REDUCING THE IMPACT OF WEIRS ON AQUATIC HABITAT

NSW DETAILED WEIR REVIEW

REPORT TO THE NEW SOUTH WALES ENVIRONMENTAL TRUST

MURRAY CMA REGION

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Environmental TRUST

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DISCLAIMER

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*.

ACKNOWLEDGEMENTS

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).

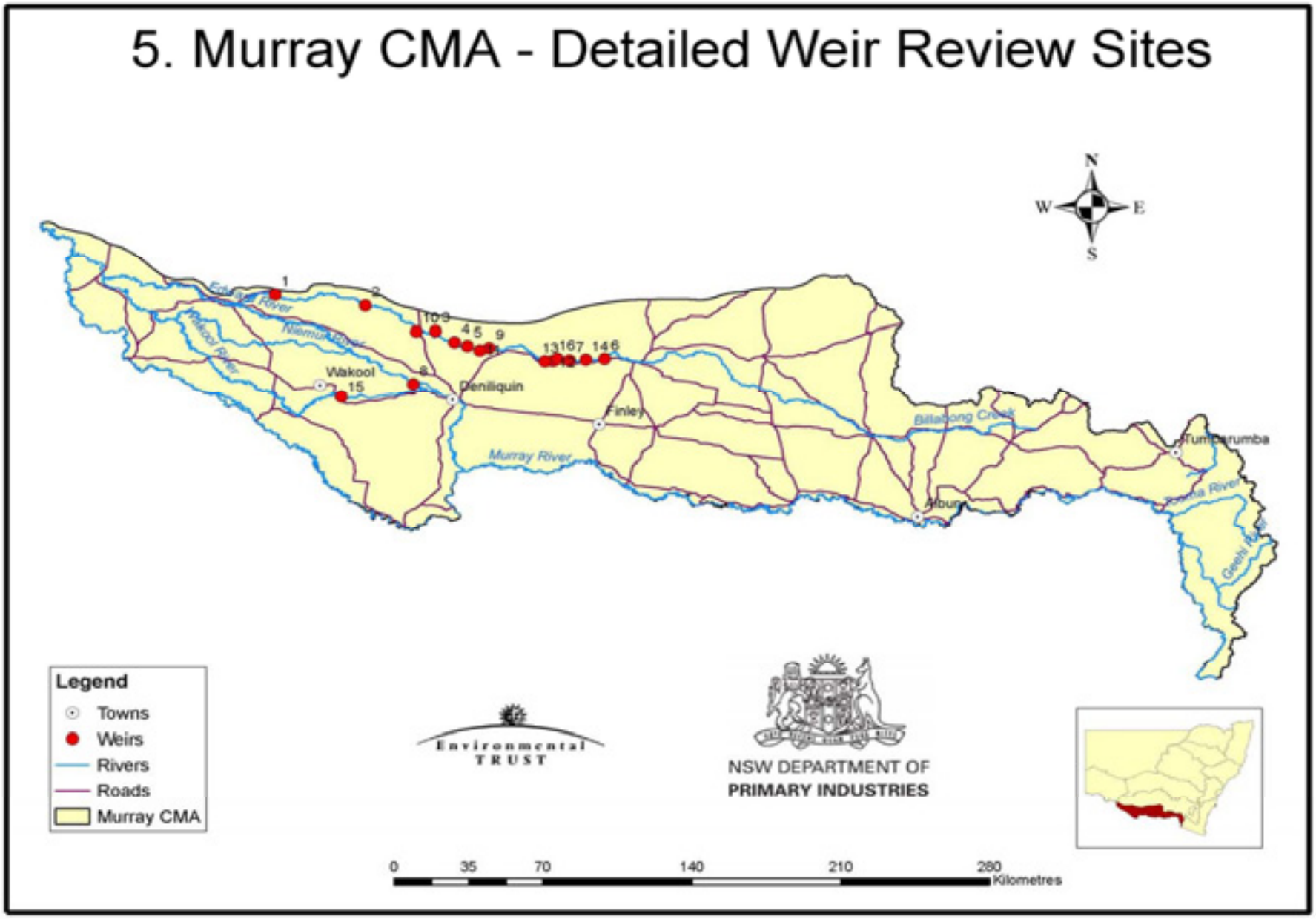
Modification criteria assessed structural use and the ease of remediating the weir. Occasionally structures were recorded during the Detailed Weir Review that were no longer used by the licensee or adjacent property owners. These obsolete weirs received a higher priority score due to the ease (e.g. low 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. Murray CMA - Detailed Weir Review Sites



Murray 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	Windouran Dam	-35.051653	144.207484	Adjustable crest (dropboards)	Billabong Creek	Windouran Pastoral Company	No	Deelder Fishlock	250 - 500K	150 - 250K	103
2	Caroonboon Dam	-35.100904	144.587223	Adjustable crest (dropboards)	Billabong Creek	Faulkiner and Sons Pty. Ltd.	No	Deelder Fishlock	250 - 500K	250 - 500K	111
3	Hartwood Weir	-35.216289	141.883729	Adjustable crest (dropboards)	Billabong Creek	State Water	No	Deelder Fishlock	250 - 500K	500K - 1M	44
4	Chinamans Dam	-35.267617	144.965685	Fixed crest (concrete)	Billabong Creek	Private	No	Removal	<50K	250 - 500K	41
5	Traceys Dam	-35.283836	145.019336	Adjustable crest (dropboards)	Billabong Creek	Private	No	Removal	50 - 150K	N/A	22.6
6	Jerilderie Town Weir	-35.342847	145.598664	Fixed crest (rock fill)	Billabong Creek	Jerilderie Shire Council	No	Full Width Rock Ramp Fishway	150 - 250K	50 - 150K	71
7	Algudgerie Weir	-35.350000	145.450000	Fixed crest (rock fill)	Billabong Creek	Algudgerie Weir Trust	No	Full Width Rock Ramp Fishway	150 - 250K	50 - 150K	39
8	Wakool Regulator	-35.460000	144.790000	Adjustable crest (dropboards)	Wakool River	State Water	No	Vertical Slot Fishway	250 - 500K	150 - 250K	62
9	Boonoke Homestead Weir	-35.293722	145.111833	Fixed crest (concrete)	Billabong Creek	Private	No	Removal	<50K	250 - 500K	37
10	Wanganella Town Weir	-35.218817	144.803849	Adjustable crest (dropboards)	Billabong Creek	Conargo Shire Council	No	Partial Removal	50 - 150K	150 - 250K	70
11	Piccaninni Dam	-35.304193	145.071382	Fixed crest (concrete)	Billabong Creek	Private	No	Removal	<50K	250 - 500K	16.6
12	Hartwood Homestead Weir	-35.351662	145.380698	Fixed crest (concrete)	Billabong Creek	Private	No	Removal	<50K	250 - 500K	18
13	Lower Woolshed Dam	-35.353883	145.347502	Fixed crest (concrete)	Billabong Creek	Private	No	Removal	<50K	N/A	23
14	Old Coree weir	-35.346353	145.519061	Adjustable crest (dropboards)	Billabong Creek	McCaughey Memorial Institute	No	Removal	50 - 150K	250 - 500K	25
15	Widgee Weir	-35.517814	144.486935	Adjustable crest (dropboards)	Wakool River	Private	No	Removal	<50K	50 - 150K	50
16	Road Paddock Dam	-35.341664	145.400021	Fixed crest (concrete)	Billabong Creek	Private	No	Removal	<50K	N/A	14
N/A	Stevens Weir	-35.436600	144.762500	Fixed crest	Edward River	State Water	No (fish passage design and concept complete)	Fishway design has been completed	>1M	N/A	N/A
N/A	Edwards River Offtake	-35.850000	144.980000	Fixed crest	Edward River	State Water	No (existing fishway needs modification)	Modification of Denil inserts to increase water depth and fish passage	<50K	N/A	N/A
N/A	Gulpa Creek Regulator	-35.860000	144.960000	Fixed crest	Gulpa Creek	State Water	No (design for denil fishway complete)	N/A	250 - 500K	N/A	N/A

WINDOURAN DAM, BILLABONG CREEK

Figure 1. Windouran Dam, Billabong Creek (04.03.2005, 142ML/day).

Figure 2. Accumulation of vegetation on Windouran Dam, Billabong Creek (04.03.2005, 142ML/day).

Description and Setting

"Windouran Dam" (Figures 1 and 2) is located approximately 33km upstream of the township of Moulamein on Billabong Creek (Murray River catchment), and is owned and managed by Windouran Pastoral Company. The weir is a regulating structure with a concrete sill and drop boards, and is approximately 2 metres high and 35 metres across the length of the crest. . The weir acts as a barrier to fish passage during most flow conditions as the weir does not drown out.

Windouran Dam is ranked as a high remediation priority within the Murray CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species or populations (Billabong Creek is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria novemaculeata*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), and the river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- Billabong Creek is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds and 'core habitats');
- Improved stream connectivity: the next barrier to fish passage upstream is Caroonboon Weir approximately 68km away. Moulamein Dam is the most downstream licensed weir on Billabong Creek before the junction with Edward River some 35km downstream; and
- Drown out of the weir (flow at which fish passage is possible, where head loss and velocity are minimal) does not occur during typical annual flows.

Hydrology

Billabong Creek originates in the Holbrook area and flows in a westerly direction for in excess of 200km before it enters the Edward River near Moulamein township. Flows within Billabong Creek below the Yanco Creek junction are regulated by Yanco Weir on the Murrumbidgee River. Yanco and Colombo Creeks are effluent tributaries of the Murrumbidgee River and subsequently feed water from the Murrumbidgee River down the Billabong Creek system.

Because of the expanse of Billabong Creek and the great number of associated instream barriers (including crossings), all structures could not be included in this review. Windouran Dam was identified as a major barrier to fish passage on Billabong Creek where little or no fish passage is possible.

There are as many as 13 other licensed barriers on the Billabong Creek between Windouran Dam and the township of Jerilderie, and potentially several unlicensed structures including several crossings that are impeding fish passage.

Flow data was obtained from the DNR river gauge on Billabong Creek at Wanganella township (station 41010810).

Information referred to in this report regarding flows within Billabong Creek was sourced from the DNR website, and describes data acquired between 18.11.1999 - 29.03.2006.

Operational Details

Windouran Dam Weir was built in 1923 for the conservation of water for irrigation, stock, and domestic supply, and is now owned and operated by a private landholder. The weir is an adjustable crest structure, consisting of a concrete sill with drop boards. At the time of inspection the weir had some build up of silt behind the weir resulting in a large amount of vegetation establishing on the right hand side of the structure and deflection of water to the left hand side (Figure 1).

Ecological Considerations

Weirs in Billabong Creek below Jerilderie were selected for the Detailed Weir Review because of their location in the system. Lowland river reaches are recognised as 'core habitats', which are crucial for fish recruitment and migration for such species as golden perch and Murray cod, which are both present in Billabong Creek. By addressing fish passage in the lower Billabong Creek fish will be able to move up from Edward River into the Billabong Creek system to spawn, seek shelter, and locate food. Ideally fish passage will be achieved along the entire Billabong and Colombo/Yanco Creek system to provide connectivity between the Murrumbidgee and Murray catchments. Initially it is important to address fish passage issues at redundant structures, and those weirs that rarely or never drown out. It is also important to acknowledge the social, economical, ecological, and hydrological implications associated with the potential modification of these weirs.

Anecdotal evidence suggests that this weir does not drown out regularly. Limited fish passage may be possible during high flow (flood events) however, if the weir only drowns out for such 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.

It has also become apparent as a result of this review that there may be several creek crossings that are currently blocking the free passage of fish along Billabong Creek. It is essential that in addition to addressing licensed weirs, other legal and illegal instream barriers be identified and remediated. Under the *NSW Fisheries Management Act 1994 (FM Act 1994), Section 219* fish passage must not be blocked temporarily or permanently unless a permit has been granted. The construction of waterway crossings require approval under Part 7 of the *FM Act 1994*, and should be consistent with the "Fish Passage Requirements for Waterway Crossings" (NSW Fisheries 2003) document. Consultation with NSW DPI should occur before the modification, repair, or replacement of all crossings on public and private roads.

Billabong Creek is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *FM Act 1994* as an endangered ecological community (NSW Fisheries 2003).

Figure 3. Billabong Creek downstream of Windouran Dam (04.03.2005,142ML/day).

Figure 4. Billabong Creek upstream of Windouran Dam (04.03.2005,142ML/day).

Both the endangered western population of the purple spotted gudgeon, and the olive perchlet would have historically been found in Billabong Creek. Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing

for all of the nine popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish (*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimps (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment during the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented. The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch, and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish, and gambusia may also be present.

