REDUCING THE IMPACT OF WEIRS ON AQUATIC HABITAT

NSW DETAILED WEIR REVIEW

REPORT TO THE NEW SOUTH WALES ENVIRONMENTAL TRUST

WESTERN CMA REGION

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Environmental TRUST

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

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

EXECUTIVE SUMMARY

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

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

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

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

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

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

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

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

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1. INTRODUCTION

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

1.1 Project scope and setting

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

1.2 Study aims and objectives

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

The primary objectives of the project were to:

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

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

2. BACKGROUND

2.1 Fish passage in NSW

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

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

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

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

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

2.2 Barriers to fish passage

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

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

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

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

The vertical walls of dams, weirs, causeways, and floodgates are the most commonly perceived barriers to migrating fish. However, hydrological barriers including excessive water velocity and turbulence that result from poorly designed fishways and culvert structures can further impede fish passage (Mallen-Cooper 1994). The degree to which a structure acts as a hydrological barrier will also be dependent upon the distance over which fish have to swim to negotiate the structure (Videler and Wardle 1991). Fish generally use two different swimming modes: fast burst swimming for covering short distance and a cruising speed for longer journeys. Depending upon the design of the crossing, fish may be able to ascend part way up barriers or poorly designed fishways, only to be washed back downstream after their energy has been expended (subsequently predisposing them to predation or disease through fatigue).

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

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

2.3 Ecological impacts of weirs

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

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

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

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

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

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

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

2.4 Policies and Legislation

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

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

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

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

3. PROJECT METHODOLOGY

3.1 Initial Weir Review

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

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

3.2 Selection of weirs for detailed review

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

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

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

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

3.3 Desktop assessment and consultation

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

3.4 Field assessment

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

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

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

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

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

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

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

3.5 Prioritisation process

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

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

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

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

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

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

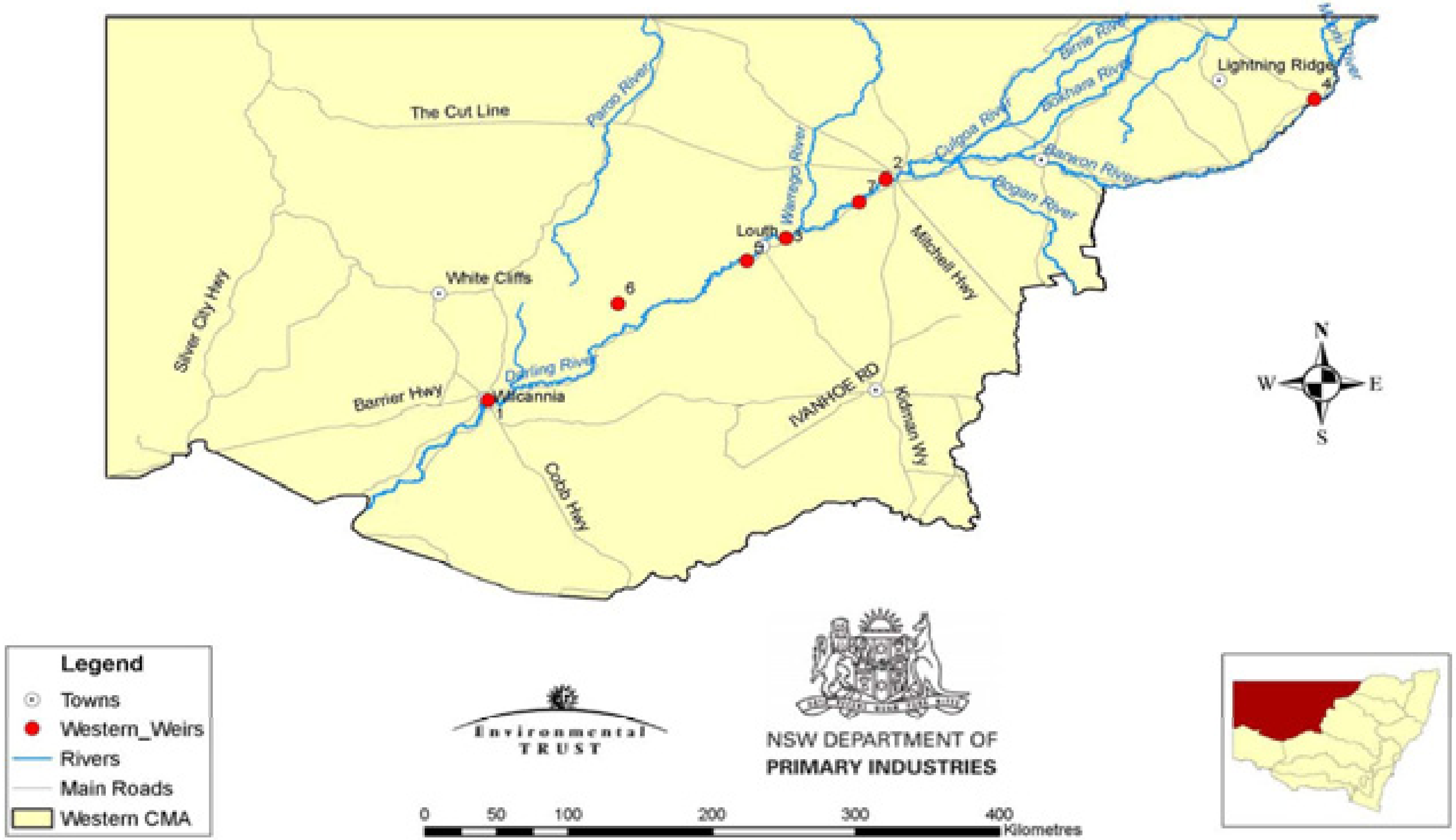
Modification criteria assessed structural use and the ease of remediating the weir. Occasionally structures were recorded during the Detailed Weir Review that were no longer used by the licensee or adjacent property owners. These obsolete weirs received a higher priority score due to the ease (e.g. low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

