time, except during high flow (flooding) conditions (see *Hydrology* section). The construction of a full width rock ramp fishway designed to pass fish prior to drown out of the structure would make a significant contribution to improving the passage of native fish at this site.

A full width rock ramp fishway would be constructed across the entire width of the weir (18 metres). Transverse rock ridges are strategically placed parallel to the weir, creating resting pools that are connected by short “riffles“. An overall gradient of 1:20 is created to pass a greater range of fish species and size classes over a wide range of flows. Detailed specifications for the construction of rock ramp fishways can be obtained from NSW DPI and should be incorporated into any detailed design.

- **Option 2 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present. With varying head loss, the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs, whilst the concrete wall of the weir would provide a suitable anchor for the fishway infrastructure. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this is dependant on site location, access, and various structural and hydrological constraints.

Projected Remediation Costs

Projected cost	**< $50K**	**$50K - $150K**	**$150K - $250K**	**$250K - $500K**	**> $500K**
Option 1			✔		
Option 2				✔	

Recommendation

The construction of a vertical slot fishway (Option 2) is the preferred remediation action for this site due to the secure anchor provided by the weir itself, and because this design is recommended for use in areas where threatened species are present.

Benefits Associated with Remediation

The Lachlan River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Kiacatoo Weir, unimpeded access to in excess of 45km of potential habitat either side of the weir would be provided for fish and other aquatic organisms.

BURRAWANG WEST WEIR, BUMBUGGAN CREEK

Figure 1. Burrawang West Weir, Bumbuggan Creek (28.04.2005, 28ML/day).

Description and Setting

Burrawang West Weir (Figure 1) is and is located approximately 35km east of Condobolin on Bumbuggan Creek in the Mid Lachlan River catchment. Bumbuggan Creek is part of an anabranch system of the Lachlan River, flowing into Goobang Creek, which in turn feeds the Lachlan near Condobolin. The structure is a privately owned fixed crest weir constructed of rock fill that is approximately 2 metres high and 20 metres across the length of the crest. During low flow conditions the weir restricts fish passage due to excessive head loss across the face of the structure, while during medium to high flows water cascades over the crest of the weir, allowing limited fish passage.

The Burrawang West Weir is ranked as a medium remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Diverse range of native fish (High Conservation Value);
- Significant instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to migrating fish is an old wooden Travelling Stock Route weir located approximately 7.5km away, while the next barrier downstream is Kennedy's Weir (privately owned) on Goobang Creek, approximately 14km away; and
- Medium frequency (40% of time) of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Operational Details

The Burrawang West Weir was constructed in 1890 for stock, irrigation, and domestic use. The structure is privately owned and is still used today for the original purpose in addition to tourism, recreation fishing, and ecological benefits. Currently, only one licensed water extractor (weir owner) draws from the weir pool, with up to 494ML per annum being licensed for removal. The weir owner also holds licenses for an additional weir on Bumbuggan Creek, although this has never been constructed. Approval for this new weir would need to be sought from NSW DPI as described in the *Fisheries Management Act 1994*, before any construction could proceed.

At the time of the inspection, water was observed seeping through the structure. This leakage would need to be addressed before any fish passage remediation works commenced (other than complete or partial removal). Minor repair works have recently occurred on the right-hand bank for scour protection and similar works are being planned for the left-hand bank.

Hydrology

Bumbuggan Creek hydrological flows were determined from the DNR river gauge (station 412017) located approximately 5.5km upstream of Burrawang West Weir. Flows in Bumbuggan Creek vary from 25 – 5,000ML/day and are controlled by Bumbuggan Weir - a State Water owned regulating structure approximately 8½km upstream of Burrawang West Weir. It is assumed that fish passage is possible following drown out of this structure, which has been predicted to occur when flows are in excess of 500ML/day (approximately 40% of the time based on time weighted flow duration curves for Bumbuggan Creek).

Information with regard to flows in Bumbuggan Creek referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and NSW DPI, and uses data acquired between 14.1.1994 – 23.03.2005.

The water pooled upstream is used for stock, irrigation, domestic, recreational, and tourism purposes. Water from the weir pool is also diverted down Yarrandbandai Creek into a section of Goobang Creek located above the junction with Bumbuggan Creek for environmental reasons. The landholder and other conservation agencies including NSW DPI, and DNR see this section of Goobang Creek as an important ecological community, and as such have identified it as a pilot site for the threatened olive perchlet (*Ambassis agassizii*) restocking program. NSW DPI (Fisheries Management) is in the interim stages of preparing an olive perchlet breeding program.

Environmental Considerations

A vertical slot fishway was recently constructed on the State Water owned Bumbuggan Creek Weir, just downstream of its junction with the Lachlan River. Ongoing monitoring will occur at this site to record the number, size and species of fish using the fishway. Although fish passage over Burrawang West Weir is possible when the structure is drowned out (approximately 40% of flows), the timing of these flows may not necessarily coincide with spawning migrations of resident fish species within the Bumbuggan and Goobang Creek system.

If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels.

Figure 2. Bumbuggan Creek downstream of Burrawang West Weir (28.04.2005, 28ML/day).

Figure 3. Bumbuggan Creek upstream of Burrawang West Weir (28.04.2005, 28ML/day).

If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir.

At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following species native species are expected to occur within Goobang and Bumbuggan Creeks: freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon and the threatened silver perch. Introduced species including redfin, common carp and gambusia are also likely to be present.

Bumbuggan Creek contains important fish habitat components including instream woody debris (Figures 2 and 3), which provides valuable shelter from strong water currents and larger avian and aquatic predators. Woody debris is also an important substrate for fish to lay eggs onto as well as for the growth of algae, which acts as a food source for macroinvertebrates.