The section of Billabong Creek at "Windouran Dam" possesses some important fish habitat including instream woody debris and aquatic vegetation. Large woody debris provides valuable shelter for fish from strong water currents, and larger avian and aquatic predators. Woody debris and aquatic vegetation also provide an important substrate for fish to lay eggs, and for the growth of algae (which then acts as a food source for macroinvertebrates).

At the time of inspection, the banks both upstream and downstream of the site were moderately vegetated (Figures 3 and 4).

Proposed Remediation Actions

The weir is still required and its removal is not considered a viable option. However, being the lower most licensed weir on the Billabong Creek it is one of the highest priority structures for fish passage within this system.

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

As the weir drowns out infrequently there remain significant periods of time where the passage of all fish will be affected. Installation of a partial width rock ramp fishway would allow fish passage past the structure prior to the structure drowning out. Alterations such as this would make a significant contribution to improving the passage of native fish within Billabong Creek, providing significant environmental benefit for a relatively small investment.

A partial width rock ramp fishway could be incorporated into the weir on the left hand side where the low flow channel currently exists. Modifications to the left hand side of the weir structure would include cutting a low flow channel in the concrete wall to increase the flow through the fishway.

By extending the spillway so that a gradient of 1:20 was formed, and by strategically placing several rock ridges to create resting pools that are connected by short riffles, this modification could provide passage to a greater range of fish species and size classes.

The partial width rock ramp fishway could be constructed perpendicular with the weir on the left hand bank with a return dog-leg. Depending on the flow variations within the creek at this location, the fishway may operate more effectively if it were run parallel to the weir. The entrance of both designs should be located close to the weir wall, and should incorporate an attraction flow to guide fish to the fishway.

Given the fluctuating water levels that are experienced in Billabong Creek (especially during low flow periods), it is recommended that a partial width rock ramp fishway be set parallel to the weir wall, so that the downstream fishway entrance can be located by fish at all flows. Fish will be attracted to water spilling over the weir crest, therefore the fishway entrance should be located as close to the weir wall as possible. If a dog-leg design were chosen, the downstream entrance to the fishway will be positioned close to the weir wall at low flows, but as flows increase, the fishway entrance will gradually be pushed further downstream making it difficult for fish to locate.

- **Option 2 –** Deelder fishlock

Power infrastructure is readily available at this site, therefore lending itself to the installation of a Deelder fishlock. A Deelder fishlock is a low level lock fishway that operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishway 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 water upstream of the weir. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

The Deelder fishlock design is considered a cost effective option for fish passage, although up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River, and has proven to be effective in passing a range of fish species and size classes including: Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch, and the threatened silver perch. The outcome of the subsequent monitoring at this site proved that “the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions” (Baumgartner 2003). Monitoring at this site continues to examine fish passage under various flow conditions and will determine whether this design is applicable to other sites across NSW.

It is possible that the Deelder fishlock design could be applied to Windouran Dam. The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is still in an experimental stage, the Deelder fishlock has already proven to be effective at passing a wide range of native fish species and size classes during low flow periods.

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.

- **Option 3** – Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred fishway design option where threatened species are present (this site is within the expected distribution of silver perch, olive perchlet, purple spotted

gudgeon, trout cod, Macquarie perch, Murray hardyhead, southern pygmy perch, and the river snail *Notopala sublineata*), and when located on the main stem or major tributary of a waterway.

At sites where varying head losses are encountered the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs.
The construction of a vertical slot fishway is the most expensive option for fish passage remediation, however it does not rely on power to operate, and is therefore suitable for remote locations.

Projected Remediation Costs

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

Recommendation

It is recommended that the installation of a Deelder fishlock be investigated (Option 2) as there is power to the site, it would cater for a greater range of flows than other designs, and would be a cheaper alternative to the vertical slot fishway (Option 3). If Option 2 is deemed too expensive, the installation of a partial width rock ramp fishway is recommended (Option 1).

Benefits Associated with Remediation

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

The reinstatement of fish passage at Windouran Dam on the Billabong Creek would reinstate access to approximately 103km of potential fish habitat upstream and downstream, and would provide connectivity between the Billabong Creek and the Edward River.

CAROONBOON WEIR, BILLABONG CREEK

Figure 1. Caroonboon Weir, Billabong Creek (04.03.2005, 142ML/day).

Figure 2. Caroonboon Weir, accumulation of vegetation on weir, Billabong Creek (04.03.2005, 142ML/day).

Description and Setting

Caroonboon Weir (Figures 1 and 2) is located approximately 43km downstream of the township of Wanganella on Billabong Creek (Murray River catchment). The weir is a regulating structure with a concrete sill and drop boards, and is approximately 2.8 metres high and 29 metres across the length of the crest. Caroonboon Weir is owned and managed by Faulkiner and Sons Pty. Ltd and is located on the property "Caroonboon". The weir does not drown out readily, and acts as a barrier to fish passage during most flow conditions.

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

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species or populations (Billabong Creek is within the expected distribution of silver perch, (*Bidyanus bidyanus)*, olive perchlet, (*Ambassis agassizii*)*,* purple spotted gudgeon, (*Mogurnda adspersa*), trout cod, (*Maccullochella macquariensis),* Macquarie perch (*Macquaria novemaculeata)*, Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*)*,* and the river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- Billabong Creek is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds or 'core habitats');
- Improved stream connectivity: the next barrier to fish passage upstream is Wanganella Town Weir approximately 43km away; the next barrier downstream is Windouran Dam approximately 68km away; and
- Drown out of the weir (flow at which fish passage is possible, where head loss and velocity are minimal) does not occur during typical annual flows.

Hydrology

Billabong Creek originates in the Holbrook area and flows in a westerly direction for in excess of 200km, before it enters the Edward River near the township of Moulamein. Yanco Weir on the Murrumbidgee River regulates flows within Billabong Creek below the Yanco Creek junction. Yanco and Colombo Creeks are effluent tributaries of the Murrumbidgee River and subsequently feed water from the Murrumbidgee River down the Billabong Creek system.

There are as many as 14 other licensed barriers on Billabong Creek between Caroonboon Weir and Jerilderie township, and potentially several unlicensed structures including creek crossings that are impeding fish passage. Because of the expanse of Billabong Creek and the large number of associated instream barriers (including crossings), all structures could not be included in this review. Caroonboon Weir was identified as a major barrier to fish passage on Billabong Creek where little or no fish passage is possible.

Flow data was obtained from the DNR river gauge on Billabong Creek at Wanganella township (station 41010810).

Information referred to in this report regarding flows within the Billabong Creek was sourced from the DNR website, and describes data acquired between 18.11.1999-01.02.05.

Operational Details

Caroonboon Weir is owned and operated by a private landholder and was built in 1928 for the conservation of water for irrigation, stock and domestic supply. The weir is an adjustable crest structure, consisting of a concrete sill with numerous drop board bays. At the time of inspection, although there were no drop boards in place, some build up of silt behind the weir was observed resulting in a large amount of vegetation establishing on the right hand side of the weir.

Ecological Considerations

Weirs in Billabong Creek below Jerilderie township were selected for the Detailed Weir Review because of their location in the system. Lowland river reaches are recognised as 'core habitats', which are crucial for fish recruitment and migration, for species such as golden perch and Murray cod, which are both present in Billabong Creek. By addressing fish passage in lower Billabong Creek, fish will be able to move up from Edward River into the Billabong Creek system to spawn, seek shelter, and locate food. Ideally fish passage will be achieved along the entire Billabong and Yanco Creek system to provide connectivity between the Murrumbidgee and Murray catchments. Initially, it is important to address fish passage issues at redundant structures and those weirs that rarely or never drowns out. It is also important to acknowledge the social, economical, ecological, and hydrological implications associated with the potential modification of these weirs.

As a result of the accounts from local landholders and natural resource managers it can be determined that this weir does not drown out readily. Many of the weirs along Billabong Creek may not drown out at all during the year unless high flows associated with flooding are experienced, which may not happen for several years consecutively. During high flow events limited fish passage may be possible, however 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.

It has become apparent as a result of this review that there may be several creek crossings that are also currently blocking the free passage of fish along Billabong Creek. It is essential that in addition to addressing licensed weirs, other legal and illegal instream barriers be identified and remediated. Under the *NSW Fisheries Management Act 1994 (FM Act 1994), Section 219*, fish passage must not be blocked temporarily or permanently unless a permit has been granted. The construction of waterway crossings require approval under *Part 7 of the FM Act 1994*, and should be consistent with the "Fish Passage Requirements for Waterway Crossings" (NSW Fisheries 2003) document. Consultation with NSW DPI should occur before the modification, repair, or replacement of all crossings on public and private roads.

Billabong Creek is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *FM Act 1994* as an endangered ecological community (NSW Fisheries 2003). Both the endangered western population of the purple spotted gudgeon (*Mogurnda adspersa*), and the olive perchlet (*Ambassis agassizii*) would have historically been found in Billabong Creek. Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing for all of the nine popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish (*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimp (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias, and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment during the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented. The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch, and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish, and gambusia also occur in the catchment.

Billabong Creek at Caroonboon Weir possesses some important fish habitat including instream woody debris and aquatic vegetation. Large woody debris provides valuable shelter for fish from strong water currents, and larger avian and aquatic predators. Woody debris and aquatic vegetation also provide an important substrate for fish to lay eggs, and for the growth of algae (which then acts as a food source for macroinvertebrates).

At the time of the inspection, the banks upstream and downstream of the weir were moderately vegetated (Figures 3 and 4). There is some erosion present downstream of the weir as a result of water scouring the banks after passing over the weir and pressures created by stock grazing (which has also resulted in less vegetation being present downstream).

Willows were also present upstream and adjacent the weir (Figures 1 and 2). It is recommended that the removal of the existing willows take place during the remediation of this weir, in addition to stock exclusion fencing and provision of off river watering points. Recently Greening Australia has been working with landholders to identify and fence many areas along Billabong Creek to encourage regeneration of riparian plant species, and contribute to improved river health.

Figure 3. Billabong Creek downstream of Caroonboon Weir (04.03.2005,142ML/day).

Figure 4. Billabong Creek upstream of Caroonboon Weir (04.03.2005, 142ML/day).

Proposed Remediation Actions

The weir is still required for provision of stock, irrigation, and domestic water supply; therefore its removal is not considered a viable option at this time.

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

As the weir drowns out infrequently there remains significant periods of time when the passage of all fish will be affected. The alteration to the existing structure and construction of a partial 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 environmental benefit for a relatively small investment.

A partial rock ramp fishway could be incorporated onto the weir on the left hand side where the low flow channel currently exists. Modifications to weir on the left hand side would include cutting a low flow channel in the concrete wall to increase the flow through the fishway, and provide attraction flows. The partial width rock ramp fishway could be constructed perpendicular with the weir on the left hand bank with a dog-leg return or, depending on flow variations within the creek at this location, the rock ramp may be utilised more effectively if it were run parallel to the weir. The entrance for both these designs should be located close to the weir and incorporate an attraction flow to guide fish to the fishway entrance. By 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 short riffles, this modification could provide passage to a greater range of fish species and size classes over a wider range of flows.

A potential limitation of a partial width rock ramp fishway is their poor performance over large variations in headwater (which can be experienced in Billabong Creek). An assessment of current management practices in relation to the addition and removal of dropboards should be undertaken to determine the potential headwater range.

- **Option 2 –** Deelder fishlock

A Deelder fishlock could also be considered at Caroonboon Weir, providing a cheaper alternative to a vertical slot fishway design, but likely to cost more than the partial width rock ramp fishway option. A Deelder fishlock is a low level lock fishway that operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. 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 water upstream of the weir. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

The Deelder fishlock design is considered a cost effective option for fish passage, although up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River, and has proven to be effective in passing a range of fish species and size classes including: Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch, and the threatened silver perch.

The outcome of the subsequent monitoring at this site proved that "the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions" (Baumgartner 2003). Monitoring at this site continues to examine fish passage under various flow conditions and will determine whether this design is applicable to other sites across NSW.

It is possible that the Deelder fishlock design could be applied to Caroonboon Weir. The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is still in an experimental stage the Deelder fishlock has already proven to be effective at passing a wide range of native fish species and size classes during low flow periods. Limitations of the Deelder fishlock is that it requires power infrastructure to operate as a fully automated system. If power is not easily accessible at this site, a significant amount of resources would need to be made available for this design, and the cost would rise significantly.

A further 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.

- **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 (this site is within the expected distribution of silver perch, olive perchlet, purple spotted gudgeon, trout cod, Murray hardyhead, southern pygmy perch, Macquarie perch and the endangered river snail. 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 concrete construction 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.