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

4. INDIVIDUAL DETAILED WEIR REVIEW REPORTS

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

5. Western CMA - Detailed Weir Review Sites



Western 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	Wilcannia Weir	-31.564166	143.393611	Fixed crest (concrete and rock fill)	Darling River	Central Darling Shire Council	No	Full Width Rock Ramp Fishway	250 - 500K	150 – 250K	501
2	Bourke Weir	-30.083000	145.883000	Fixed crest (concrete)	Darling River	Bourke Shire Council	No	Deelder Fishlock	500K - 1M	500K - 1M	250
3	Darling River Weir (20A)	-30.478333	145.258611	Fixed crest (sheet metal piling, concrete and rock fill)	Darling River	State Water	No (Submerged Orifice Fishway present)	Denil Inserts (view to Full Width Rock Ramp Fishway)	150 - 250K	500K - 1M	165
4	Collarenebri Weir (5)	-29.552700	148.568300	Fixed crest (concrete)	Barwon River	State Water	No (Submerged Orifice Fishway present)	Deelder Fishlock	250 - 500K	500K - 1M	82
5	Louth Weir (21)	-30.633000	145.012000	Fixed crest (sheet metal piling, concrete and rock fill)	Darling River	State Water	No (Submerged Orifice Fishway present)	Denil Inserts (view to Full Width Rock Ramp Fishway)	150 - 250K	500K - 1M	185
6	Tilpa Weir (24)	-30.922861	144.206111	Fixed crest (sheet metal piling, concrete and rock fill)	Darling River	State Water	No (Submerged Orifice Fishway present)	Denil Inserts (view to Full Width Rock Ramp Fishway)	150 - 250K	500K - 1M	378
7	Darling River Weir (19A)	-30.236666	145.718333	Fixed crest (sheet metal piling and concrete)	Darling River	State Water	No (Submerged Orifice Fishway present)	Denil Inserts (view to Vertical Slot Fishway)	150 - 250K	500K - 1M	149
N/A	Woorawadin Weir	-29.875000	148.263000	Fixed crest	Barwon River	State Water	No	TBA	TBA	N/A	N/A
N/A	Calmundy Weir (8)	-29.752700	148.376600	Fixed crest	Barwon River	State Water	No	TBA	TBA	N/A	N/A
N/A	Brewarrina Weir	-29.967000	146.853000	Fixed crest	Barwon River	State Water	No (Submerged Orifice Fishway present)	Replace with a high and low flow Partial Width Rock Ramp Fishway	>1M	N/A	N/A
N/A	Darling River Weir (11A)	-30.013000	148.097000	Fixed crest	Darling River	State Water	No	Vertical Slot Fishway, with upgrade of weir and installation of fishway planned for 06/07	>1M	N/A	N/A
N/A	Nidgery Weir	-30.549055	146.427388	Fixed crest	Bogan River	Nidgery Weir Trust	No	Partial Width Rock Ramp Fishway (investigations currently underway)	50 - 100K	N/A	N/A
N/A	Gongolgon Weir	-30.349200	146.894800	Fixed crest	Bogan River	State Water	No	TBA	TBA	N/A	N/A

WILCANNIA WEIR, DARLING RIVER

Figure 1. Wilcannia Weir, Darling River (04.12.2004, 0ML/day).

Figure 2. Wilcannia Weir, Darling River (04.12.2004, 0ML/day).

Description and Setting

Wilcannia Weir (Figures 1 and 2) is located on the Darling River within the town limits of Wilcannia, on the foreshore of the caravan and camping grounds, in the Mid-Darling River catchment (Western CMA). Wilcannia Weir is approximately 3.9 metres high and 60 metres across the length of the crest. The weir is a fixed crest structure constructed of concrete and rock fill, and has no gates or culverts associated with it. The weir acts as a barrier to fish passage when flows are less than approximately 7,900ML/day (Cooney 1994) due to excessive head loss, increased turbulence, and increased velocity across the face of the structure.