The weir site has moderately vegetated banks with some minor erosion present either side of the structure. Aquatic vegetation is present within Bumbuggan Creek, consisting mainly of ribbon weed and some cumbungi. Riparian vegetation is dominated by river red gum, however some sections lack sufficient ground cover, with cropping encroaching on the riparian buffer zone. The creek would benefit from riparian fencing and revegetation – such works could be undertaken in conjunction with fish passage remediation at Burrawang West Weir.

Proposed Remediation Actions

The weir owner is understanding regarding the impacts of the weir on fish passage, and is willing to support modifications to the structure provided that the ability to conserve water for stock, irrigation, domestic, and tourism purposes are not compromised.

- **Option 1 –** Full width rock ramp fishway

This option would provide an improvement to fish passage and the movement of other aquatic fauna within Bumbuggan Creek. The informal nature of the existing structure would preclude the installation of a vertical slot fishway in its current state, making a full width rock ramp fishway the most effective option. However the benefits gained through construction of a full width rock ramp fishway may not be justified given the relatively high drown out frequency of the structure and that the movement of fish past the barrier is possible for significant periods of time during regulated flow.

- **Option 2 -** Construction of low flow fishway channel

Despite the relatively high drown out frequency of the structure (see *Operational Details*), there remain significant periods of time when the passage of all fish will be affected. If these periods coincide with spawning migrations for particular species, the weir will continue to have a significant impact on the migratory fish community within the creek.

The alteration to the existing structure to include a low flow channel designed to pass fish prior to the drown out of the structure would make a significant contribution to improving the passage of native fish, and provide a significant benefit for a relatively small investment.

In a manner similar to a partial width rock ramp fishway, rock ridges could be strategically placed to create resting pools that are connected by riffles to provide passage to a greater range of fish species and size classes during adequate flow periods. Detailed specifications for the construction of rock ramp fishways (and therefore the overall premise for a bypass channel) can be obtained from NSW DPI and should be incorporated into any construction designs.

- **Option 3 –** Removal

The complete removal of the structure would provide the greatest benefit to the health of Bumbuggan Creek and provide significant improvements in the availability of aquatic and riparian habitat to fish and other aquatic organisms. Much of the current function of the weir in supplying water for irrigation, stock and domestic needs could potentially be met through alternative means, however the landholder's requirement that modifications do not compromise its role in an existing tourism enterprise may not be as easily addressed.

Negotiations are currently underway to remove the old wooden TSR Weir on Bumbuggan Creek (7.5km upstream). This structure is no longer being utilised, and is in a state of disrepair. Although this weir would be drowned out during medium-high flow conditions, it may limit the upstream and downstream movement of some fish during low flows. Initial consultation with the Rural Lands Protection Board and Mulguthrie Station (adjacent landholders) has indicated that the wooden structure is no longer used and could be removed. Further discussions with NSW DNR and other stakeholders will be required prior to these works commencing. The removal of the TSR weir would result in the free passage for fish from Burrawang West Weir, up through Bumbuggan Creek fishway and into the main stem of the Lachlan River.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1			✔		
Option 2		✔			
Option 3	✔				

Recommendation

The construction of a low flow fishway channel (Option 2) is the preferred remediation action for this site.

Benefits Associated with Remediation

The Bumbuggan and Goobang Creek system is important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Burrawang West Weir unimpeded access to in excess of 20km of habitat would be provided to fish and other aquatic organisms.

TRAVELLING STOCK RESERVE (TSR) WEIR, BUMBUGGAN CREEK

Figure 1. TSR Weir, Bumbuggan Creek (28.04.2005, 28ML/day).

Description and Setting

The TSR Weir (Figure 1) is located on Bumbuggan Creek approximately 45km south east of Condobolin within the Mid Lachlan River catchment. The junction of the Lachlan River and Bumbuggan Creek is located between Island Creek junction with the Lachlan, and Jemalong Weir. Bumbuggan Creek flows into the Goobang Creek and is part of an anabranch system. The Goobang Creek flows back into the Lachlan River downstream, just within the town limits of Condobolin. The weir is constructed of wood and some rock fill, and is approximately 1 metre high and 20 metres across the length of the crest. The weir is a fixed crest structure, with no regulating infrastructure or culverts associated with it. During low flow conditions, the weir restricts fish passage due to excessive head loss and increased turbulence across the face of the structure, with limited fish passage possible when flows are in excess of 200ML/day.

The TSR Weir is ranked as a medium remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (the site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Diverse range of native fish (High Conservation Value);
- Significant instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to migrating fish is Jemalong Weir located approximately 24km away, while the next barrier downstream is Kennedy's Weir on Goobang Creek, approximately 7.5km away; and

- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

The flows within Bumbuggan Creek are controlled by the State Water owned and operated regulating structure Bumbuggan Weir, located approximately 500 metres upstream from this site. Flows within the system are consequently highly variable and range from 25 – 5,000ML/day.

The closest DNR river gauge (station 412017) is located approximately 2km downstream on Bumbuggan Creek. Information with regard to flows within the Bumbuggan Creek referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and NSW DPI, and uses data acquired between 14.01.1994 – 23.03.2005.

It has been estimated that the weir would drown out with flows in excess of 200ML/day. The time weighted flow duration curve for Bumbuggan Creek shows that flows would exceed 200ML/day approximately 68% of the time.