Projected Remediation Costs

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

Recommendation

It is recommended that the installation of a Deelder fishlock be investigated (Option 2) as it would cater for a greater range of flows, and operate more effectively within the variable flow environment of Billabong Creek. If the cost of this design is dependant on acquiring power at the site, the vertical slot fishway (a more expensive alternative) should be further investigated.

Benefits Associated with Remediation

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

The reinstatement of fish passage at Caroonboon Weir on Billabong Creek would reinstate access to approximately 111km of potential fish habitat either side of this site.

HARTWOOD WEIR, BILLABONG CREEK

Figure 1. Hartwood Weir, Billabong Creek (04.03.2005, 142ML/day).

Figure 2. Hartwood Weir downstream erosion protection works, Billabong Creek (04.03.2005, 142ML/day).

Description and Setting

"Hartwood Weir" (Figures 1 and 2) is located approximately 42km west of the township of Jerilderie on Billabong Creek (Murray River catchment). The weir is a regulating structure with a concrete sill and drop boards, and is approximately 2.5 metres high and 15 metres across the length of the crest. Hartwood Weir is owned and managed by State Water and acts as a barrier to fish passage during most flow conditions, as the weir does not drown out.

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

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species or populations (Billabong Creek is within the expected distribution of silver perch, (*Bidyanus bidyanus*), olive perchlet, (*Agassis agassizii*), purple spotted gudgeon, (*Mogurnda adspersa*), trout cod, (*Maccullochella macquariensis*), Macquarie perch (*Macquaria novemaculeata*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), and the river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- Billabong Creek is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds and 'core habitats');
- Improved stream connectivity: the next barrier to fish passage upstream is the privately owned "Lower Woolshed Weir" approximately 15km away; the next barrier downstream is the Boonoke Homestead Weir approximately 29km away; and
- Drown out of the regulator (flow at which fish passage is possible, where head loss and velocity are minimal) does not occur.

Hydrology

Billabong Creek originates in the Holbrook area and flows in a westerly direction for in excess of 200km, where it enters the Edward River near the township of Moulamein. Flows within Billabong Creek below the Yanco Creek junction are regulated by Yanco Weir on the Murrumbidgee River. Yanco and Colombo Creeks are effluent tributaries of the Murrumbidgee River and subsequently feed water from the Murrumbidgee River down the Billabong Creek system.

There are a total of 15 licensed weirs along both the regulated and unregulated section of Billabong Creek. Because of the expanse of Billabong Creek and the large number of associated instream barriers, all structures could not be included in this review. Hartwood Weir was identified as a major barrier to fish passage on Billabong Creek where little or no fish passage is possible.

There are five other licensed barriers on Billabong Creek between Hartwood Weir and the township of Jerilderie, including Road Paddock Dam, Hartwood Homestead Weir, Lower Woolshed Dam, an unnamed weir on the property "Coree", and Algudgerie Weir. Hartwood Weir is designed to back water upstream where it is diverted down Forest Creek for stock, domestic, and irrigation supply.

Flow data was obtained from the DNR river gauge on Billabong Creek at Jerilderie (station 409016). Information referred to in this report regarding flows within the Billabong Creek was sourced from State Water and the DNR website, and describes data acquired between 02.10.1984 – 21.12.2005.

Operational Details

Hartwood Weir was built in 1926 for the conservation and diversion of water for irrigation, stock, and domestic supply down Forest Creek. The weir is an adjustable release structure constructed of concrete, with five drop board bays that enable water levels in the weir pool to be manipulated. Hartwood Weir is owned and operated by State Water. During the Initial Weir Review conducted by NSW Fisheries in 2000, it was noted that Hartwood Weir was scheduled for replacement and would be upgraded to a fully automated gated weir. As of May 2006 no works had begun on the upgrade of the weir. During discussions with State Water at this time, the potential upgrade of Hartwood Weir was confirmed but no time frame could be given for the scheduled works. It is not likely that this structure will be upgraded in the near future, as other larger structures across the catchment have become a higher priority.

Ecological Considerations

Weirs in Billabong Creek below Jerilderie were selected for the Detailed Weir Review due to their location in the system. Lowland river reaches are recognised as 'core habitats', which are crucial for fish recruitment and migration for species such as golden perch and Murray cod, which are both present in Billabong Creek. By addressing fish passage in lower Billabong Creek, fish will be able to move up from Edward River into the Billabong Creek system to spawn, seek shelter, and locate food. Ideally fish passage will be achieved along the entire Billabong and Yanco Creek system to provide connectivity between the Murrumbidgee and Murray catchments. Initially it is important to address fish passage issues at redundant structures and those weirs that rarely or never drown out. It is also important to acknowledge the social, economical, ecological, and hydrological implications associated with the potential modification of these weirs.

It has become apparent as a result of this review that there may be several creek crossings that are also currently blocking the free passage of fish along Billabong Creek. It is essential that in addition to addressing licensed weirs, other legal and illegal instream barriers be identified and remediated. Under the *NSW Fisheries Management Act 1994 (FM Act 1994), Section 219*, fish passage must not be blocked temporarily or permanently unless a permit has been granted. The construction of waterway crossings requires approval under *Part 7 of the FM Act 1994*, and should be consistent with the "Fish Passage Requirements for Waterway Crossings" (NSW Fisheries 2003) document. Consultation with NSW DPI should occur before the modification, repair, or replacement of all crossings on public and private roads.

Billabong Creek is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *FM Act 1994* as an endangered ecological community (NSW Fisheries 2003). Both the endangered western population of the purple spotted gudgeon (*Mogurnda adspersa*), and the olive perchlet (*Ambassis agassizii*) would have historically been found in Billabong Creek.

Figure 3. Disused crossing downstream of "Hartwood Weir", Billabong Creek (04.03.2005,142ML/day).

Figure 4. Billabong Creek upstream of "Hartwood Weir" (04.03.2005,142ML/day).

Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing for all of the nine popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish

(*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimp (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment during the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented. The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch, and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish, and gambusia also occur in the catchment.

The section of Billabong Creek at Hartwood Weir possesses some important fish habitat including instream woody debris, which provides valuable shelter for fish from strong water currents, larger avian and aquatic predators. Woody debris also provides an important substrate for fish to lay eggs and for the growth of algae (which then acts as a food source for macroinvertebrates).

At the time of the inspection, the banks upstream and downstream of the site were moderately vegetated. There were several willows present directly upstream and downstream of the weir (Figures 3 and 4). There is some erosion present downstream of the weir as a result of water scouring the banks after passing over the weir and pressures created by stock grazing. There is also a redundant creek crossing located approximately 100 metres downstream. In its current condition the crossing is not directly impacting on fish passage, however while the infrastructure remains in place there is a possibility that debris could collect at this point, creating a barrier to fish and potentially increasing the potential for erosion through deflection of water into the banks.

It is recommended that removal of the existing willows take place during future modification or replacement of this weir. Partial or complete removal of the redundant crossing downstream as well as stock exclusion fencing is also recommended for this site. Recently Greening Australia has been working with landholders to identify and fence many areas along Billabong Creek to encourage regeneration of riparian plant species, and contribute to improved river health.

Proposed Remediation Actions

Hartwood Weir is a total barrier to fish passage and as a result it is recommended that fish passage options be further investigated at this site.

- **Option 1 –** Deelder fishlock

A Deelder fishlock is a low level lock fishway that operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. 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 water upstream of the weir. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

The Deelder fishlock design is considered a cost effective option for fish passage, although up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River, and has proven to be effective in passing a range of fish species and size classes including: Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch, and the threatened silver perch. The outcome of the subsequent monitoring at this site proved that "the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions" (Baumgartner 2003). Monitoring at this site continues to examine fish passage under various flow conditions and will determine whether this design is applicable to other sites across NSW.

It is possible that the Deelder fishlock design could be applied to Hartwood Weir during the replacement/upgrade of the structure. The results of the Balranald fishlock study will provide some useful concepts that could be applied to this site. Although it is still in an experimental stage, the Deelder fishlock has already proven to be effective at passing a wide range of native fish species and size classes during low flow periods.

A limitation of the Deelder fishlock is that it requires power infrastructure to operate as a fully automated system. If power is not easily accessible at this site, a significant amount of resources would need to be made available for this design, and the cost would rise significantly.

A further 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.

- **Option 2** – Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred fishway design option where threatened species are present (this site is within the expected distribution of silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, southern pygmy perch, and the river snail *Notopala sublineata*), and when located on the main stem or major tributary of a waterway. At sites where varying head losses are encountered the vertical slot fishway would be more effective than other fishway designs in passing a greater range of fish size classes.

The construction of a vertical slot fishway is the highest cost option for fish passage remediation at Hartwood Weir, however it does not rely on power to operate, and is therefore suitable for remote locations.

Projected Remediation Costs

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

Recommendation

It is recommended that the installation of a Deelder fishlock be investigated to remediate fish passage at Hartwood Weir (Option 1). The vertical slot fishway design (Option 2) should also be considered and both be further assessed in a fishway options study.

Benefits Associated with Remediation

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

The reinstatement of fish passage at Hartwood Weir on Billabong Creek would reinstate access to approximately 44km of potential fish habitat either side of the weir.

BOONOKE HOMESTEAD WEIR, PICCANINNI, TRACEYS, AND CHINAMANS DAM, BILLABONG CREEK

Figure 1. Boonoke Homestead Weir (constructed 1927), Billabong Creek (04.03.2005, 142ML/day).

Figure 2. Piccaninni Dam (constructed 1919), Billabong Creek (04.03.2005, 142ML/day).

Figure 3. Tracey's Dam (constructed 1911), Billabong Creek (04.03.2005, 142ML/day).

Figure 4. Chinamans Dam (constructed 1914), Billabong Creek (04.03.2005, 142ML/day).

Description and Setting

Boonoke Homestead Weir (Figure 1) is located approximately 12km downstream of the Conargo Bridge. Piccaninni Dam (Figure 2) is a further 8km downstream, Tracey's Dam (Figure 3) is located another 8.6km downstream, with Chinamans Dam (Figure 4) located on the property "Boonoke" a further 14km downstream towards the township of Wanganella. These weirs are located on Billabong Creek within the Murray River catchment. All four weirs are overshot structures composed of concrete and are of similar in dimensions. All four weirs are owned and managed by one private company, and all act as barriers to fish passage during most flow conditions.

The above mentioned weirs are ranked as high remediation priorities within the Murray CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species (Billabong Creek is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria novemaculeata*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), and the river snail (*Notopala sublineata*));
- Billabong Creek is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds 'core habitats');
- Diverse range of native fish (High Conservation Value);
- Improved stream connectivity: the next barrier to fish passage upstream from Boonoke Homestead Weir is the State Water owned "Hartwood Weir" approximately 29km away. The next barrier downstream of Chinaman's Dam is Wanganella Dam - approximately 27km away. The distance between the four weirs reviewed here is approximately 30km; and
- Drown out of all four weirs does not occur during normal flow conditions (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Billabong Creek originates in the Holbrook area and flows in a westerly direction for in excess of 200km where it enters the Edward River near the township of Moulamein. Flows within the Billabong Creek below the Yanco Creek junction are regulated by Yanco Weir on the Murrumbidgee River. Yanco and Colombo Creeks are effluent tributaries of the Murrumbidgee River and subsequently feed water from the Murrumbidgee River down the Billabong Creek system.

There are a total of 15 licensed weirs along both the regulated and unregulated section of Billabong Creek. Because of the expanse of Billabong Creek the great number of associated instream barriers, all structures could not be included in this review. The four above-mentioned weirs were identified as major barriers to fish passage on Billabong Creek where little or no fish passage is possible. It was suggested in the Initial Weir Review (NSW Fisheries 2000), that the weir pool created by Chinamans Dam extends up to Tracey's Dam.

During site inspections undertaken in May 2000, Tracey's Dam was the only structure of these four weirs that was drowned out and where fish passage was possible.

Between Boonoke Homestead Weir (upper most weir of the four), and the town of Jerilderie, there are 7 other licensed barriers on the Billabong Creek.

Flow data was obtained from the DNR river gauge on Billabong Creek at Wanganella township (station 41010810). Information referred to in this report regarding flows within Billabong Creek was sourced from State Water and the DNR website, and describe data acquired between 18.11.1999-01.02.2005.

Operational Details

The four weirs are owned and operated by the same private landholder. Boonoke Homestead Weir was built in 1927, and is a fixed crest overshot concrete weir approximately 2 metres in high and 26 metres wide. The weir is currently used for the provision of water for stock and domestic use. At the time of the inspection the structure appeared stable and there were no visible leaks in the wall and abutments.

Piccaninni and Chinamans Dam were built in 1919 and 1914 respectively, are similar in construction and size, both being approximately 2 metres high and 30 metres wide. Both structures are used for the provision of water for stock and irrigation purposes, and at the time of inspection both structures possessed some cracks in the wall and abutments. It could not be determined whether the cracks were affecting the structural integrity of the weirs.