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

- Class 1 fish habitat - major permanently flowing waterway and presence of threatened fish species and populations (this site is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), and the endangered river snail (*Notopala sublineata*));
- Distributed within the Aquatic Endangered Ecological Community of the Lowland Catchment of the Darling River;
- Diverse range of native fish (High Conservation Value);
- Diverse instream habitat;
- Improved stream connectivity: the next upstream barrier to fish is Tilpa Weir (No. 24) approximately 255km upstream, the next barrier downstream is Menindee Main Weir approximately 251km away. Both of these structures are owned and operated by the State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Darling River upstream of Menindee are not regulated. Wilcannia Weir is located downstream of the confluence with Warrego, Culgoa, Bokhara, Bogan, Barwon, and Paroo Rivers. The Barwon-Darling River headwaters originate in southeast Queensland and are fed by the Macintyre, Gwydir, Namoi, Castlereagh and Macquarie Rivers in NSW alone. The Paroo and Warrego Rivers are intermittent watercourses that feed a significant volume of water into the system during flood conditions. There are 14 other barriers to fish passage that exist upstream within NSW and include (from nearest to farthest) Tilpa Weir (No. 24), Louth Weir 21, Weir 20A, Weir 19A, Bourke, Brewarrina (No. 15), Walgett 11A, Woorawadian (No. 10), Calmundi (No. 8), Collarenebri (No. 5), Banarway, Presbury (No. 2), Comilaroy (No. 1), and Mungindi Weirs.

The closest DNR river gauge is located at Wilcannia on the Darling River (station 425008). Information referred to in this report regarding flows in the Darling River are sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from State Water, DNR and NSW DPI, and describes data acquired between 13.11.1974 – 22.09.2005.

It has been estimated that in its current condition the weir would allow some fish passage at flows in excess of 7,900ML/day (Cooney 1994).

The time weighted flow duration curve for the Barwon River at station 425008 shows that flows would exceed 7,900ML/day 23% of the time.

Over the last few years the Darling River has stopped flowing at Wilcannia for several months at a time due to the drought conditions being experienced in the region. During 2003, flows within the Darling River at Wilcannia did not exceed 4,000ML/day at any time, and drown out of the weir did not occur. In the last 2 years the weir has only drowned out four times. Successive dry years can prevent the migration of native fish, and in some circumstances can prevent spawning events from taking place at all. The cumulative impact of non-spawning events can have massive impacts on the native fish populations and lead to the decline of some species.

There are currently many licensed water extractors including Central Darling Shire Council who utilise the water in the upstream weir pool for varying purposes including stock, irrigation, domestic, and town water supply.

Operational Details

Wilcannia Weir was built in 1945 and is currently not considered to be in a stable condition. The structure is owned and operated by the Central Darling Shire Council who have indicated that repair work may be needed in the future to secure the town water supply. Council are aware that if the weir is modified, approval must be sought from NSW DPI to ensure that fish passage is provided.

During inspection of this site, mention was made of investigations carried out in the past regarding the construction of a new weir downstream of this site. NSW DPI understand that any plans to pursue an additional weir have been put on hold, and there is currently no intention by Central Darling Shire Council to carry out these works in the near future.

If the Council were to seek approval for a second weir on the Darling River in the future, they would be required to provide fish passage at the site by constructing a vertical slot fishway and investigating the future management of the existing weir for potential partial or complete removal.

Ecological Considerations

Wilcannia Weir was identified in Cooney (1994) as a priority for improved fish passage within the Barwon-Darling system. Fish passage may be possible approximately 23% of the time due to drown out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Darling River. If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is only drowned out only for short periods, water levels at the structure may have dropped as fish are moving upstream, and prior to them reaching the weir. At these times fish could therefore continually miss the opportunity to move past the structure.

The next fish passage barrier located downstream, Menindee Weir, is currently being investigated for fish passage remediation. The Menindee Lakes system has, in the past, been the centre of discussions relating to water supply security, and more recently fish passage.

State Water is currently entering into discussions with stakeholders, including NSW DPI, about the future management of the entire Menindee Lakes system.

Figure 3. Darling River downstream of Wilcannia Weir (04.12.2004, 0ML/day).

Figure 4. Darling River upstream of Wilcannia Weir (04.12.2004, 0ML/day).

The NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) identified as many as 30 different fish species, which were expected to occur within the Darling River Basin, 14 of which were actually caught during the survey in 1996. The following native fish species are expected to occur within the Darling River Basin and potentially within the river at Wilcannia Weir: Darling River hardyhead, flyspecked hardyhead, western carp gudgeon, spangled perch, Murray cod, golden perch, crimson spotted rainbowfish, bony herring, Hyrtl's tandan, flathead gudgeon, dwarf flathead gudgeon, Australian smelt, freshwater catfish, in addition to the threatened silver perch, olive perchlet, and purple spotted gudgeon. The actual distribution and conservation status of the above threatened species within the Darling River Basin were identified in Morris *et al.* (2001). Alien species including goldfish, common carp, gambusia, and tench are also likely to be present in the waterway. This species list may vary across the basin, however, and should be viewed as a guide only for the purpose of this review.