Operational Details

The weir may have originally been built to conserve water prior to the construction of the much larger Bumbuggan Weir located 500 metres upstream. The TSR Weir currently does not have any licensed weir pool extractors. Reliable water for travelling stock is available within the creek and behind the State Water owned Bumbuggan Weir.

There are no records of the weir having ever been licensed, and there are therefore no records to indicate when it may have been built or by who. Based on the materials used to construct the weir it may have been built in the late 1800's or early 1900's.

This structure is no longer being utilised, and is currently in a state of disrepair, in addition the weir is breached on the left hand bank, which would allow intermittent fish passage for a limited number of fish size classes. Although the TSR Weir would be drowned out during medium-high flow conditions, it may limit the upstream and downstream movement of some fish during low flows. While this small weir remains in place, there is also the potential for debris to collect behind the structure and further restrict fish movement.

Environmental Considerations

Bumbuggan Creek Weir, located approximately 500 metres upstream, has recently been fitted with a vertical slot fishway and monitoring by NSW DPI indicates it is passing many fish species (monitoring is ongoing). There are no other major barriers to fish located on Bumbuggan Creek, however the next barrier is Jemalong Weir, approximately 24km upstream on the Lachlan River. The closest barrier downstream is Burrawang West Weir, which is located on Bumbuggan Creek approximately 7.5km away.

Fish passage during low flow conditions is limited. Although fish passage may be possible approximately 68% of the time, the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Bumbuggan/Goobang Creek system, especially given the variable nature of flows within downstream of Bumbuggan Weir.

Furthermore if the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels.

Figure 2. Bumbuggan Creek downstream of TSR Weir (28.04.2005, 28ML/day).

Figure 3. Bumbuggan Creek upstream of TSR Weir (28.04.2005, 28ML/day).

If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following species native species are expected to occur within Goobang and Bumbuggan Creeks: freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon, and the threatened silver perch. Introduced species including redfin, common carp, and gambusia are also likely to be present.

The riparian vegetation along Bumbuggan Creek either side of the weir was dominated by river red gum and a moderate grassy understorey at the time of inspection, with some minor bank erosion present on the downstream side (Figures 2 and 3).

Woody debris is plentiful along this section of the creek and is a major component of fish habitat and not only provides protection from predators and strong water currents but can also serve as a substrate on which fish can lay eggs and algae and other food sources can grow.

This site would benefit from riparian rehabilitation works including fencing off the creek from grazing, and realigning some snags to protect the banks, and would complement any fish passage remediation works at this site.

Proposed Remediation actions

There is no confirmed owner of the TSR Weir; therefore retaining the weir would provide no economic or social benefits.

- **Option 1 –** Removal

Initial consultation with the adjacent landowners (Rural Lands Protection Board (RLPB) and Mulguthrie Station) has indicated that the wooden structure is no longer used and could be removed. Further discussions with DNR and other stakeholders will be required prior to these works commencing, however the RLPB have shown a willingness to support fish passage remediation works at this site.

The removal of this structure would result in the free passage for fish from the Burrawang West Weir, up through the Bumbuggan Weir fishway, and into the main stem of the Lachlan River. It would also allow movement of fish from the Lachlan River downstream to Burrawang West Weir. The complete removal of the structure would therefore provide the greatest benefit to the health of Bumbuggan Creek, and provide significant improvements in the availability of aquatic and riparian habitat to fish and other organisms.

- **Option 2 –** Full width rock ramp fishway

The construction of a fishway at this site is not a viable option, considering the weir is in a state of disrepair. The relatively high drown out frequency of the structure is a significant factor when considering future options for the site. The high cost of constructing a full width rock ramp fishway may not be justified given that movement of fish past the barrier is possible for significant periods of time during regulated flow.

Projected Remediation Cost

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1	✔				
Option 2			✔		

Recommendation

The complete removal of this weir (Option 1) is the preferred remediation action for this site.

Benefits Associated with Remediation

The Bumbuggan and Goobang Creek system contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system likely to generate substantial benefits to native fish and other aquatic organisms within the system, and reinstate more natural nutrient and sediment transportation processes.

By reinstating fish passage at the TSR Weir, in excess of 8km of potential habitat either side of the weir would be provided to fish and other aquatic organisms.

KENNEDY'S WEIR, GOOBANG CREEK

Figure 1. Kennedy's Weir defunct regulating structure, Goobang Creek (28.04.2005, 95ML/day).

Figure 2. Kennedy's Weir, rock spillway, Goobang Creek (28.04.2005, 95ML/day).

Description and Setting

Kennedy's Weir (Figures 1 and 2) is located on Goobang Creek, approximately 25km east of Condobolin, in the Mid Lachlan River catchment. The weir is located downstream of the junction of Bumbuggan and Goobang Creeks. Goobang Creek feeds into the Lachlan River, just within the town limits of Condobolin downstream.

Kennedy's Weir is approximately 1.5 metres high and approximately 25 metres across the length of the crest. The weir is a regulating structure constructed of steel gates with wooden framework, a concrete apron and a rock spillway. The structure would limit the movement of fish and other aquatic organisms during low flow periods, with the rock spillway also influencing fish passage at flows less than 450ML/day due to excessive head loss and increased turbulence across the face of the structure.

Kennedy's Weir is ranked as a medium remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Diverse range of native fish (High Conservation Value);
- Good instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to fish is Burrawang West Weir located on the Bumbuggan Creek approximately 7.5km away. The next barrier downstream is Brady's Weir which is located on Goobang Creek approximately 4km away; and
- Medium frequency (46% of time) of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Goobang Creek hydrological flows were determined from the DNR river gauge (station 412014) located downstream at the Lachlan Council Weir on the Goobang Creek. Information with regard to flows within Goobang Creek referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and NSW DPI, and uses data acquired between 01.01.1985 – 05.04.2005.