Tracey's Dam is similar in construction to Wanganella Town Weir, being approximately 1.8 metres high and 20 metres across the width of the creek. This structure has ten drop board bays allowing the opportunity to manage water levels upstream. At the time of the inspection no boards were in place.

Ecological Considerations

Weirs in Billabong Creek below Jerilderie township were selected for the Detailed Weir Review because of their location in the system. Lowland river reaches are recognised as 'core habitats', which are crucial for fish recruitment and migration for species such as golden perch and Murray cod, which are both present in Billabong Creek. By addressing fish passage in lower Billabong Creek, fish will be able to move up from Edward River into the Billabong Creek system to spawn, seek shelter, and locate food. Ideally fish passage will be achieved along the entire Billabong and Colombo/Yanco Creek system to provide connectivity between the Murrumbidgee and Murray catchments. Initially it is important to address fish passage issues at redundant structures and those weirs that rarely or never drown out. It is also important to acknowledge the social, economical, ecological, and hydrological implications associated with the potential modification of these weirs.

Although limited fish passage may be possible during high flow events, if the weir only drowns out for such 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 5. Billabong Creek downstream and upstream of Boonoke Homestead Weir (04.03.2005, 142ML/day).

It has become apparent as a result of this review that there may be several creek crossings that are also currently blocking the free passage of fish along Billabong Creek. It is essential that in addition to addressing licensed weirs, other legal and illegal instream barriers be identified and remediated. Under the *NSW Fisheries Management Act 1994* (*FM Act 1994*), *Section 219* fish passage must not be blocked temporarily or permanently unless a permit has been granted. The construction of waterway crossings requires approval under Part 7 of the *FM Act 1994* and should be consistent with the "Fish Passage Requirements for Waterway Crossings" (NSW Fisheries 2003) document. Consultation with NSW DPI should occur before the modification, repair, or replacement of all crossings on public and private roads.

Figure 6. Billabong Creek downstream and upstream of Piccaninni Dam (04.03.2005, 142ML/day).

Billabong Creek is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *FM Act 1994* as an endangered ecological community (NSW Fisheries 2003). Both the endangered western population of the purple spotted gudgeon (*Mogurnda adspersa*), and the olive perchlet (*Ambassis agassizii*) would have historically been found in Billabong Creek.

Figure 7. Billabong Creek downstream and upstream of Tracey's Dam (04.03.2005, 142ML/day).

Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing for all of the nine popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish (*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimps (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

Figure 8. Billabong Creek downstream and upstream of Chinamans Dam (04.03.2005, 142ML/day).

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment during the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented.

The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch, and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish, and gambusia also occur in the catchment.

This section of Billabong Creek possesses some important fish habitat including instream woody debris and aquatic vegetation. Large woody debris provides valuable shelter for fish from strong water currents and larger avian and aquatic predators. Woody debris and aquatic vegetation also provide an important substrate for fish to lay eggs, and for the growth of algae (which then acts as a food source for macroinvertebrates).

At the time of the inspection, the banks upstream and downstream of the weirs were moderately vegetated (Figures 5-8), although some erosion was present downstream of the weirs due to water scouring the banks after passing over the weirs and pressures created by stock grazing.

The banks of the creek upstream and downstream of Boonoke Homestead Weir were covered with willows. No willows were observed at any of the other sites. It is recommended that the removal of the existing willows take place during the modification or removal of Boonoke Homestead Weir in addition to stock exclusion fencing, and provision of off river watering points at each of the sites. Recently Greening Australia has been working with landholders to identify and fence many areas along Billabong Creek to encourage regeneration of riparian plant species, and contribute to improved river health.

Proposed Remediation Actions

All four weirs are barriers to fish passage. It is therefore recommended that the fish passage options below be further investigated, with the most appropriate option applied to each site.

- **Option 1 –** Removal

Many of the weirs present on the Billabong Creek were constructed prior to regulation of the system (~1928). Although extraction of water may currently take place upstream of these structures, there may be some scope to modify or remove them whilst retaining the ability to pump water in the absence of a weir. It is therefore recommended that consideration be given to the removal of one or more of the four structures. As indicated in the previous review conducted in 2000, the weir pool created by Chinamans Dam extends up to Tracey's Dam, therefore continued water extraction is likely to be possible within this reach following the removal of Tracey's Dam.

At the time of writing, consultation with the property owner had not occurred regarding possible fish passage remediation options at these sites, and cost benefit analysis of retaining these weirs still needed to be established. It is necessary to ensure that the ability of the landholder to access water for stock, domestic, and irrigation purposes is not compromised. Negotiation should take place to satisfy the needs of the landholder, whilst establishing effective fish passage at all four weirs.

An evaluation of the structural integrity all of these weirs is required to determine if removal or installation of a fishway is the more appropriate option.

If major repairs or modifications were required, fish passage would need to be incorporated into the new design. If the removal of one or more of these weirs could be achieved it would provide long-term benefits for the health of the entire Billabong Creek system.

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

As all four weirs drown out infrequently, there remain significant periods of time where the passage of all fish will be affected. The alteration to the existing structure to install a partial width rock ramp fishway would provide fish passage prior to the drown out of the structure, significantly improving the passage of native fish, and providing a significant environmental benefit for a relatively small investment.

A partial width rock ramp fishway could be incorporated into each of the weirs where the low flow channel currently exists (alternatively a low flow channel could be created by cutting a section out of the wall to increase flow through the fishway). The partial width rock ramp fishway should be built by extending the existing spillway on a gradient of 1:20, with strategically placed rock ridges forming resting pools that are connected by short riffles. Depending on the flow variations at this location, the fishway may operate more effectively if it were run parallel to the weir. The entrance should be located close to the weir and should incorporate an attraction flow to guide fish to the fishway.

A partial width rock ramp fishway will provide passage to a greater range of fish species and size classes prior to drown out of the structure, however its success would still be limited by fluctuating water levels that are experienced in Billabong Creek. As both Piccaninni and Chinamans Weirs both have visible cracks, repairs may be need to be undertaken prior to the installation of any fishway.

- **Option 3 –** Deelder Fishlock

All four weirs may lend themselves to a Deelder fishlock design. A Deelder fishlock is a low level lock fishway that operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. 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 water upstream of the weir. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

The Deelder fishlock design is considered a cost effective option for fish passage, although until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River and has proven to be effective in passing a range of fish species and size classes including: Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch, and the threatened silver perch. The outcome of the subsequent monitoring at this site proved that “the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions” (Baumgartner 2003). Monitoring at this site continues to examine fish passage under various flow conditions and will determine whether this design is applicable to other sites across NSW.

A limitation of the Deelder fishlock is that it requires power infrastructure to operate as a fully automated system. This fishway design should therefore only be considered where existing power infrastructure is available or could be easily accessed. If power infrastructure is not available at these sites, alternative fishway options should be considered, as the cost of construction would rise significantly.

A further 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.

- **Option 4** – Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred fishway design option where threatened species are present (this site is within the expected distribution of silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, southern pygmy perch and the river snail *Notopala sublineata*), and when located on the main stem or major tributary of a waterway. At sites where varying head losses are encountered the vertical slot fishway would be more effective than other fishway designs in passing a greater range of fish size classes. The construction of a vertical slot fishway is the highest cost option for fish passage remediation at these sites, however it does not rely on power to operate and is therefore suitable for remote locations.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K- $250K	$250K - $500K	$500K - $1M
Option 1		✔			
Option 2			✔		
Option 3				✔	
Option 4				✔	

Recommendation

It is recommended that the removal of Tracey's Dam be investigated (Option 1), and removal of the other three weirs also be considered.

It is recommended that if the Boonoke Homestead Weir is still required, the installation of a Deelder fishlock be investigated for this site (Option 3). If power infrastructure is available at Chinamans Dam and Piccaninni Dam, a Deelder fishlock could also be considered for these two sites; otherwise a vertical slot fishway design should be investigated further (Option 4).

Benefits Associated with Remediation

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

The reinstatement of fish passage at Boonoke Homestead Weir, Piccaninni, Tracey's, and Chinamans Dams on Billabong Creek would reinstate access to approximately 56km of potential fish habitat upstream and downstream of these structures.

JERILDERIE TOWN WEIR AND ALGUDGERIE WEIR, BILLABONG CREEK

Figure 1. Jerilderie Town Weir (constructed 1894, last modified 1943), Billabong Creek (07.03.2005, 98ML/day).

Figure 2. Algudgerie Weir (constructed 1909), Billabong Creek (07.03.2005, 98ML/day).

Description and Setting

Jerilderie Town Weir (Figure 1) is located within the town limits of Jerilderie. Algudgerie Weir (Figure 2) is located approximately 26km downstream of Jerilderie Weir on Billabong Creek at a Travelling Stock Reserve. Both weirs are located in the Lower Murray River catchment. Jerilderie and Algudgerie weirs are overshot weirs constructed of rock. The Jerilderie Town Weir is currently managed by the Jerilderie Shire Council, whilst ownership and management responsibilities of Algudgerie Weir are currently the responsibility of the Algudgerie Weir Trust. Both weirs act as barriers to fish passage over most flow conditions.

Jerilderie and Algudgerie weirs are ranked as high remediation priorities within the Murray CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species or populations (Billabong Creek is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria novemaculeata*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), and the river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- Billabong Creek is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds and 'core habitats');
- Improved stream connectivity: the next barrier to fish passage upstream would most likely be on Colombo Creek (whose junction with Billabong Creek is approximately 45km upstream of Jerilderie township); the next barrier downstream from Algudgerie Weir is Old Coree Weir approximately 13km away; and
- Drown out of both weirs (flow at which fish passage is possible, where head loss and velocity are minimal) does not occur readily.

Hydrology

Billabong Creek originates in the Holbrook area and flows in a westerly direction for in excess of 200km, before it enters the Edward River near the township of Moulamein. Flows within Billabong Creek below the Yanco Creek junction are regulated by Yanco Weir on the Murrumbidgee River. Yanco and Colombo Creeks are effluent tributaries of the Murrumbidgee River and subsequently feed water from the Murrumbidgee River down the Billabong Creek system.

There are a total of 15 licensed weirs along both the regulated and unregulated section of Billabong Creek. Because of the expanse of Billabong Creek and the large number of associated instream barriers, all structures could not be included in this review. Jerilderie Town Weir and Algudgerie Weir were identified as major barriers to fish passage on Billabong Creek where limited fish passage is possible.

Flow data was obtained from the DNR river gauge on Billabong Creek at Jerilderie (station 409016).

Information referred to in this report regarding flows within the Billabong Creek was sourced from State Water and the DNR website, and describes data acquired between 02.10.1984 – 21.12.2005.

Jerilderie Town Weir and Algudgerie Weir do not drown out annually. It has been estimated that drown out of Jerilderie Weir occurs when flows are in excess of 800ML/day, whilst Algudgerie Weir drowns out when flows are in excess of 1500ML/day. Based on the time weighted flow duration curve for Billabong Creek at this location, flows are equal to or greater than 1500ML/day approximately <10% of time. It is reasonable to assume that at this time limited fish passage may be possible, however further hydrological analysis is required to determine whether the available window for upstream fish passage correlates with the key migration periods for native fish.

Operational Details

The Jerilderie Town Weir was originally built around 1894 and was last modified in 1943. The weir is a fixed crest overshot rock weir approximately 2 metres in height and 30 metres along the length of the crest, and is owned and managed by Jerilderie Shire Council. Jerilderie Town Weir is currently used for the provision of water for domestic use, with the town water supply pipe located upstream. At the time of the inspection the structure appeared stable and there were no visible leaks in the wall and abutments.

Algudgerie Weir was built in 1909 and is owned and managed by the Algudgerie Weir Trust. The weir is a fixed crest overshot rock weir approximately 2.2 metres high and 35 metres along the length of the crest, and was originally built as a water supply for stock, domestic, and irrigation use. Maintenance of the weir has not been required for the last 10 years.

As many as seven private landholders/ companies and the Rural Lands Protection Board are executors of the Algudgerie Weir Trust. Both Jerilderie Town Weir and Algudgerie Weirs have been recognised by Jerilderie Shire Council as being a significant cultural asset to the local region. On the southern side of the creek adjacent to the weir the land is a Travelling Stock Reserve.