This site has some instream woody debris, which is an important component of fish habitat. The area surrounding the weir is dominated by river red gum, with the lower banks either side of the weir having little or no vegetation present, most likely as a result of prevailing drought conditions at the time of inspection (Figures 3 and 4). There was some minor erosion at this site at the time of inspection as a result of the lack of vegetation cover on the banks. Riparian fencing should be encouraged in this area, along with provision of alternative off stream watering points, both of which could be undertaken in conjunction with any fish passage remediation works at this site.

Proposed Remediation Actions

There remain significant periods of time when the passage of all fish will be affected. If these periods coincide with the spawning migrations for particular species, the weir will continue to have a significant impact on the migratory fish community within the river. It should 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 when undertaking fish passage remediation works.

As the weir is still required, its removal is not considered a viable option at this time.

- **Option 1 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present, or where the weir is on the main stem of a river or a major tributary. With varying head loss the vertical slot fishway would be more effective than other fishway designs in passing a greater range of fish size classes. The cost of the vertical slot fishway is based on a broad estimate of $150,000 per vertical metre, although this amount is dependent on site location and access, along with various structural and hydrological constraints.

Currently the weir is not considered to be in a good condition and, in its current state, this type of fishway would not be recommended unless the weir wall was reinforced.

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

The construction of a partial width rock ramp fishway would make a significant contribution to improving the passage of native fish prior to drown out of the structure. Existing rock at the weir site could be rearranged and incorporated into the fishway, so that the existing spillway is extended to create a gradient of 1:20. The fishway design would be a reverse dog-leg arrangement where the fishway is perpendicular to the weir on the left hand bank with a return so that the entrance is located close to the weir to take advantage of attraction flows. Alternatively the rock ramp could be run parallel to the weir if head and tail water levels fluctuate considerably. The fishway itself would comprise several rock ridges to create resting pools and small rises in elevation between the pools.

This modification would provide passage to a greater range of fish species and size classes over a greater range of flows, and is considered the most cost effective option for this site.

- **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). The main benefit of constructing a full width rock ramp fishway at this site would be that the added weir reinforcement gained from the full width design compared to the partial width design, which would only strengthen part of the weir structure. The main disadvantage for construction of a full width rock ramp fishway is the increased cost. This is predominantly due to the considerable amount of rock that must be imported to the site.

The weir currently stands at approximately 4 metres in height, and as such, both the partial width and full width rock ramp fishways would extend approximately 80 metres downstream to achieve the required 1:20 slope. A low flow channel with a pool depth of approximately 500mm would need to be incorporated into the centre of the structure to allow for fish passage at lower flows. Detailed specifications relating to rock ramp fishways can be obtained from NSW DPI and should be considered prior to the development of engineering designs.

Recommendation

Under current conditions, the construction of a full width rock ramp fishway (Option 3) is the preferred remedial action for Wilcannia Weir. Alternatively, should the existing weir require structural modifications or repairs, it is recommended that a vertical slot fishway (Option 1), be incorporated into the work plan to provide fish passage past this site over a wide range of flows.

Projected Remediation Costs

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

Benefits Associated with Remediation

The Darling River contains important fish habitat that should be protected. The reinstatement of fish passage along the entire Barwon-Darling River system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Wilcannia Weir, in excess of 501km of potential habitat either side of this site would again become accessible to fish and other aquatic organisms.

BOURKE WEIR, DARLING RIVER

Figure 1. Bourke Weir, Darling River (01.12.2004, 144.6ML/day).

Figure 2. Defunct boat lock, Bourke Weir, Darling River (01.12.2004, 144.6ML/day).

Description and Setting

Bourke Weir (Figure 1), also known as Davidsons Lock and Weir, is located just downstream of Bourke on the Darling River in the Upper Darling catchment (Western CMA). The weir is approximately 3 metres high and 60 metres across the length of the crest, it is a concrete fixed crest structure, with no gates or culverts associated with it. A boat lock is connected to the weir (Figure 2), but was made redundant in 1941, when it was capped with concrete. Fish passage for some larger recreational species is possible when flows are greater than 10,000ML/day (Harris 2001). During flows less than this excessive head loss, increased turbulence, and increased velocity across the face of the structure prevent the upstream passage of all fish.

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

- Class 1 fish habitat - major permanently flowing waterway and presence of threatened fish species and populations (this site is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), and the endangered river snail (*Notopala sublineata*));
- Located within the Aquatic Endangered Ecological Community of the Lowland Catchment of the Darling River;
- Diverse range of native fish (High Conservation Value);
- Instream and riparian habitat condition is good;
- Improved stream connectivity: the next upstream barrier to fish is Brewarrina Weir approximately 210km upstream, the next barrier downstream is Weir 19A approximately 40km away. Both structures are owned and operated by State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Darling River upstream of Menindee are not regulated. Bourke Weir is located downstream of the confluences with the Culgoa, Bokhara, Barwon, and Bogan Rivers. The Barwon-Darling River headwaters originate in southeast Queensland and are fed by the Macintyre, Gwydir, Namoi, Castlereagh and Macquarie Rivers in NSW alone. The Paroo and Warrego Rivers are intermittent watercourses that feed a significant volume of water into the system during flood conditions. There are nine other barriers to fish passage that exist upstream from Collarenebri within NSW and include (from nearest to farthest) Brewarrina (No. 15), Walgett (No. 11A), Woorawadian (No. 10), Calmundi (No. 8), Collarenebri (No. 5), Banarway, Presbury (No. 2), Comilaroy (No. 1), and Mungindi Weirs.