Drown out has been estimated to occur when flows are greater than 450ML/day. The time weighted flow duration curve for Bumbuggan Creek shows that flows would exceed 450ML/day approximately 46% of the time.

There are two barriers to fish passage located upstream from Kennedy's Weir on the Bumbuggan Creek, and a further two weirs (Jemalong Weir and Cottons Weir) located upstream on the Lachlan River.

There is currently one licensed water extractor (the weir owner) who draws water from the upstream weir pool.

Operational Details

Kennedy's Weir is privately owned. The weir was built in the 1890's to provide stock, irrigation, and domestic water, which continues to be its purpose today.
In recent years however, irrigation has not been undertaken due to prevailing drought conditions.

Kennedy's Weir consists of two main components: the first is a defunct gated section that was previously used to regulate flows passing down Goobang Creek; the second is the rock spillway that has the potential to block upstream and downstream fish passage at flows less than 450ML/day.

Ecological Considerations

Fish passage may be possible at 46% of the time when the structure drowns out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Goobang Creek system. If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focusing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden and silver perch and Murray cod occur in the area and have recently been caught. The High Conservation Value (HCV) database (NSW DPI accessed 10.08.05) states that the following species native species are expected to occur within Goobang Creek: freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon and the threatened silver perch. Introduced species including redfin, common carp, and gambusia are also likely to be present.

Goobang Creek surrounding Kennedy's Weir had minimal understorey vegetation (Figure 3) at the time of inspection due to prevailing drought conditions. The dominant over storey vegetation was river red gums, with no willows present.

The creek downstream of the weir possesses some important fish habitat including instream large woody debris (Figures 3 and 4), which provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. In addition, woody debris also provides an important substrate for fish to lay eggs and the growth of algae (thereby creating a food source for macroinvertebrates).

The rehabilitation of this site including riparian fencing should be undertaken in conjunction with any fish passage remediation works at this site.

Figure 3. Goobang Creek downstream of Kennedy's Weir (28.04.2005, 95ML/day).

Figure 4. Goobang Creek upstream of Kennedy's Weir (28.04.2005, 95ML/day).

Proposed Remediation Actions

The landholder would support modifications to their weir provided that the ability to conserve water for stock, irrigation, and domestic water is not compromised. The landholder has previously offered to remove the steel gates and associated infrastructure when machinery was next available, however to date no works have been undertaken at this site to improve fish passage.

Complete removal of the structure is not an option being considered at this time due to the landholder's reliance on the weir pool for stock and domestic water supply, whilst the informal nature of the existing structure would also preclude the installation of a vertical slot fishway without considerable modification to the weir.

The relatively high drown out frequency of the structure, predicted to be 46% of the time, is a significant factor when considering future options for the site, with fish passage options aimed to enhance fish movement prior to drown out.

- **Option 1 –** Full width rock ramp fishway

The existing spillway lends itself to the construction of a full width rock ramp fishway. Currently there is a significant amount of rock fill located downstream, with only a small amount needing to be brought to the site. The rock spillway could be modified to cater for fish passage during a greater range of flow conditions by extending the rock fill further downstream to create a gradient of at least 1:20. With strategically placed transverse rock ridges to create resting pools that are connected by small riffles, fish passage may be available to a greater range of fish species and size classes during these times. A low flow channel could direct water down the centre of the fishway, with the outer edges coming into effect as flows increase. The cost of a full width rock ramp fishway at Kennedy's Weir is estimated at less than $10,000.

- **Option 2 –** Removal of defunct regulatory infrastructure only

The removal of only the regulating structure would prevent this infrastructure continuing to inhibit the passage of fish during small river rises and would prevent debris accumulating behind the weir. The landholder would support the removal of the defunct regulating infrastructure. The cost of removal of the regulating infrastructure is estimated at less than $5,000.

Projected Remediation Costs

Projected cost	**< $50K**	**$50K - $150K**	**$150K - $250K**	**$250K - $500K**	**> $500K**
Option 1		✔			
Option 2	✔				

Recommendation

It is recommended that a full width rock ramp fishway (Option 1) be constructed in addition to the removal of the regulating infrastructure (Option 2).

Benefits Associated with Remediation

The Bumbuggan and Goobang Creek system is important fish habitat that should be protected. Reinstatement of fish passage along the entire system is likely to generate substantial benefits to native fish and other aquatic organisms, and reinstate natural nutrient and sediment transport processes. By reinstating fish passage at Kennedy's Weir unimpeded access to in excess of 19km of potential habitat would be provided to fish and other aquatic organisms.

BRADY'S WEIR, GOOBANG CREEK

Figure 1. Brady's Weir, Goobang Creek (28.04.2005, 95ML/day).

Figure 2. Brady's Weir, Goobang Creek (28.04.2005, 95ML/day).

Description and Setting

Brady's Weir (Figures 1 and 2) is located on Goobang Creek approximately 10km east of Condobolin in the Mid Lachlan River catchment. The weir is located upstream of the junction of the Goobang Creek and the Lachlan River (approximately 11km downstream), and is easily accessible via private property.

The weir in its current state of disrepair is approximately 0.85 metres high and approximately 25 metres across the length of the crest. The weir is a fixed crest structure with no regulating infrastructure associated with it and currently influences fish passage at flows less than 300ML/day. If Brady's Weir is reinstated to its original level, as has been indicated by the landholder, the weir will have the potential to block fish passage at flows less than 700ML/day due to excessive head loss and increased turbulence across the face of the structure.