Ecological Considerations

Weirs in Billabong Creek below Jerilderie township were selected for the Detailed Weir Review due to their location in the system. Lowland river reaches are recognised as ‘core habitats’, which are crucial for fish recruitment and migration, for species such as golden perch and Murray cod, which are both present in Billabong Creek. By addressing fish passage in lower Billabong Creek, fish will be able to move up from Edward River into the Billabong Creek system to spawn, seek shelter, and locate food. Ideally fish passage will be achieved along the entire Billabong and Colombo/Yanco Creek system to provide connectivity between the Murrumbidgee and Murray catchments. Initially it is important to address fish passage issues at redundant structures, and those weirs that rarely or never drown out. It is also important to acknowledge the social, economical, ecological, and hydrological implications associated with the potential modification of these weirs.

Although limited fish passage may be possible during high flow events, 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.

It has become apparent as a result of this review that there may be several creek crossings that are also currently blocking the free passage of fish along Billabong Creek. It is essential that in addition to addressing licensed weirs, other legal and illegal instream barriers be identified and remediated. Under the *NSW Fisheries Management Act 1994* (*FM Act 1994*)*, Section 219*, fish passage must not be blocked temporarily or permanently unless a permit has been granted. The construction of waterway crossings requires approval under *Part 7 of the FM Act 1994*, and should be consistent with the "Fish Passage Requirements for Waterway Crossings" (NSW Fisheries 2003) document. Consultation with NSW DPI should occur before the modification, repair or replacement of all crossings on public and private roads.

Billabong Creek is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *FM Act 1994* as an endangered ecological community (NSW Fisheries 2003). Both the endangered western population of the purple spotted gudgeon (*Mogurnda adspersa*), and the olive perchlet (*Ambassis agassizii*) would have historically been found in Billabong Creek. Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing for all of the nine popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish (*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimp (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias, and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment during the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented. The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch, and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish and gambusia also occur in the catchment.

The specifications given when constructing fishways state that it should operate over 95% of all flow conditions. However, it has been estimated that fish passage at Algudgerie Weir may only be possible <10% of time. If the weir only drowns out for such 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 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 recreational species.

This section of Billabong Creek possesses some important fish habitat including instream woody debris and aquatic vegetation. Large woody debris provides valuable shelter for fish from strong water currents, and larger avian and aquatic predators. Woody debris and aquatic vegetation also provide an important substrate for fish to lay eggs, and for the growth of algae (which then acts as a food source for macroinvertebrates).

Figure 3. Billabong Creek downstream and upstream of Jerilderie Town Weir (07.03.2005,98ML/day).

Figure 4. Billabong Creek downstream and upstream of Algudgerie Weir (07.03.2005, 98ML/day).

At the time of the inspection, the banks upstream and downstream of the weirs were moderately vegetated (Figures 3 and 4).

There was some erosion present downstream from both weirs due to water scouring the banks after passing over the weirs, and pressures created by stock grazing and public access (Figures 3 and 4). Downstream of Algudgerie Weir there were several willows present on the left hand bank.

It is recommended that the removal of the existing willows take place during remediation of Algudgerie Weir for fish passage, in addition to stock exclusion fencing and provision of off river watering points.

Recently Greening Australia has been working with landholders to identify and fence many areas along Billabong Creek to encourage regeneration of riparian plant species, and contribute to improved river health.

Proposed Remediation Actions

Both Jerilderie and Algudgerie weirs are significant barriers to fish passage, and it is recommended that fish passage options be further investigated for both sites. In their current state, however, both weirs require a complete rebuild to allow for more formal fishway designs (such as a vertical slot fishway, or Deelder fishlock) to be constructed. Proposed remediation actions therefore recommend modification of the existing rock wall to form either a partial width or full width rock ramp fishway to facilitate fish passage.

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

A partial width rock ramp design could be considered at both Jerilderie Town Weir and Algudgerie Weir to provide fish passage prior to structure drown out. As both weirs drown out infrequently (at the most <10% of the time), there remains significant periods of time where the passage of all fish will be affected. The alteration to the existing structures to incorporate a partial width rock ramp fishway would make a significant contribution to improving the passage of native fish and provide a significant environmental benefit for a relatively small investment.

Modifications to the weir would include creating a low flow channel in the existing rock wall to direct flow through the fishway. By extending the existing spillway so that a gradient of 1:20 was created, and by strategically placing several rock ridges to create resting pools that are connected by short riffles, this modification (partial width rock ramp fishway) could provide passage to a greater range of fish species and size classes than is currently possible.

The partial width rock ramp fishway could be constructed perpendicular to the weir with a return dog-leg, or depending on the flow variations within the creek at this location, the fishway may operate more effectively if it were run parallel to the weir. The entrance of both designs should be located close to the weir wall, and should incorporate an attraction flow to guide fish to the fishway. However successful operation of the fishway would still be limited by fluctuating water levels that are experienced in Billabong Creek (especially during low flow periods).

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

The construction of a full width rock ramp fishway would provide similar benefits as a partial width rock ramp fishway (Option 1), although the costs incurred would be greater due to the considerable amount of rock needing to be imported to create a fishway with a slope of 1:20.

As both weirs are approximately 2 metres high, both the partial width rock ramp and full width rock ramp fishways would extend approximately 40 metres downstream (although the partial width rock ramp fishway would dog-leg back toward the weir, meaning that the downstream extension of the structure would be approximately 10 metres).

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.

Projected Remediation Costs

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

Recommendation

Despite the higher cost, it is recommended that a full width rock ramp fishway (Option 2) be investigated for both Jerilderie Town Weir and Algudgerie Weir as this design allows for fish passage over a greater range of flows than a partial width rock ramp fishway (Option 1).

Benefits Associated with Remediation

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

The reinstatement of fish passage at Jerilderie Town Weir and Algudgerie Weir on Billabong Creek would reinstate access to over 30km of potential fish habitat either side of these structures.

WAKOOL OFFTAKE REGULATOR, WAKOOL RIVER

Figure 1. Wakool Regulator, Wakool River (02.03.2005, 42ML/day).

Figure 2. Wakool Regulator looking from downstream, Wakool River (02.03.2005, 42ML/day).

Figure 3. Wakool Regulator looking from downstream, Wakool River. Comparative photo in low flow conditions (27.07.04, 0ML/day).

Description and Setting

Wakool Regulator (Figures 1, 2, and 3) is located approximately 25km north west of Deniliquin on the Wakool River (Lower Murray River catchment). The weir is approximately 2 metres in height and 15 metres across the length of the crest. The weir is a regulating structure constructed of concrete, and has a mechanical regulating gate and four bays with drop boards. The weir acts as a barrier to fish passage during most flow conditions as the regulator does not drown out.

The Wakool Regulator is ranked as a high remediation priority within the Murray CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species (the Wakool River is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria novemaculeata*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*) and the river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- The Wakool River is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds and 'core habitats');

- Improved stream connectivity: there are no licensed weirs located upstream from the Wakool Regulator on the Wakool River. The next licensed weir below the Wakool Regulator is a privately owned weir approximately 42km away on the property “Widgee”; and
- Drown out of the regulator (flow at which fish passage is possible, where head loss and velocity are minimal) does not occur. During low flow periods one gate may be lifted free of the water.

Hydrology

Wakool River is supplied with water diverted into the Edward River from the Mulwala Canal and diverted back into the supply system via the Collogen Creek offtake at Stevens Weir. The flows within Wakool River are determined by the pool height at Stevens Weir, and are managed so that flows do not over top the Wakool Offtake Regulator.

The Wakool Offtake Regulator is located approximately 22km downstream of the junction with Edward River. There is one other licensed barrier on the Wakool River, which regulates water into Merangatuk Creek approximately 20km upstream of the Wakool Offtake Regulator. This barrier would not prevent the natural migration of fish into the Edward River or vice versa during high flow (flood) events, due to a wetland area that would become inundated during these high flow events and potentially link the Wakool and Edward Rivers.

Flow data was obtained from the DNR river gauge at the Wakool River Offtake Regulator (station 409019). Information referred to in this report regarding flows within the Wakool River was sourced from State Water and the DNR website, and describes data acquired between 23.12.1974 – 21.12.2005. Average flows of between 30-50ML/day are released down the Wakool River. A maximum of 100ML/day can be released from Stevens Weir down the Wakool River. It is estimated that drown out of the weir during flood conditions may take place during flows in excess of 1000ML/day. Advice from State Water is that the Wakool Offtake Regulator has not drowned out in at least the last 5 years.

Operational Details

Wakool Offtake Regulator was built in 1935 for the conservation of water for irrigation, stock, and domestic supply. The adjustable release weir regulates water flowing within the Wakool River via a manually operated regulating gate, and four drop board bays. The structure is owned and operated by State Water. It is envisaged that the Wakool Offtake Regulator will be upgraded in the next 2-3 years. It is at this time that fish passage remediation should be investigated.

Ecological Considerations

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment during the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented.

The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch, and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish, and gambusia also occur in the catchment.

Figure 4. Wakool River downstream of Wakool Regulator (02.03.2005, 42 ML/day).

Figure 5. Wakool River upstream of Wakool Regulator (02.03.2005, 42ML/day).

Little or no water is directed down the Wakool River during the winter months when water demand for irrigation ceases (Figure 4). At this time the vertical lift gate is generally lifted free of the water and some fish passage may be possible. Unfortunately this time of the year does not coincide with the natural migratory period of native fish in the Murray catchment, which is linked to rises in water temperature and increases in river flow, and would provide little benefit for spawning fish.

The Wakool River is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *Fisheries Management Act 1994* as an endangered ecological community (NSW Fisheries 2003). Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing for all nine of the popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish (*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimps (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

The Wakool River at the Wakool Offtake Regulator possesses some important fish habitat including instream woody debris, which provides valuable shelter for fish from strong water currents, and larger avian and aquatic predators. Woody debris also acts as an important substrate for fish to lay eggs, and for the growth of algae (which then acts as a food source for macroinvertebrates). At the time of inspection, the banks both upstream and downstream of the site were moderately vegetated (although with limited grass cover), with no introduced pest plant species present (Figures 4 and 5).

The Wakool River has in the past experienced high levels of salinity. In August 2003 a salinity alert was announced by DNR for the Wakool River with estimated levels reaching 5000EC. The high salinity levels were thought to be a result of groundwater discharge into the river combined with low river heights over the winter months.

Proposed Remediation Actions

The Wakool Offtake Regulator is still required by State Water to manage flows within the Wakool River, however the weir remains a total barrier to fish passage. As a result it is recommended that management of the regulating structure be re-assessed, and fish passage options be further investigated for this site.

- **Option 2 –** Deelder fishlock

A Deelder fishlock should be considered at Wakool Regulator and is a cheaper alternative to a vertical slot fishway design. A Deelder fishlock is a low level lock fishway that operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. 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 water upstream of the weir. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

The Deelder fishlock design is considered a cost effective option for fish passage, although up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River, and has proven to be effective in passing a range of fish species and size classes including: Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch, and the threatened silver perch. The outcome of the subsequent monitoring at this site proved that "the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions" (Baumgartner 2003). Monitoring of fish passage at this site continues to examine fish passage under various flow conditions and will determine whether this design is applicable for application at other sites across NSW.

Although it is still in an experimental stage, the Deelder fishlock has already proven to be effective at passing a wide range of native fish species and size classes during low flow periods.

A limitation of the Deelder fishlock is that it requires power infrastructure to operate as a fully automated system. If power is not easily accessible at this site, a significant amount of resources would need to be made available for this design, and the cost would rise significantly.

A further 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.

- **Option 2** – Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred fishway design option where threatened species are present (this site is within the expected distribution of silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, southern pygmy perch and the river snail *Notopala sublineata*), and when located on the main stem or major tributary of a waterway. At sites where varying head losses are encountered the vertical slot fishway would be more effective than other fishway designs in passing a greater range of fish size classes.
The construction of a vertical slot fishway is the most expensive option for fish passage remediation, however it does not rely on power to operate, and is therefore suitable for remote locations.

Projected Remediation Costs

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

Recommendation

It is recommended that the installation of a vertical slot fishway be investigated (Option 2) due to the low head difference present across the weir structure, and the lack of power infrastructure at the site.

Appropriate management of the vertical lift gate to limit its affect on fish larvae is also a priority for this site.

Additionally, when water is not required to be retained for irrigation use during the winter months, the vertical lift gate and drop boards should be raised clear of the water to reinstate a natural flow regime and effective fish passage.

Benefits Associated with Remediation

The Wakool River contains important fish habitat that should be protected, and the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment.

The reinstatement of fish passage at the Wakool Regulator on the Wakool River would reinstate access to in excess of 62km of potential fish habitat upstream and downstream within the Wakool River alone.

WANGANELLA TOWN WEIR, BILLABONG CREEK

Figure 1. Wanganella Town Weir, Billabong Creek (04.03.2005, 142ML/day).

Figure 2. Wanganella Town Weir looking across the crest, Billabong Creek (04.03.2005, 142ML/day).