The closest DNR river gauge is located within the Bourke Weir pool on the Darling River (station 425003). Information referred to in this report regarding flows in the Darling River was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and staff from State Water, DNR and NSW DPI, and describes data acquired between 01.06.1980 – 22.09.2005.

The weir is preventing fish passage during most flow conditions. It has been estimated that the weir in its current structural condition would drown out with flows in excess of 10,000ML/day with a head loss of approximately 300-500mm (Cooney

1994). The time weighted flow duration curve for the Barwon River at Bourke shows that flows would exceed 10,000ML/day less than 21% of the time (based on the available flow data between 1980 – 2005).

There are currently many licensed water extractors who utilise the water in the upstream weir pool for varying purposes including stock, irrigation, domestic, and town water supply.

Operational Details

The Bourke Weir and Lock is owned and operated by Bourke Shire Council. The structure was built in 1897 to make river transport more reliable, with construction being initiated by river merchants (URL: http://www.heritage.nsw.gov.au). The National Trust of Australia registered Bourke Weir and Lock in 1986, and as such its heritage values need to be conserved when considering fish passage remediation at this site. On the right hand bank a defunct boat lock exists (Figure 2), which acts as a reminder of the history associated with the river and the township of Bourke.

In 2004, Bourke Shire Council made a submission to the Heritage Council to raise the height of the weir. The aim of the project was to further secure the town water supply when the Darling River stops flowing. Currently the town water supply has been estimated to last 12 months after cease to flow - raising the weir would provide an additional five months of water supply to the town. Bourke Shire Council is aware that an environmental assessment would be required, with the provision of a fishway being essential. As explained in the *NSW Fisheries Management Act* 1994, “the Minister may require a person who constructs, alters or modifies a dam or weir to provide fish passage”. Subsequent approval by NSW DPI and DNR will also need to be sought before any on ground works commence.

Ecological Considerations

Bourke Weir was identified in Cooney (1994) as a priority for improving fish passage within the Barwon-Darling system. Limited fish passage may be possible less than 21% of the time when the structure overtops, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Darling River. 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.

Fish passage at the next weir upstream (Brewarrina Weir) will soon be possible given that the structure is currently being investigated for a partial width rock ramp fishway and on ground works are expected to commence in 2006.

Consultation with the Brewarrina Aboriginal Working Party, general community, and Brewarrina Shire Council has been a major focus of this fish passage remediation project with efforts to engage the whole community during fish passage negotiations at the Bourke Weir also essential.

Figure 3. Darling River downstream of Bourke Weir (01.12.2004, 144.6ML/day).

Figure 4. Darling River upstream of Bourke Weir (01.12.2004, 144.6ML/day).

The NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) identified as many as 30 different fish species that were expected to occur within the Darling River Basin, 14 of which were actually caught during the survey in 1996. The following native fish species are expected to occur within the Darling River Basin, and potentially within the river at Bourke Weir: Darling River hardyhead, flyspecked hardyhead, western carp gudgeon, spangled perch, Murray cod, golden perch, crimson spotted rainbowfish, bony herring, Hyrtl's tandan, flathead gudgeon, dwarf flathead gudgeon, Australian smelt, freshwater catfish, in addition to the threatened silver perch, olive perchlet, and purple spotted gudgeon. The actual distribution and conservation status of the above threatened species within the Darling River Basin were identified in Morris *et al*. (2001). Alien species including goldfish, common carp, gambusia, and tench are also likely to be present in the waterway. This species list may vary across the basin and for the purpose of this review it should be viewed as a guide only.

This site has some instream woody debris, which is an important component of fish habitat. The area surrounding the weir is dominated by river red gum and the lower banks either side of the weir have limited understorey vegetation, possibly as a result of prevailing drought conditions at the time of inspection (Figures 3 and 4). There is very little erosion at this site due to the presence of the stable bedrock, which acts to prevent bed lowering.

Proposed Remediation Actions

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

As the weir is still required, its removal is not considered a viable option at this time.

- **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 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 of fish passage at this site continues and will observe fish passage under various flow conditions, determining whether this design is applicable to other sites across NSW.

Further trials of Deelder fishlocks have been recommended by Thorncraft and Harris (2000) at other sites along the Murrumbidgee River. This includes the Berembed and Yanco Weirs, which currently have ineffective submerged orifice fishways.

As with Balranald Weir, the Deelder fishlock could be installed into the existing boat lock on the right hand side of Bourke 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.

The Deelder fishlock would need to be fully automated, with power infrastructure a necessity for establishment at this site. Provided that power is available, the Deelder fishlock could be constructed more cost effectively than the vertical slot fishway design.