Brady's Weir is ranked as a medium remediation priority within the Lachlan CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of a threatened fish species (this site is within the expected distribution of silver perch, *Bidyanus bidyanus*);
- Diverse range of native fish (High Conservation Value);
- Significant instream and riparian habitat condition;
- Improved stream connectivity: the next upstream barrier to fish is Kennedy's Weir located on Goobang Creek approximately 4km away. The nearest barrier downstream is the Crown owned weir located on Goobang Creek approximately 12km away, which is operated and maintained by Lachlan Shire Council; and
- Medium frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Goobang Creek hydrological flows were determined from the DNR river gauge (station 412014) located downstream at the Lachlan Council Weir on the Goobang Creek. Information with regard to flows within Goobang Creek referred to in this report was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from DNR and NSW DPI, and uses data acquired between 01.01.1985 – 05.04.2005.

Drown out of the Brady's Weir in its current state has been predicted to occur when flows are in excess of 300ML/day, or in excess of 700ML/day if the weir is reinstated. The time weighted flow duration curve for the Goobang Creek shows that flows would exceed 300ML/day approximately 63% of the time, whilst flows would exceed 700ML/day only 33% of the time.

There are three barriers to fish passage upstream of Brady's Weir on the Goobang and Bumbuggan Creeks, and a further two weirs (Jemalong and Cottons Weirs) located upstream on the Lachlan River.

There are currently two licensed water extractors utilising the upstream weir pool with a total annual allocation of 980ML.

Operational Details

At the time of the inspection the weir had major structural faults and was breached left of the centre. The landholder has advised that they would like to reinstate the weir to its original level to secure water for the property and have approached NSW DPI (Fisheries Management) for advice. The landholder is aware that if the weir is modified they will be required to provide fish passage.

Brady's Weir is used as a water source for stock and domestic use, and in the past has been used for irrigation when water restrictions were not in place. The weir is also used as a recreational area for the landholder, visitors, and some recreational anglers.

Ecological Considerations

Fish passage may currently be possible at 63% of the time when the structure is drowned out, and will be further restricted to 33% when the weir is reinstated. The structure also has the potential to further restrict fish movement as the accumulation of debris behind the weir interrupts the flow of water over the weir. In addition, the timing of flows when they do occur may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Goobang Creek system. If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case, however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure. It should also be remembered that it is important to try and achieve fish passage for all species and life stages, rather than focussing on the traditional iconic adult recreational species.

Anecdotal evidence from local anglers and landholders indicates that fish species including freshwater catfish, golden perch, silver perch, and Murray cod occur in this area, and have recently been caught. The (High Conservation Value) HCV database (NSW DPI accessed 10.08.05) states that the following species native species are expected to occur within Goobang Creek: freshwater catfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon, carp gudgeon and the threatened silver perch. Introduced species including redfin, common carp and gambusia are also likely to be present.

During the site inspection, Goobang Creek adjacent to this site was found to have no understorey vegetation in some areas (Figures 3 and 4), most likely as a result of prevailing drought conditions and uncontrolled stock access to the creek. The dominant vegetation was river red gums. Unlike many other sites in the Lachlan, willows were not present either side of the weir.

Rehabilitation of this site, including riparian fencing, controlled stock access points, or off stream watering points should be undertaken in conjunction with any fish passage remediation works to improve surrounding fish habitat.

Figure 3. Goobang Creek downstream of Brady's Weir (28.04.2005, 95ML/day).

Figure 4. Goobang Creek upstream of Brady's Weir (28.04.2005, 95ML/day).

Proposed Remediation Actions

If the structure is retained and major refurbishment takes place, the installation of fish passage is required under the *Fisheries Management Act 1994*. The landholder is committed to habitat rehabilitation and has shown willingness to incorporate fish passage at this site provided some financial assistance and technical advice was provided. The landholder has offered in-kind support with regard to providing a fishway. The relatively high drown out frequency of the structure is a significant factor when considering future options for the site.

- **Option 1 –** Complete removal

Complete removal of the structure would provide the greatest benefit to the health of Goobang Creek and provide significant improvements in the availability of aquatic and riparian habitat. Although this would be the most cost effective solution for fish passage remediation at this site (estimated cost of removal being less than $5,000), the landholder is not supportive of its removal, as it is relied on for supplying water for irrigation, stock and domestic needs.

- **Option 2 –** Full width rock ramp fishway (weir refurbishment with rock fill)

If the weir was reinstated with rock fill, a full width rock ramp fishway should be constructed, as the informal nature of a rock fill weir would preclude the installation of a vertical slot fishway without considerable alteration and high costs. In addition, the creek is relatively narrow at this point, making a full width rock ramp fishway the most effective option.

- **Option 3 –** Vertical slot fishway (refurbishment as a fixed crest concrete weir)

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present. With varying head loss the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs. The refurbishment of the weir with concrete would allow for secure anchoring of the vertical slot fishway and its associated infrastructure.

Although the structure would be drowned out several times a year (see *Operational Details*), there remain significant periods of time when the passage of all fish is affected. If these periods do not coincide with spawning migrations for particular species, the weir will continue to have a significant impact on the migratory fish community within the creek. Both the full width rock ramp fishway and the vertical slot fishway would pass fish prior to drown out of the structure, and would make a significant contribution to improving native fish passage at the site.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K - $250K	$250K - $500K	> $500K
Option 1	✔				
Option 2			✔		
Option 3				✔	

Recommendation

The recommendation for this site is dependant on the construction materials used to refurbish the existing weir. If the weir were refurbished with rock fill, Option 2 would be the preferred option. If the weir were refurbished as a fixed crest concrete structure, Option 3 would be the preferred option. If an alternate water supply could be established for the upstream licensed extractors, the weir should be totally removed (Option 1).