Description and Setting

Wanganella Town Weir (Figures 1 and 2) is located approximately 500 metres downstream of the township of Wanganella on Billabong Creek (Murray River catchment). The weir is a regulating structure with a concrete sill and drop boards, and is approximately 2 metres in height and is approximately 30 metres across the length of the crest. The weir is owned and managed by Conargo Shire Council, and acts as a barrier to fish passage during low flow conditions, although drown out is estimated to occur when flows are in excess of 400ML/day.

Wanganella Town Weir is ranked as a high remediation priority within the Murray CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species (Billabong Creek is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria novemaculeata*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), and the river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- Billabong Creek is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds and 'core habitats');
- Improved stream connectivity: the next barrier to fish passage upstream is Chinamans Dam approximately 27km away. The next barrier downstream is Caroonboon Dam approximately 43km away; and
- Drown out of the weir (flow at which fish passage is possible, where head loss and velocity are minimal) occurs several times a year.

Hydrology

Billabong Creek originates in the Holbrook area and flows in a westerly direction for in excess of 200km where it enters the Edward River near the township of Moulamein. Flows within Billabong Creek below the Yanco Creek junction are regulated by Yanco Weir on the Murrumbidgee River. Yanco and Colombo Creeks are effluent tributaries of the Murrumbidgee River, and subsequently feed water from the Murrumbidgee River down the Billabong Creek system.

There are as many as 13 other licensed barriers on Billabong Creek between Wanganella Town Weir and Jerilderie township, and potentially several unlicensed structures including several crossings that are also impeding fish passage.

Because of the expanse of Billabong Creek and the large number of associated instream barriers (including crossings), all structures could not be included in this review. Wanganella Town Weir was identified as a moderate barrier to fish passage on Billabong Creek where inadequate fish passage was occurring.

It has been estimated that drown out of the weir occurs when flows are in excess of 400ML/day.

Based on the time weighted flow duration curve for Billabong Creek at this location, flows are equal to or greater than 400ML/day approximately 33% of time. It is therefore reasonable to assume that at this time fish passage is possible. However, further hydrological analysis is required to determine whether the available window for upstream fish passage correlates with the key migration periods for native fish.

Flow data was obtained from the DNR river gauge on Billabong Creek at Wanganella (station 41010810). Information referred to in this report regarding flows within Billabong Creek was sourced from the DNR website, and describes data acquired between 18.11.1999 - 01.02.05.

Operational Details

Wanganella Town Weir is owned and operated by Conargo Shire Council, and was built in 1927 for the conservation of water for the township of Wanganella. The weir is an adjustable crest structure, consisting of a concrete sill with 10 drop board bays. At the time of inspection no drop boards were in place as there was sufficient water upstream to pump all year round. Town water is extracted from Billabong Creek approximately 500 metres upstream from the weir, at a rate of approximately 20ML/annum.

Ecological Considerations

Weirs in Billabong Creek below Jerilderie were selected for the Detailed Weir Review because of their location in the system. Lowland river reaches are recognised as 'core habitats', which are crucial for fish recruitment and migration for species such as golden perch and Murray cod, which are both present in Billabong Creek. By addressing fish passage in lower Billabong Creek, fish will be able to move up from Edward River into the Billabong Creek system to spawn, seek shelter, and locate food. Ideally fish passage will be achieved along the entire Billabong and Colombo/Yanco Creek system to provide connectivity between the Murrumbidgee and Murray catchments. Initially it is important to address fish passage issues at redundant structures and those weirs that rarely or never drown out. It is also important to acknowledge the social, economical, ecological, and hydrological implications associated with the potential modification of these weirs.

It has become apparent as a result of this review that there may be several creek crossings that are also currently blocking the free passage of fish along Billabong Creek. It is essential that in addition to addressing licensed weirs, other legal and illegal instream barriers be identified and remediated. Under the *NSW Fisheries Management Act 1994* (*FM Act 1994*), *Section 219* fish passage must not be blocked temporarily or permanently unless a permit has been granted. The construction of waterway crossings require approval under Part 7 of the *FM Act 1994*, and should be consistent with the "Fish Passage Requirements for Waterway Crossings" (NSW Fisheries 2003) document. Consultation with NSW DPI should occur before the modification, repair, or replacement of all crossings on public and private roads.

Billabong Creek is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *FM Act 1994* as an endangered ecological community (NSW Fisheries 2003). Both the endangered western population of the purple spotted gudgeon (*Mogurnda adspersa*), and the olive perchlet (*Ambassis agassizii*) would have historically been found in Billabong Creek.

Figure 3. Billabong Creek downstream of Wanganella Town Weir (04.03.2005, 142ML/day).

Figure 4. Billabong Creek upstream of Wanganella Town Weir (04.03.2005, 142ML/day).

Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing for all of the nine popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish

(*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimps (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias, and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment during the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented. The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch, and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish, and gambusia also occur in the catchment.

The specifications given when constructing fishways state that it should operate over 95% of all flow conditions. However, it has been estimated that fish passage at Wanganella Town Weir may only be possible 33% of time. 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 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.

The section of Billabong Creek at Wanganella Town Weir possesses some important fish habitat including instream woody debris and aquatic vegetation. Large woody debris provides valuable shelter for fish from strong water currents, and larger avian and aquatic predators. Woody debris and aquatic vegetation also provide an important substrate for fish to lay eggs, and for the growth of algae (which then acts as a food source for macroinvertebrates).

At the time of the inspection, the banks both upstream and downstream of the weir were sparsely vegetated with some erosion present downstream (Figures 3 and 4).

Proposed Remediation Actions

Although this structure drowns out several times a year, it continues to form a fish passage barrier for the majority of the time. It is for this reason that investigation into the potential remediation options below should occur. The structure remains operational to some extent, and therefore complete removal is not an option at this time.

- **Option 1 –** Partial removal

At the time of the inspection there was no fish passage possible due to the presence of a headloss across the structure. Anecdotal evidence suggests that the weir drowns out several times during the year, however this may not necessarily coincide with key migration periods for native fish.

The complete removal of the Wanganella Town Weir would provide the greatest benefit to the health of Billabong Creek and provide significant improvements in the availability of aquatic and riparian habitat. However, as this weir provides a pumping pool for the Wanganella Town water supply, it continues to serve a purpose to the community, and during low flow periods provides water security for the town.

One option to complete removal may be to lower the height of the weir to ensure that the structure is drowned out during lower flow periods. The concrete drop board bays and a section of the weir itself could be removed to decrease headloss across the structure and ensure that the structure is drowned out at smaller increases in river height. This would drop the level of the upstream weir pool slightly, but is unlikely to impact on the ability of Conargo Council to extract town water. Extensive consultation is required with Council, upstream landholders, and the general community prior to carrying out these works.

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

A partial width rock ramp fishway design could be considered at the Wanganella Town Weir to provide fish passage prior to drown out of the weir. Although the weir drowns several times during the year there remains significant periods of time where the passage of all fish will be affected. The alteration to the existing structure to incorporate a partial width rock ramp would make a significant contribution to improving the passage of native fish and provide a significant environmental benefit for a relatively small investment, particularly if it was determined that lowering of the weir height was not possible.

Modifications to the weir would include cutting a low flow channel in the concrete wall to increase the flow through the fishway. By extending the existing spillway so that a gradient of 1:20 was formed, and by strategically placing several rock ridges to create resting pools that are connected by short riffles, this modification could provide passage to a greater range of fish species and size classes than is currently possible.

The partial width rock ramp fishway could be constructed perpendicular to the weir with a return dog-leg, or depending on the flow variations within the creek at this location, the fishway may operate more effectively if it were run parallel to the weir. The entrance of both designs should be located close to the weir wall, and should incorporate an attraction flow to guide fish to the fishway. Given the fluctuating water levels that are experienced in Billabong Creek (especially during low flow periods), it is recommended that a partial width rock ramp fishway be set parallel to the weir wall, so that the downstream fishway entrance can be located by fish at all flows. Fish will be attracted to water spilling over the weir crest, therefore the fishway entrance should be located as close to the weir wall as possible. If a dog-leg design were chosen, the downstream entrance to the fishway will be positioned close to the weir wall at low flows, but as flows increase, the fishway entrance will gradually be pushed further downstream making it difficult for fish to locate.

- **Option 3 –** Deelder fishlock

A Deelder fishlock is a low level lock fishway that operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishway 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 water upstream of the weir. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

The Deelder fishlock design is considered a cost effective option for fish passage, although up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River, and has proven to be effective in passing a range of fish species and size classes including: Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch, and the threatened silver perch. The outcome of the subsequent monitoring at this site proved that "the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions" (Baumgartner 2003). Monitoring at this site continues to examine fish passage under various flow conditions and will determine whether this design is applicable to other sites across NSW.

It is possible that the Deelder fishlock design could be applied to Wanganella Town Weir, although a limitation of the Deelder fishlock is that it requires power infrastructure to operate as a fully automated system. If power is not easily accessible at this site (or it is necessary to establish solar power), a significant amount of resources would need to be made available for this design, and the cost would rise significantly.

A further 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.

Given that the structure is relatively low and drowns out several times a year construction of a Deelder fishlock may be too great for this site.

Projected Remediation Costs

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

Recommendation

It is recommended that the partial removal of the weir be investigated (Option 1). If this option is not viable, the construction of a partial width rock ramp fishway is the next best option to reinstate fish passage at this site (Option 2).

Benefits Associated with Remediation

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

The reinstatement of fish passage at Wanganella Town Weir on Billabong Creek would reinstate access to approximately 70km of potential fish habitat upstream and downstream from this site.

HARTWOOD HOMESTEAD WEIR, LOWER WOOLSHED DAM, AND ROAD PADDOCK DAM, BILLABONG CREEK.

Figure 1. Hartwood Homestead Weir (constructed 1927), Billabong Creek (07.03.2005, 98ML/day).

Figure 2. Road Paddock Dam (constructed 1915), Billabong Creek (07.03.2005, 98ML/day).

Figure 3. Lower Woolshed Dam (constructed 1915), Billabong Creek (07.03.2005, 98ML/day).

Description and Setting

Hartwood Homestead Weir (Figure 1) is located on Billabong Creek approximately 30km west of the township of Jerilderie. Road Paddock Dam and Lower Woolshed Dams are located a further 6km and 8km downstream on the property "Hartwood Station". These weirs are all located in the Murray River catchment. The three weirs are all concrete overshot weirs of similar in dimensions, and are all owned and managed by one private landholder who currently mostly extracts from Yanco Creek. Hartwood Homestead Weir, Road Paddock Dam and Lower Woolshed Dam weirs act as barriers to fish passage over most flow conditions.

The above mentioned weirs are ranked as high remediation priorities within the Murray CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species or populations (Billabong Creek is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria novemaculeata*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), and the river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- Billabong Creek is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds and 'core habitats');

- Improved stream connectivity: the next barrier to fish passage upstream is a privately owned weir on the property “Old Coree” approximately 12km away. The next barrier downstream of Lower Woolshed Dam is the State Water owned “Hartwood Weir” approximately 15km away; and
- Drown out of the three weirs (flow at which fish passage is possible, where head loss and velocity are minimal) does not occur readily.

Hydrology

Billabong Creek originates in the Holbrook area and flows in a westerly direction for in excess of 200km where it enters the Edward River near the township of Moulamein. Flows within Billabong Creek below the Yanco Creek junction are regulated by Yanco Weir on the Murrumbidgee River. Yanco and Colombo Creeks are effluent tributaries of the Murrumbidgee River and subsequently feed water from the Murrumbidgee River down the Billabong Creek system.

There are a total of 15 licensed weirs along both the regulated and unregulated section of Billabong Creek. Because of the expanse of Billabong Creek and the great number of associated instream barriers, all structures could not be included in this review. Hartwood Homestead Weir, Road Paddock Dam and Lower Woolshed Dam weirs were identified as a major barrier to fish passage on Billabong Creek where little or no fish passage is possible.

Between Hartwood Homestead Weir and the town of Jerilderie there are three other licensed barriers on the Billabong Creek.

Flow data was obtained from the DNR river gauge on Billabong Creek at Jerilderie township (station 409016). Information referred to in this report regarding flows within the Billabong Creek was sourced from State Water and the DNR website, and describes data acquired between 02.10.1984 – 21.12.2005.

Operational Details

The three weirs are owned and operated by a private landholder.

Hartwood Homestead Weir was built in 1927, and is a fixed crest overshot concrete weir approximately 3 metres in height and 30 metres wide. The weir is currently used for the provision of water for stock and domestic use. At the time of the inspection the structure appeared stable, with no visible leaks in the wall and abutments.