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 option where threatened species are present, or where the weir is on the main stem of a river or a major tributary. 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, and the presence of the defunct boat lock makes 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 amount is dependent on site location and access, along with various structural and hydrological constraints that may exist at the site. Construction of the fishway may be considered on the right hand bank where the redundant boat lock exists, or alternatively the fishway could be constructed independently provided that an adequate attraction flow was created adjacent to the downstream fish way entrance.

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

A full width rock ramp fishway would not operate as effectively as a vertical slot fishway under current variable conditions, such as differing head loss. In addition, a considerable amount of rock would need to be imported to the site to create a full width rock ramp fishway. The weir currently sits 3 metres high and, if built to the specifications of a 1:20 gradient, would be required to extend more than 60 metres downstream. A full width rock ramp may therefore be better suited to a minor tributary with unregulated flows.

Projected Remediation Costs

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

Recommendation

The presence of a defunct boat lock provides a significant opportunity for modification to facilitate fish passage. The preferred option for remediation is to investigate the construction of a vertical slot fishway within the existing boat lock. This could provide significant savings in terms of coffer dams and concrete framework. Such an investigation could also consider the feasibility of a fish lock that utilised some or all of the existing defunct boat lock.

Benefits Associated with Remediation

The Darling River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system generating substantial benefits to the ecology of the catchment. The reinstatement of fish passage at Bourke Weir on the Darling River would provide unimpeded access to in excess of 250km of potential habitat for fish and other aquatic organisms.

WEIR 20A, DARLING RIVER

Figure 1. Weir 20A, Darling River (02.12.2004, 144.6ML/day).

Figure 2. Submerged orifice fishway, Weir 20A, Darling River (02.12.2004, 144.6ML/day).

Description and Setting

Weir 20A (Figure 1) is located approximately 40km upstream from Louth on the Darling River in the Upper Darling catchment (Western CMA). The weir is approximately 4 metres high and 36 metres across the length of the crest and is constructed of sheet metal piling, concrete and rock fill. Weir 20A is a fixed crest structure, with no gates or culverts associated with it. There is a redundant submerged orifice fishway (Figure 2), which in its current state does not pass fish. The weir acts as a barrier to fish passage due to excessive head loss, increased turbulence, and increased velocity at flows less than approximately 8,000ML/day (Cooney 1994).

Weir 20A is ranked as a high remediation priority within the Western CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of threatened fish species and populations (this site is within the expected distribution of silver perch (*Bidyanus bidyanus),* olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*) and the endangered river snail (*Notopala sublineata*));
- Distributed within the Aquatic Endangered Ecological Community of the Lowland Catchment of the Darling River;
- Diverse range of native fish (High Conservation Value);
- Instream and riparian habitat condition (presence of instream woody habitat);
- Improved stream connectivity: The next upstream barrier to fish is Weir 19A approximately 105km upstream, whilst the next barrier downstream is Louth Weir 21A approximately 60km away. Both structures are owned and operated by State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Darling River upstream of Menindee are not regulated. Weir 20A is located downstream of the confluences with the Warrego, Culgoa, Bokhara, Barwon, and Bogan Rivers. The Barwon-Darling River headwaters originate in southeast Queensland and are fed by the Macintyre, Gwydir, Namoi, Castlereagh and Macquarie Rivers in NSW alone. The Paroo and Warrego Rivers are intermittent watercourses that feed a significant volume of water into the system during flood conditions. There are 11 other barriers to fish passage that exist upstream within NSW and include (from nearest to farthest) Weir 19A, Bourke, Brewarrina (No. 15), Walgett (No. 11A), Woorawadian (No. 10), Calmundi (No. 8), Collarenebri (No. 5), Banarway, Presbury (No. 2), Comilaroy (No. 1), and Mungindi Weirs.

The closest DNR river gauge is located within the Bourke Weir pool on the Darling River (station 425003). Information referred to in this report regarding flows in the Darling River was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), as well as staff from State Water, DNR and NSW DPI, and describes data acquired between 01.06.1980 – 22.09.2005.

It has been estimated that the weir in its current condition would allow limited fish passage with flows in excess of 8,000ML/day, with a head loss of approximately 110mm (Cooney 1994).

The time weighted flow duration curve for the Darling River at station 425004 shows that flows would exceed 8,000ML/day 27% of the time (based on available flow data between 1980 – 2005).

There are currently many licensed water extractors who utilise the water in the upstream weir pool for various purposes including stock, domestic, irrigation and town water supply.

Operational Details

Weir 20A is owned and operated by State Water and was built in 1983. The weir is currently used for recreation, stock, domestic, and some irrigation supply by upstream water users. The weir currently has a submerged orifice fishway on the left hand bank, which consists of 13 cells on a slope of 1:9. At the time of the inspection the fishway was in a state of disrepair, with no noticeable attraction flow to the fishway entrance.

Ecological Considerations

Weir 20A was identified in Cooney (1994) as a priority for improved fish passage within the Barwon-Darling system. The flow duration curves for this region indicate that fish passage may be possible approximately 27% of the time, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Darling River. 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.

The NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) identified as many as 30 different fish species that were expected to occur within the Darling River Basin, 14 of which were actually caught during the survey in 1996. The following native fish species are expected to occur within the Darling River Basin and potentially within the river at Weir 20A: Darling River hardyhead, flyspecked hardyhead, western carp gudgeon, spangled perch, Murray cod, golden perch, crimson spotted rainbowfish, bony herring, Hyrtl's tandan, flathead gudgeon, dwarf flathead gudgeon, Australian smelt, freshwater catfish, as well as the threatened silver perch, olive perchlet, and purple spotted gudgeon. The actual distribution and conservation status of the above threatened species within the Darling River Basin are identified in Morris *et al*. (2001). Alien species including goldfish, common carp, gambusia, and tench are also likely to be present within the waterway. This species list may vary across the basin and should be viewed as a guide only for the purpose of this review.

The area surrounding Weir 20A has some instream woody debris, which is an important component of fish habitat. The site is dominated by river red gum, and the lower banks, both upstream and downstream of the weir, have limited understorey vegetation (Figures 3 and 4). At the time of the inspection conditions were dry as the district was experiencing drought. Despite the dry conditions, there was very little erosion at the site due to the presence of stable bedrock, which acts to prevent bed lowering.

Figure 3. Darling River downstream of Weir 20A (02.12.2004, 144.6ML/day).

Figure 4. Darling River upstream of Weir 20A (02.12.2004, 144.6ML/day).

Proposed Remediation Actions

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

Tilpa Weir (No. 24), Louth Weir 21, Weir 20A, and Weir 19A are all significant structures occurring between Wilcannia Weir and Bourke Weir on the Darling River (a total distance of approximately 700km). Although these structures were built for the purposes of stock, domestic, and irrigation supply, the relatively low levels of extraction from the river may make it possible for their current uses could be met by alternative water source technology. Such alternatives would allow for a detailed assessment of the future of the weirs to be undertaken to determine if their potential removal would provide an overall benefit to the health of the Darling River.

Whilst NSW DPI understands that these structures provide a significant social amenity, it is recommended that as a first priority an investigation into the provision of water to surrounding landholders by alternative means be undertaken. An investigation of this sort will allow determination of whether any or all of these structures can be removed without impacting surrounding landholders. If it is found to be technically feasible, detailed consultation with all stakeholders should be commenced to ascertain community attitudes towards such a proposal.

As a second (short term) measure, it is recommended that all structures have a Denil insert installed into the existing (ineffective) fishways. This will ensure that at least some of the larger bodied native fish species are able to negotiate these structures prior to drown out of the structures.

- **Option 1** – Retrofitting existing fishway with a Denil insert

There is some scope for improvements to the existing fishway that may allow it to function more effectively. At present it represents a total barrier to fish passage, alienating fish within the Darling River. It is possible that by retrofitting the existing fishway with a Denil insert it would achieve an increase in fish passage.

A Denil fishway is a channel incorporating U-shaped baffles that reduce velocity and turbulence so that fish can ascend without undue stress. Denil fishways are cheaper than vertical slot fishways because they can be constructed on steeper slopes, therefore requiring less materials during construction (Baumgartner 2005). The slope of the current fishway is estimated to be in excess of 1:9. Mallen-Cooper (2000) recommends that Denil inserts should only be considered where the slope is equal to or less than 1:12. It is therefore recommended that in this instance the effectiveness of the fishway should not be compromised for a cheaper outcome, particularly given the presence of threatened species at this site. Some experimental work on Denil fishways is currently being undertaken in NSW and may recommend a modified version of the Denil fishway be used in the future on slopes steeper than 1:12.

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

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

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

Potentially a considerable amount of rock would need to be imported to create a fishway with a slope of 1:20. As Weir 20A is approximately 4 metres high, a full width rock ramp fishways would extend nearly 80 metres downstream.

Recommendation

It is recommended that alternative water source extraction technology be investigated for Weir 20A to determine if its potential removal would provide an overall benefit to the health of the Darling River. If it is found to be technically feasible, detailed consultation with all stakeholders should be commenced to ascertain community attitudes towards such a proposal.

Secondly it is recommended that a Denil insert (Option 1) be installed into the existing ineffective submerged orifice fishway at Weir 20A, as a short term measure to improve fish passage. Should it be determined that structure removal is not possible, it is recommended that a full width rock ramp fishway (Option 2) be constructed at Weir 20A, to enable fish passage at a greater range of flows than is currently possible.

If Weir 20A was scheduled for a complete rebuild, so that the structure was a more formalised concrete construction, it is recommended that a vertical slot fishway be installed. Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present, where the weir is on the main stem of a river, or a major tributary. With varying head loss the vertical slot fishway would be more effective than other designs in passing a greater range of fish size classes.

Projected Remediation Costs

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

Benefits Associated with Remediation

The Darling River contains important fish habitat that should be protected, and the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Weir 20A it would allow unimpeded access to potential habitat for fish and other aquatic organisms in excess of 165km either side of this site.

COLLARENEBRI WEIR (No. 5), BARWON RIVER

Figure 1. Collarenebri Weir (No. 5), Barwon River (16.05.05, 8.7ML/day).