Benefits Associated with Remediation

NSW DPI has identified the Bumbuggan and Goobang Creek system as containing important fish habitat that should be protected, and reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Brady's Weir unimpeded access to in excess of 14km of potential habitat would be provided to fish and other aquatic organisms.

By addressing fish passage along the entire Goobang and Bumbuggan Creek system it would generate an enormous benefit to the resident fish species. The cumulative result of the proposed fish passage remediation works at all five weirs could be implemented as a demonstration reach, incorporating other riparian rehabilitation works including fencing, weed removal and revegetation with native species.

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7. APPENDICES

Appendix A: Detailed Weir Assessment Proforma

Please note: It is important to complete as much of this form as possible in the office to avoid unnecessary delays in the field.

PRELIMINARY QUESTIONS Fish Passage

1. Is the structure a barrier to fish passage (a drop of 10cm can create a barrier, as can high velocities through round piped culverts) YES**/** NO.

(i) Please describe (eg. Drop >10cm, Slope >1:20, Increased velocity, Increased turbulence, Debris, Minimum Flow depth (<200mm)……

(ii) Significance of the structure as a barrier to fish passage: headloss (height of fall from headwater to tailwater)……..cm

(iii) Description of water flow over structure
Vertical fall/ steep cascade/ moderate cascade/ gentle incline/ high velocity through pipe/ Moderate velocity through pipe/ other……..

Date of review:

Name of Reviewer:

Contact phone No:

SECTION 1 OWNERSHIP AND LICENCE INFORMATION

1a ***Barrier/ Structure location information:***

Name of weir:

General directions, landmarks etc:

Name of nearest town:

Grid Reference:

Name of Watercourse:

Catchment Management Area:

Local Government Area:

(it is essential that a topographic map be attached for the location of each weir)

1b ***Structure Ownership details:***

Type (eg. private, local Govt., state Govt):
Owner Name: .....

1c ***Land Ownership details:***

Owner of land on which structure is built

DIPNR/ State Water/ Crown Land/ Private / Other……..

Is access to the structure via Easement / Public road / Other……

Property Boundaries on which structure is located Lot……..Dp……

Plan Number……

1d ***Contact person for weir assessment details:***

Position Title: Owner name:

Office Address:

Phone: Mobile:

1e ***Weir Licence details (if applicable):***

Licence No: .....

Date of issue: ..... Date of expiry: .....

Licensing Office: .....

License Type (stock/domestic/irrigation/other):……..

SECTION 2 STRUCTURAL AND OPERATIONAL DETAILS

2a (i) ***Type of Structure*** **(Please describe):**

(ii) ***Barrier Construction material:***

Concrete ☐

Earth & rock ☐

Sheet piling ☐ with rock fill ☐ or other ……

Cribwork or gabion modules ☐ with rock fill ☐ or other ……

(cribwork type/material eg. steel or timber)……

2b ***Structure dimensions:***

…….. (m) crest length (length in metres at the weir crest)

…….. (m) vertical height (from the downstream toe to weir crest)

2c (i) ***Barrier type (eg. fixed or adjustable release structure):***

Fixed Crest Structure ☐ Adjustable release structure ☐

(ii) ***Release operations (if gated or regulated):***

…….. mechanism (eg. Gates, valves, removable boards, spillway etc.)

..... release frequency

..... duration

..... season of opening

(iii) ***Additional features of structure*** *(eg. Bottom release valve, skimmer box or siphon outlet configuration – for surface release, existing fishway, navigation lock, spillway, automated operation etc.):*

2d (i) ***Is the structure critical to the operations of the property or land use adjacent?***

Yes / No

Please provide brief details:

.....

2d (ii) ***Could the current operation of the structure be modified to improve environmental conditions?***

.....

2e (i) ***What is the current condition of the structure?***

working ☐ unserviceable ☐ decommissioned ☐

(ii) ***In terms of structural stability, does the structure require any of the following?*** Yes / No

immediate maintenance ☐ modification ☐ replacement ☐

Please provide details:

SECTION 3 WEIR/BARRIER USE

3a (i) **Date of construction:**

(ii) **Original use or purpose/s (if known):**

3b (i) **Current purpose/s of the structure** (eg. Irrigation, flood control, town water supply, re regulation, domestic, stock, industrial, drought water storage, recreation, river crossing, access). Please comment.

(ii) **Additional uses** (eg. Recreation, aesthetic, road crossing, environment, boundary fence).
Please comment.

3c (i) **Number of direct weir pool users (eg. Pumping licences upstream & downstream licenses served)**

List Users;

1 …….. 2 ……

3 …….. 4 ……

4 …….. 6 ……

(For more users please use separate sheet)

(ii) **Number of licensed customers using weir pool**
(Please fill out attached sheet – Appendix 1 to provide details of these customers)

(iii) **Number of Riparian Stock and Domestic pumps using weir pool**

(iv) **Additional beneficiaries of structures (eg. Local community water supply, fishing groups)**

3d (i) **List any recognised Heritage or cultural values associated with the structure. (Check heritage list)**
See Austral & ERM (2003) for details and also check the heritage resister at http://www.heritage.nsw.gov.au.
…….

(ii) **List any areas of Aboriginal Heritage significance associated with the structure.** (Contact should be made with local Aboriginal Lands Council & Department Environment & Conservation office to discuss aboriginal issues).

…….

3e **What types of land use operates in the riparian and floodplain zones adjacent to the weir pool?**

…….