Road Paddock and Lower Woolshed Dams were both built in 1915, and are similar in construction, being approximately 1-2 metres high and 30 metres wide. . Currently both weirs are in a state of disrepair and have been smothered by willows, which are currently severely restricting water flow past this point. Neither of the weirs is currently being used for water extraction, or being maintained. At the time of inspection there were visible leaks in the walls and some erosion downstream of the weirs.

Ecological Considerations

Weirs in Billabong Creek below Jerilderie were selected for the Detailed Weir Review because of their location in the system. Lowland river reaches are recognised as ‘core habitats’, which are crucial for fish recruitment and migration for species such as golden perch and Murray cod, which are both present in Billabong Creek.

By addressing fish passage in the lower Billabong Creek, fish are able to move up from Edward River into the Billabong Creek system to spawn, seek shelter, and locate food. Ideally fish passage will be achieved along the entire Billabong and Colombo/Yanco Creek system to provide connectivity between the Murrumbidgee and Murray catchments. Initially it is important to address fish passage issues at redundant structures and those weirs that rarely or never drown out. It is also important to acknowledge the social, economical, ecological, and hydrological implications associated with the potential modification of these weirs.

Anecdotal evidence suggests that these weirs do not drown out regularly. Limited fish passage may be possible during high flow (flood events) however, if the weir only drowns out for such 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.

It has become apparent as a result of this review that there may be several creek crossings that are currently blocking the free passage of fish along Billabong Creek. It is essential that in addition to addressing licensed weirs, other legal and illegal instream barriers be identified and remediated. Under the *NSW Fisheries Management Act 1994 (FM Act 1994), Section 219* fish passage must not be blocked temporarily or permanently unless a permit has been granted. The construction of waterway crossings requires approval under Part 7 of the *FM Act 1994*, and should be consistent with the "Fish Passage Requirements for Waterway Crossings" (NSW Fisheries 2003) document. Consultation with NSW DPI should occur before the modification, repair, or replacement of all crossings on public and private roads.

Billabong Creek is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *FM Act 1994* as an endangered ecological community (NSW Fisheries 2003). Both the endangered western population of the purple spotted gudgeon, and the olive perchlet would have historically been found in Billabong Creek. Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing for all of the nine popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish (*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimps (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias, and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment during the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented.

Figure 4. Billabong Creek downstream and upstream of Hartwood Homestead Weir (07.03.2005,98ML/day).

Figure 5. Billabong Creek downstream and upstream of Road Paddock Dam (07.03.2005, 98ML/day).

Figure 6. Billabong Creek downstream and upstream of Lower Woolshed Dam (07.03.2005, 98ML/day).

The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch, and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish, and gambusia also occur in the catchment.

Billabong Creek at this location possesses some important fish habitat including instream woody debris and aquatic vegetation. Large woody debris provides valuable shelter for fish from strong water currents, and larger avian and aquatic predators. Woody debris and aquatic vegetation also provide an important substrate for fish to lay eggs, and for the growth of algae (which then acts as a food source for macroinvertebrates).

At the time of inspection, the banks upstream and downstream of the weirs were moderately vegetated (Figures 4-6). There was some erosion present downstream of the weirs as a result of water scouring the banks after passing over the weir, and pressures created by stock grazing. At the Lower Woolshed and Road Paddock Weirs there were large stands of willows upstream of the structures, as well as on and adjacent the weirs themselves (Figures 5 and 6).

It is recommended that the removal of existing willows take place during the modification or removal of these weirs, as well as installation of stock exclusion fencing and off river watering points. Recently Greening Australia has been working with landholders to identify and fence many areas along the Billabong Creek to encourage regeneration of riparian plants and contribute to improved river health.

Proposed Remediation Actions

These weirs form total barriers to fish passage. It is therefore recommended that fish passage options be further investigated at these sites.

- **Option 1 –** Removal of Lower Woolshed and Road Paddock Dams

Both Lower Woolshed and Road Paddock Dam weirs are no longer being maintained and are in a state of disrepair. The willow infestation at these two sites is also impacting on flows in the creek. At the time of inspection there was no fish passage possible, and it was difficult to see how fish passage could be achieved at all but flooding conditions. The complete removal of these two structures would provide the greatest benefit to the health of Billabong Creek and provide significant improvements in the availability of aquatic and riparian habitat. The weirs are no longer required and are beginning to fail. Removal of these two structures has a much greater cost benefit than reinstating the weirs and developing alternative fish passage options such as those outlined below.

- **Option 2 –** Partial width rock ramp fishway (Hartwood Homestead Weir)

A partial width rock ramp design could be considered at the Hartwood Homestead Weir to provide fish passage prior to drown out of the weir. As the weir drowns out infrequently, there remain significant periods of time where the passage of all fish will be affected. The alteration to the existing structure to install a partial width rock ramp fishway would make a significant contribution to improving the passage of native fish within Billabong Creek, and provide a significant environmental benefit for a relatively small investment.

Modifications to the weir would include cutting a low flow channel in the concrete wall to increase the flow through the fishway. By extending the existing spillway so that a gradient of 1:20 was formed, and by strategically placing several rock ridges to create resting pools that are connected by short riffles, this modification could provide passage to a greater range of fish species and size classes than is currently possible.

The partial width rock ramp fishway could be constructed perpendicular to the weir with a return dog-leg, or given the fluctuating water levels that are experienced in Billabong Creek (especially during low flow periods), the fishway may operate more effectively if it were run parallel to the weir. The entrance of both designs should be located close to the weir wall, and should incorporate an attraction flow to guide fish to the fishway.

It is recommended that a partial width rock ramp fishway be set parallel to the weir wall, so that the downstream fishway entrance can be located by fish at all flows. Fish will be attracted to water spilling over the weir crest, therefore the fishway entrance should be located as close to the weir wall as possible. If a dog-leg design were chosen, the downstream entrance to the fishway will be positioned close to the weir wall at low flows, but as flows increase, the fishway entrance will gradually be pushed further downstream making it difficult for fish to locate.

- **Option 3 -** Deelder fishway (Hartwood Homestead Weir)

A Deelder fishlock is a low level lock fishway that operates in a similar manner to a boat lock and consists of two chambers divided by an internal weir. The fishway 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 water upstream of the weir. Fish are encouraged to swim through the lock using a series of attraction flows and crowding screens.

The Deelder fishlock design is considered a cost effective option for fish passage and up until 2002, had not been applied to Australian rivers. The Deelder fishlock was trialled in Australia at Balranald Weir on the Murrumbidgee River, and has proven to be effective in passing a range of fish species and size classes including: Australian smelt, juvenile bony bream, crimson spotted rainbowfish, golden perch, and the threatened silver perch. The outcome of the subsequent monitoring at this site proved that “the Deelder fishlock was extremely effective at providing passage for Australian native fish under low – flow conditions” (Baumgartner 2003). Monitoring at this site continues to examine fish passage under various flow conditions and will determine whether this design is applicable to other sites across NSW.

It is possible that the Deelder fishlock design could be applied at Hartwood Homestead Weir provided power could be made available to the site, or whether it is economical to establish solar power at this location. If power is not easily accessible at this site, a significant amount of resources would need to be made available for this design, and the cost would rise significantly.

A further 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.

- **Option 4** – Vertical slot fishway (Hartwood Homestead Weir)

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred fishway design option where threatened species are present (this site is within the expected distribution of seven threatened fish species and the endangered river snail *Notopala sublineata*), and when located on the main stem or major tributary of a waterway.

At sites where varying head losses are encountered the vertical slot fishway would be more effective in passing a greater range of fish size classes than other fishway designs. The construction of a vertical slot fishway is the most expensive option for fish passage remediation, however it does not rely on power to operate, and is therefore suitable for remote locations.

Projected Remediation Costs

Projected cost	< $50K	$50K - $150K	$150K- $250K	$250K - $500K	$500K - $1M
Option 1	✔				
Option 2			✔		
Option 3				✔	
Option 4				✔	

Recommendation

Nearly all of the weirs present on the Billabong Creek were constructed prior to the regulation of the system (~1928). Although extraction of water may currently take place upstream of some of these structures, there may be some scope to modify or remove them whilst retaining the ability to pump water in the absence of a weir.

It is recommended that the removal of Lower Woolshed and Road Paddock Dams be investigated (Option 1), and the removal of all willows at these sites be undertaken as part of fish passage remediation works.

It is recommended that the removal of Hartwood Homestead Weir also be investigated, and if water security for Hartwood Station can still be guaranteed without the weir, it should be removed. If retention of the weir is necessary, the installation of a Deelder fishlock (Option 3) or a vertical slot fishway (Option 4) should be investigated.

Benefits Associated with Remediation

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

The reinstatement of fish passage at the three above mentioned weirs on Billabong Creek would reinstate access to approximately 42km of potential fish habitat upstream and downstream of these weirs.

OLD COREE WEIR, BILLABONG CREEK

Figure 1. Old Coree Weir, Billabong Creek (07.03.2005, 142ML/day).

Figure 2. Old Coree Weir crest, Billabong Creek (07.03.2005, 142ML/day).

Description and Setting

Old Coree Weir (Figures 1 and 2) is located approximately 38km downstream of the township of Jerilderie on Billabong Creek (Murray River catchment).

The weir is a regulating structure with a concrete sill and drop board bays, the remaining concrete abutment is approximately 1.5 metres in height and 25 metres across the length of the crest. The weir is owned and managed by McCaughey Memorial Institute and is located on the property "Old Coree". Old Coree Weir acts as a barrier to fish passage during most flow conditions as the weir does not drown out readily.

Old Coree Weir is ranked as a high remediation priority within the Murray CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species (Billabong Creek is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria novemaculeata*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*), and the river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- Billabong Creek is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds and 'core habitats');
- Improved stream connectivity: the next barrier to fish passage upstream is Algudgerie Weir approximately 13km away; the next barrier downstream is the Hartwood Homestead Weir approximately 12km away; and
- Drown out of the weir (flow at which fish passage is possible, where head loss and velocity are minimal) does not occur during typical annual flows.

Hydrology

Billabong Creek originates in the Holbrook area and flows in a westerly direction for in excess of 200km before it enters the Edward River near the township of Moulamein. Flows within Billabong Creek below the Yanco Creek junction are regulated by Yanco Weir on the Murrumbidgee River. Yanco and Colombo Creeks are effluent tributaries of the Murrumbidgee River and subsequently feed water from the Murrumbidgee River down the Billabong Creek system.

Because of the expanse of Billabong Creek and the large number of associated instream barriers (including crossings), all structures could not be included in this review. Old Coree Weir was identified as a major barrier to fish passage on Billabong Creek where little or no fish passage is possible.

There are two other licensed barriers known to exist on the Billabong Creek between Old Coree Weir and Jerilderie township, and potentially several unlicensed structures including several crossings that are impeding fish passage.

Flow data was obtained from the DNR river gauge on Billabong Creek at Jerilderie (station 410016). Information referred to in this report regarding flows within the Billabong Creek was sourced from the DNR website, and describes data acquired between 18.11.1999-01.02.05.

Operational Details

Old Coree Weir was built in 1976 for the conservation of water for irrigation, stock, and domestic supply, and is now owned and operated by a private company.
The weir is an adjustable crest structure, consisting of a concrete sill with numerous drop board bays. Currently there are no drop boards in place, and the majority of the wooden infrastructure has been washed away. At the time of the inspection the weir was not being maintained, although the structure was still pooling a considerable amount of water, and creating a head loss of approximately one metre.

Ecological Considerations

Weirs in Billabong Creek below Jerilderie township were selected for the Detailed Weir Review because of their location in the system. Lowland river reaches are recognised as 'core habitats', which are crucial for fish recruitment and migration for species such as golden perch and Murray cod, which are both present in Billabong Creek. By addressing fish passage in lower Billabong Creek, fish will be able to move up from Edward River into the Billabong Creek system to spawn, seek shelter, and locate food. Ideally fish passage will be achieved along the entire Billabong and Yanco Creek system to provide connectivity between the Murrumbidgee and Murray catchments. Initially it is important to address fish passage issues at redundant structures and those weirs that rarely or never drown out. It is also important to acknowledge the social, economical, ecological, and hydrological implications associated with the potential modification of these weirs.

Although limited fish passage may be possible during high flow events, 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.

It has become apparent as a result of this review that there may be several creek crossings that are also currently blocking the free passage of fish along Billabong Creek. It is essential that in addition to addressing licensed weirs, other legal and illegal instream barriers be identified and remediated. Under the *NSW Fisheries Management Act 1994* (*FM Act 1994*)*, Section 219* fish passage must not be blocked temporarily or permanently unless a permit has been granted. The construction of waterway crossings requires approval under Part 7 of the *FM Act 1994* and should be consistent with the "Fish Passage Requirements for Waterway Crossings" (NSW Fisheries 2003) document. Consultation with NSW DPI should occur before the modification, repair, or replacement of all crossings on public and private roads.

Billabong Creek is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *FM Act 1994* as an endangered ecological community (NSW Fisheries 2003). Both the endangered western population of the purple spotted gudgeon (*Mogurnda adspersa*), and the olive perchlet (*Ambassis agassizii*) would have historically been found in Billabong Creek.

Figure 3. Downstream of Old Coree Weir Billabong Creek (07.03.2005, 98L/day).

Figure 4. Upstream of Old Coree Weir, Billabong Creek (07.03.2005, 98ML/day).

Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing for all of the nine popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish

(*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimps (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment during the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented. The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch, and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish, and gambusia also occur in the catchment.

This section of Billabong Creek at Old Coree Weir possesses some important fish habitat including instream woody debris and aquatic vegetation. Large woody debris provides valuable shelter for fish from strong water currents, and larger avian and aquatic predators. Woody debris and aquatic vegetation also provides an important substrate for fish to lay eggs, and for the growth of algae (which then acts as a food source for macroinvertebrates).

At the time of the inspection, the banks upstream and downstream of the weir were moderately vegetated (Figures 3 and 4). There is some erosion present downstream of the weir as a result of water scouring the banks after passing over the weir and pressures created by stock grazing (which has also resulted in less vegetation being present downstream). No willows were present at this site.

Proposed Remediation Actions

- **Option 1** – Removal

Most of the weirs present on the Billabong Creek were constructed prior to the regulation of the system (~1928). Although extraction of water may currently take place upstream of these structures, there may be some scope to modify or remove them whilst retaining the ability to pump water in the absence of a weir. It is therefore recommended that consideration be given to the removal of Old Coree Weir.

At the time of writing consultation with the property owner had not occurred regarding possible fish passage remediation options at this site, and cost benefit analysis of retaining this weir still needed to be established. It is necessary to ensure that the ability of the landholder to access water for stock, domestic, and irrigation purposes is not compromised. Negotiation should take place to satisfy the needs of the landholder, whilst establishing effective fish passage at this site. If the removal of this weir could be achieved it would provide long-term benefits for the health of the entire Billabong Creek system.

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

As the weir drowns out infrequently, there remain significant periods of time where the passage of all fish will be affected. The alteration to the existing structure to install a partial width rock ramp fishway would provide fish passage prior to drown out of the structure, significantly improving the passage of native fish, and providing a significant environmental benefit for a relatively small investment.

A partial width rock ramp fishway could be incorporated into weir where the low flow channel currently exists. Some modification to weir would be required, including cutting a low flow channel in the concrete wall to increase the flow through the fishway and provide attractant flows. A partial width rock ramp fishway should be built on a gradient of 1:20, with strategically placed rock ridges creating a series of resting pools that are connected by short riffles.

Depending on the flow variations at this location, the fishway may operate more effectively if it were run parallel to the weir, so that the downstream fishway entrance was always sited close to the weir wall, ensuring it could be found at all flows. If the fishway were not run parallel, the entrance should be located close to the weir (dog-legged back upstream) and should incorporate an attraction flow to guide fish to the fishway. A partial width rock ramp fishway will provide passage to a greater range of fish species and size classes prior to drown out of the structure, however its operation would still be limited by fluctuating water levels that are experienced in Billabong Creek (especially during low flow periods).

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

The construction of a full width rock ramp fishway would provide similar benefits as a partial width rock ramp fishway (Option 2), although the costs incurred would be greater due to the considerable amount of rock needing to be imported to create a fishway with a slope of 1:20. As Old Coree Weir is only 1.5 metres high, both the partial width rock ramp and full width rock ramp fishways would extend approximately 30 metres downstream (although the partial width rock ramp fishway would dog-leg back toward the weir, meaning that the downstream extension of the structure would be approximately 15 metres).

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.

Projected Remediation Costs

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

Recommendation

It is recommended that the removal of the weir (Option 1) be investigated through discussions with the landholder. If the landholder wishes to retain the weir, the installation of a Deelder fishlock should be investigated (Option 3).

Benefits Associated with Remediation

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

The reinstatement of fish passage at Old Coree Weir on Billabong Creek would reinstate access to approximately 25km of potential fish habitat either side of this site.

WIDGEE WEIR, WAKOOL RIVER

Figure 1. Widgee Weir, Wakool River (02.03.2005, 42ML/day).

Figure 2. Widgee Weir structural failure on right hand side, Wakool River (02.03.2005, 42ML/day).

Description and Setting

Widgee Weir (Figures 1 and 2) is located approximately 25km north west of Deniliquin on the Wakool River (Lower Murray River catchment). The weir is a concrete regulating structure that is approximately 1 metre high and 15 metres across the length of the crest. Flow is managed using five bays with drop boards. The weir acts as a barrier to fish passage during most flow conditions because it does not drown out readily.

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

- Class 1 fish habitat - major permanently flowing waterway and presence of one or more threatened fish species (the Wakool River is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria novemaculeata*), Murray hardyhead (*Craterocephalus fluviatilis*), southern pygmy perch (*Nannoperca australis*) and the river snail (*Notopala sublineata*));
- Diverse range of native fish (High Conservation Value);
- The Wakool River is located within the Lower Murray River catchment that has been listed as an endangered ecological community in NSW;
- 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 spawning grounds and 'core habitats');
- Improved stream connectivity: the next barrier to fish passage upstream is Wakool Regulator approximately 42km away. There are no other licensed weirs below Widgee Weir on the Wakool River before it returns back to the Edward River (main flow via Yallakool Creek); and
- Drown out of the weir (flow at which fish passage is possible, where head loss and velocity are minimal) occurs readily.

Hydrology

The Wakool River is supplied by water diverted into the Edward River from the Mulwala Canal and diverted back into the supply system via the Collogen Creek offtake at Stevens Weir. Widgee Weir is located approximately 63km downstream of the junction of the Edward River. There are two other licensed barriers on the Wakool River upstream: the Wakool Regulator and a privately owed regulator, although the privately owned regulator would not prevent the natural migration of fish into Edward River or vice versa during high flow events. A wetland area adjacent the structure becomes inundated during high flow events, thereby potentially linking the Wakool and Edward Rivers.

Flow data was obtained from the DNR river gauge at the Wakool River Offtake Regulator (station 409019). Information referred to in this report regarding flows within the Wakool River was sourced from State Water and the DNR website, and describes data acquired between 23.12.1974 – 21.12.2005.

Average flows of between 30-50ML/day are released down the Wakool River, whilst a maximum of 100ML/day can be released from Stevens Weir down the Wakool River at any one time.

It is estimated that drown out of the Widgee Weir may take place during flood conditions when flows are in excess of 500ML/day. Anecdotal evidence suggests that the weir has not drowned out in at least the last five years. The adjacent landholder recalled that the last time the weir was totally under water was during the floods of 1975.

Operational Details

Widgee Weir was built in 1971 for the conservation of water for irrigation, stock, and domestic supply, and today it is owned and operated by a private landholder for stock and domestic use. The weir is a concrete adjustable release structure, with five drop board bays that are used to manipulate water levels in the upstream weir pool.

Currently the weir is leaking on the right hand bank and requires repairs. If the weir were to be replaced or repaired, the landholder must seek permission from NSW DPI, and may be required to provide fish passage during this process.

Ecological Considerations

Anecdotal evidence suggests that this weir does not drown out regularly. Limited fish passage may be possible during high flow (flood events) however, 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.

The following native species were sampled within the Murray River catchment during the NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) including: golden perch, spangled perch, bony herring, Australian smelt, flyspecked hardyhead, carp gudgeon, flathead gudgeon, two-spined blackfish, climbing galaxias, mountain galaxias and crimson spotted rainbowfish. Despite Murray cod not being sampled in the Murray catchment in the NSW Fish and Rivers in Stress survey, recreational fishers are still catching this species, although anecdotal evidence suggests that their numbers have been dramatically reduced and populations have become fragmented. The Murray catchment is also within the expected distribution of the following threatened species: silver perch, olive perchlet, purple spotted gudgeon, trout cod, Macquarie perch, Murray hardyhead, pygmy perch and the endangered river snail *Notopala sublineata*. Introduced species including common carp, goldfish, and gambusia also occur in the catchment.

The Wakool River is part of the natural drainage system of the Lower Murray River catchment that has been listed under the threatened species provisions of the *Fisheries Management Act 1994* (*FM Act 1994*), as an endangered ecological community (NSW Fisheries, 2003).

Figure 3. Wakool River downstream of Widgee Weir (02.03.2005, 42ML/day).

Figure 4. Wakool River upstream of Widgee Weir (02.03.2005, 42ML/day).

Currently all of the aquatic species that fall within the Lower Murray Ecological Community are protected, however arrangements are in place to allow continued recreational fishing for all of the nine popular native species including Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), freshwater catfish

(*Tandanus tandanus*), river blackfish (*Gadopsis marmoratus*), yabbies (*Cherax destructor*), Murray cray (*Euastacus armatus*), freshwater shrimps (*Paratya australiensis* and *Caridina mccullochi*), and freshwater prawns (*Macrobrachium australiense*).

The Wakool River at Widgee Weir possesses some important fish habitat including instream woody debris, which provides valuable shelter for fish from strong water currents, and larger avian and aquatic predators. Woody debris also acts as an important substrate for fish to lay eggs, and for the growth of algae (which then acts as a food source for macroinvertebrates).

At the time of inspection, the banks both upstream and downstream of the site were moderately vegetated, although they possessed little or no grass ground cover. Several willows were present upstream of the weir (Figure 3 and 4).

The Wakool River has in the past experienced high levels of salinity. In August 2003, a salinity alert was announced by DNR (then DIPNR) for the Wakool River with estimated levels reaching 5000EC. The high salinity levels were thought to be a result of groundwater discharge into the river combined with low river heights over the winter months.

Proposed Remediation Actions

The weir is a significant barrier to fish passage. It is therefore recommended that management of the regulating structure be re-assessed, and fish passage options be further investigated for this site.

Option 1 – Removal/ modification

As the weir currently requires repairs, a remediation option could be to partially or completely remove the structure. The adjacent landholder continues to require water for stock and domestic use as a high priority. However, because Wakool River is highly regulated, and minimum flows as indicated by State Water do not fall below 30ML/day, there is some scope to establish water security at this site. An agreement would need to be made between State Water and the landholder to ensure the capacity of the landholder to extract water is not compromised. Water security could be improved by modifying the pump site by increasing the depth of the pumping pool, and if necessary upgrading the pumping infrastructure.

The removal of the entire structure would allow for fish passage past the weir during all flow conditions. The concrete abutments and dropboards could be removed at a relatively low cost. An alternative to entire removal may be the partial removal of the weir through removal of all the drop boards. The cost associated with this option would be negligible, however there is no way to regulated the removal of the boards, and through a change of property ownership previous agreements reached between the existing landholder, State Water, and NSW DPI would be difficult to transfer to the new owner. If water security can be met at this site with the entire removal of the weir it is recommended that this option be investigated.

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

The alteration of the existing structure to allow installation of a partial width rock ramp fishway will enable fish to pass the structure prior to drown out, and would make a significant contribution to improving the passage of native fish for a relatively small investment.

Modifications to the weir would include cutting a low flow channel in the concrete wall to increase the flow through the fishway. By extending the existing spillway so that a gradient of 1:20 was formed, and by strategically placing several rock ridges to create resting pools that are connected by short riffles, this modification (partial width rock ramp fishway) could provide passage to a greater range of fish species and size classes than is currently possible.

The partial width rock ramp fishway could be constructed perpendicular to the weir with a return dog-leg, or depending on the flow variations within the creek at this location, the fishway may operate more effectively if it were run parallel to the weir. The entrance of both designs should be located close to the weir wall, and should incorporate an attraction flow to guide fish to the fishway.

If water levels fluctuate greatly in the Wakool River, it is recommended that a partial width rock ramp fishway be set parallel to the weir wall so that the downstream fishway entrance can be located by fish at most flows. Fish will be attracted to water spilling over the weir crest, therefore the fishway entrance should be located as close to the weir wall as possible. If a dog-leg design were chosen, the downstream entrance to the fishway will be positioned close to the weir wall at low flows, but as flows increase, the fishway entrance will gradually be pushed further downstream making it difficult for fish to locate.

Projected Remediation Costs

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

Recommendation

It is recommended that removal of this weir (Option 1) be further investigated. If State Water and the landholder cannot reach a water security agreement, it is recommended that Option 2 be investigated.

Benefits Associated with Remediation

The Wakool 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.

The reinstatement of fish passage at Widgee Weir on the Wakool River would reinstate access to approximately 50km of potential fish habitat upstream and downstream of this site within the Wakool River alone.

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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