…….

SECTION 4 WEIR SETTING

4a (i) ***What is the stream classification of the watercourse at the weir location?*** *(please refer to appendix 2)*

(ii) ***How wide is the watercourse upstream of the weir pool*** *(beyond the influence of the weir)**?***

(m)

(iii) ***Is the watercourse a tributary, anabranch, or floodrunner?***

4b (i) ***What is the total catchment area upstream of the weir?***
……. (sq. km)

(ii) ***What is the proportion of the catchment controlled by the weir*** *(upstream to the next river bed obstruction include natural and artificial).*
……. %

4c (i) ***What is the distance upstream of the weir to the next major river bed obstruction*** *(eg. Weir or other barrier)? Please name structure.*

(km) Structure name and/or type

(ii) ***What is the distance downstream of the barrier to the next major river bed obstruction*** *(including natural)?*

(km) Structure name and/or type

(iii) ***Is the barrier a Coastal River?*** Yes / No

If Yes is the barrier a tidal barrage or located in the tidal zone or immediately upstream of the estuary?

Please provide details:
……..

(iv) ***Do upstream water users pump freshwater from weir pool? If yes how may they be affected by removal of the structure?****(Obtain advise as necessary eg hydrologist)*
……

4d ***What section of the catchment is the structure located (circle one)?***

Upper *Middle* *Lower*

SECTION 5 HYDROLOGY INFORMATION

5a (i) ***What is the average depth of water in the pool immediately upstream of the barrier?***

…..... (m)

5a (ii) ***What is the height of the stream banks above the crest of the structure?***

……(m)

5b ***Is there a defined weir pool? If yes, how long is it?***

Yes / No (m)

5c (i) ***Is there a continuous flow across the crest of the barrier? Or through a pipe, gate or other regulator?***

Yes / No Yes / No

(ii) ***Is the stream regulated or unregulated*** Regulated / Unregulated

(iii) ***How does the flow vary?*** (eg daily, seasonally, flood, rainfall)

Comments:
…..

5d ***How frequently does drownout occur?***

…..... (per year) OR don't know

5e (i) ***Is there information on the water quality in the weir pool or releases?*** *Yes / No*

If yes where is the information held or located?
…..

(ii) ***Is there evidence of salinity, acid sulphate soils, scalding, or other soil problems in the vicinity of the weir pool?***

Yes / No / don't know

Please describe:
…..

(iii) ***Has there been any changes to groundwater levels in the vicinity of the weir pool?***
Yes / No / don't know

SECTION 6 GEOMORPHIC INFORMATION

6a ***Are there any signs of bed erosion downstream of the barrier?***

Yes / No / don't know

Comments:

6b (i) ***What is the condition of the stream banks adjacent to the barrier?***

Intact ☐ minor erosion ☐ extensive erosion ☐

Please describe:

(ii) ***What is the condition of the stream banks upstream of the barrier?***

Intact ☐ minor erosion ☐ extensive erosion ☐

Please describe:

6b (iii) ***What is the condition of the stream banks downstream of the barrier?***

Intact ☐ minor erosion ☐ extensive erosion ☐

Please describe:

6c (i) ***Is there any evidence of siltation in the weir pool?***

Yes / No / don't know

Please describe:……

(ii) ***If yes, what is the difference in bed level on the upstream and downstream side of the barrier wall?***

…..... (m)

(iii) ***Has any mining or other associated activities taken place in the catchment upstream of the structure?***

Is there any chance of contaminated sediment behind structure ie. Heavy metals etc?

(Please provide details……

6d (i) ***Is there an accumulation of debris around the structure? (eg LWD, sediment, gross pollutants etc)***

Yes / No Please describe

(ii) ***If yes, is it causing problems to the structure or operation of gates, spillways or fish ladders associated with the weir?***

Yes / No

Please describe:
……

6e (iii) ***Is desnagging carried out upstream of the structure?***

Yes / No / don't know

SECTION 7 ECOLOGICAL CONSIDERATIONS

7a (i) ***Does the structure have a fishladder, rock ramp, or some other allowance for fish passage?***

Yes / No structure type: …....

(ii) ***If yes, has there been fish monitoring and/or an inspection to support fish passage?***

Yes / No / don't know

Comments:

(iv) ***What native fish species are present or are expected to occur at this site (ie. Refer to guidelines + local knowledge if available).***

……
……

(v) ***What introduced fish species are present or are expected to occur at this site (ie. Refer to guidelines + local knowledge).***

……
……

7b (i) ***Has there been any outbreak of nuisance aquatic/riparian weeds within the weir pool area eg. lippia, water hyacinth, willows ?***

Yes / No

Comments:
.....

(ii) ***Have there been any outbreaks of blue-green algae?***

Yes / No/ don't know

If yes, what time of year and how frequently do outbreaks occur?

…..... season …..... (frequency)

7c (i) ***How extensive is the vegetation cover on the banks of the river? (<50m from water line).***

Well vegetated ☐ moderately vegetated ☐ poorly vegetated ☐

Dominant species present (including native and introduced):

…..

Please comment on native riparian vegetation and introduced plant species:

…..

(ii) ***Is there any evidence of dieback occurring near the weir pool?***

Yes / No

Comments:

…..

…..

7d ***What percent of the weir pool area is colonised by aquatic vegetation eg. Phragmites, cumbungi?***

<5% ☐ 5-10% ☐ 10-30% ☐ <30% ☐

Dominant species present (including native and introduced):

…..

7e ***Are there any rare and threatened flora and fauna species, populations or communities known to occur in the area?***

Yes / No / Don't know

Comments
……

……

7f (i) ***Is the river bank along the weir pool fenced?***

Yes / No / partial one side / both sides

Comments:
…..

(ii) **Do stock have access to the river?**

Yes / **No /** **partial** **one side /** **both sides**

Comments:
……

SECTION 8 RECOMMENDATIONS

8a ***Removal Option*** *YES / NA (please circle)*

(i) **Is the structure required by the adjacent Landholders?** Yes / No.

Comments:
……

(ii) **Is the structure required by the Community, fishing club, access, aesthetics?** Yes / No.

Comments:
……

(iii) **Is the structure acting as a bed control structure? (Seek advice from DIPNR if unsure)**
……

If the Answer to Question 8 (i)-(iii) is No

Is demolition of the structure supported by owner? Yes / No

Comments:
……

Would any person or group object to the weir being demolished?

Please describe:
……
……

(vi) **Is the weir remote/difficult to access?** Yes / No
If Yes, please describe access/location (Is there all weather access?)
……
……

(VI) ESTIMATED COST OF REMOVAL/PARTIAL (USE COST MATRIX- APPENDIX 3) OR CONTRACTOR QUOTE?

8b **Fishway options** *YES/NA (please circle)*

(i) **Does the structure lend itself to the addition of a fishway?** YES/NO

(ii) **Fishway type best suited to the structure** (Please take into account habitat, fish species, hydrology of watercourse)? Vertical slot / Full Width Rock Ramp / Partial Width Rock Ramp / Denil Insert/ Lock/ Other

(III) ESTIMATED COST OF FISHWAY BASED ON APPROX. $150 000 PER VERTICAL METER?

=

Comments (Include supporting literature and any correspondence with fishway experts):
……
……
……

8c **Modification of Structure to allow for fish passage**

(i) **Please describe proposed works (eg. Box culverts etc)?**
……
……

(II) ESTIMATED COST OF PROPOSED WORKS

8d Suggested management action (eg removal of drop boards, gated weir opening, removal of debris)

Comments (Include supporting literature and correspondence)

……
……
……
……

8e No action recommended

Comments (Include supporting literature and correspondence)

……
……
……
……

SECTION 9 ADDITIONAL INFORMATION

For further information:

- Austral Archaeology Pty Ltd & ERM Australia Pty Ltd, (2003), Heritage Assessment of 206 River Structures, Coastal and Central Regions, NSW, (Final Report and Appendix A: Group Two, Volume One).
- NSW DPI (Fisheries) Aquatic Habitat Rehabilitation database
- Pethebridge, Lugg and Harris (1998) Obstructions to fish passage in New South Wales south coast streams. NSW Fisheries final report series No 4 ISSN 1440-3544
- Williams RJ, Watford FA (1996) An inventory of impediments to tidal flow in NSW estuarine fish habitats *Wetlands (Australia)* 15, 44-54.

Appendix B: Weir Prioritisation Scheme for NSW Coastal CMAs

INITIAL PRIORITISATION					
A) STREAM HABITAT VALUE					**SCORE**
Primary aquatic habitat rating					
Habitat Class	1	2	3	4	
Location in the system	Tidal	Lower	Middle	Upper	
Downstream obstructions	0	1-2	3 - 5	> 5	
Habitat opened if remediated	> 100 km	50 – 100 km	20 - 50 km	10 - 20 km	< 10 km
B) STRUCTURE IMPACT CRITERIA					
Environmental effect rating					
Physical barrier: Headloss	> 2000 mm	1000 - 2000 mm	500 – 1000 mm	100 - 500 mm	
Drown out frequency per annum	> 4	2 - 4	1		
SECONDARY PRIORITISATION					
C) ENVIRONMENTAL CRITERIA					
Secondary aquatic habitat rating					
Instream habitat condition	Good	Fair	Poor		
Riparian condition	Good	Fair	Poor		
Siltation	None	Minor	Major		
Threatened species	Habitat Class 1-2	Habitat Class 3	None		
D) MODIFICATION CRITERIA					
Structure use and remediation cost					
Maintenance Required	Yes	No			
Redundant Weir	Yes	No			
Ease of Remediation	Removal	Modification	Fishway installation		
Ancillary uses	Flood mitigation	Bed Control	Recreation		
				TOTAL	

Appendix C: Weir Prioritisation Scheme for NSW Inland CMAs

INITIAL PRIORITISATION						
A) STREAM HABITAT VALUE						**SCORE**
Primary aquatic habitat rating						
Habitat Class	1	2	3	4		
Location in the system	Lower	Middle	Upper			
Downstream obstructions	0	1-5	5-10	>10		
Habitat opened if remediated	>150 km	100 – 150 km	50 - 100 km	20 - 50 km	<20 km	
B) STRUCTURE IMPACT CRITERIA						
Environmental effect rating						
Physical barrier: Headloss	>3000 mm	2000 - 3000 mm	1000 – 2000 mm	200 - 1000 mm		
Drown out frequency per annum	>5%	1-5%	0%			
Undershot Structure	Yes	No				
SECONDARY PRIORITISATION						
C) ENVIRONMENTAL CRITERIA						
Secondary aquatic habitat rating						
Instream habitat condition	Good	Fair	Poor			
Riparian condition	Good	Fair	Poor			
Threatened species	Habitat Class 1-2	Habitat Class 3	None			
D) MODIFICATION CRITERIA						
Structure use and remediation cost						
Redundant Weir	Yes	No				
Ease of Remediation	Removal	Modification	Fishway installation			
					TOTAL	


aquatic habitat rehabilitation
making more fish
...naturally