Figure 2. Submerged orifice fishway, Collarenebri Weir (No. 5), Barwon River (16.05.05, 8.7ML/day).

Description and Setting

Collarenebri Weir (No. 5) (Figure 1) is located just outside the town limits of Collarenebri on the Barwon River, approximately 1km downstream of the Gwydir Highway Bridge in the Upper Barwon Darling catchment (Western CMA). The fixed crest concrete weir is approximately 1.6 metres high and 60 metres across the length of the crest, and has no gates or culverts associated with it. There is currently a submerged orifice fishway (Figure 2), which does not pass fish. The weir acts as a barrier to all fish when flows are less than approximately 18,000ML/day due to excessive head loss, increased turbulence, and increased velocity across the face of the structure.

Figure 3. Aboriginal fish traps, Barwon River at Collarenebri (16.05.2005, 8.7ML/day).

Local residents made note of the presence of Aboriginal fish traps located directly downstream of the weir (Figure 3). During low flow periods the traps are visible on the left side within the high flow channel. Any fish passage remediation works that may take place at this site would need to be mindful of Aboriginal Heritage values of the area and would need to involve consultation with the community about proposed works.

The Collarenebri Weir (No. 5) is ranked as a high remediation priority within the Western CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of threatened fish species and populations (this site is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), and the endangered river snail (*Notopala sublineata*));
- Located within the Aquatic Endangered Ecological Community of the Lowland Catchment of the Darling River;
- Diverse range of native fish (High Conservation Value);

- Instream and riparian habitat condition is good;
- Improved stream connectivity: the next upstream barrier to fish is Banarway Weir approximately 46km upstream; the next barrier downstream is Calmundi Weir (No. 8) approximately 36km away. Both structures are owned and operated by State Water, although State Water would like to relinquish ownership of Calmundi Weir to DNR. Calmundi Weir is used to supply stock and domestic water, and has an ineffective fishway that requires replacement; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Barwon River upstream of Walgett are not regulated. The Collarenebri Weir (No. 5) is located downstream of the confluences with Boomi, Mehi, and the Gwydir Rivers. The Barwon-Darling River headwaters originate in southeast Queensland and are fed by the Macintyre, Gwydir, Namoi, Castlereagh and Macquarie Rivers in NSW alone. The Paroo and Warrego Rivers are intermittent watercourses that feed a significant volume of water into the system during flood conditions. There are four other barriers to fish passage that exist upstream of Collarenebri within NSW and include (from nearest to farthest) Banarway, Presbury (No. 2), Comilaroy (No. 1), and Mungindi Weirs.

The closest DNR river gauge is located within the Collarenebri Weir (No. 5) pool on the Barwon River (station 422003). Information referred to in this report regarding flows in the Barwon River was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and staff from State Water, DNR and NSW DPI, and describes data acquired between 01.07.1944 – 22.09.2005.

The weir is preventing fish passage during most flow conditions. It has been estimated that the weir in its current structural condition limited fish passage would be possible with flows in excess of 18,000ML/day with a head loss of approximately 110mm (Cooney 1994). The time weighted flow duration curve for the Barwon River at Collarenebri shows that flows would exceed 18,000ML/day less than 4% of the time (based on the available flow data between 1944 – 2005).

There are currently many licensed water extractors who utilise the water in the upstream weir pool, for varying purposes including stock, irrigation, domestic and town water supply.

Operational Details

Collarenebri Weir (No. 5) is owned and operated by State Water. The weir was built in 1968 to supply water to the town of Collarenebri and provide water for stock domestic and irrigation use.

There is a non-functioning submerged orifice fishway associated with the structure on the right hand side. The concrete fishway consists of five cells, each approximately one metre square, and is set on a slope greater than 1:6, which would limit the passage of most native fish in the Barwon River.

Ecological Considerations

Collarenebri Weir (No. 5) was identified by Cooney (1994) as a priority for improved fish passage within the Barwon-Darling system. Fish passage may be possible less than 4% of the time when the structure overtops, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Barwon River. 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.

Figure 4. Darling River downstream of Collarenebri Weir (No. 5) (16.05.2005, 8.7ML/day).

Figure 5. Darling River upstream of Collarenebri Weir (No. 5) (16.05.2005, 8.7ML/day).

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.

The NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) identified as many as 30 different fish species that were expected to occur within the Darling River Basin, 14 of which were actually caught during the survey in 1996. The following native fish species are expected to occur within the Darling River Basin and potentially within the Barwon River near Collarenebri: Darling River hardyhead, flyspecked hardyhead, western carp gudgeon, spangled perch, Murray cod, golden perch, crimson spotted rainbowfish, bony herring, Hyrtl's tandan, flathead gudgeon, dwarf flathead gudgeon, Australian smelt, freshwater catfish, in addition to the threatened silver perch, olive perchlet, and purple spotted gudgeon. The actual distribution and conservation status of the above threatened species within the Darling River Basin were identified in Morris *et al*. (2001). Alien species including goldfish, common carp, gambusia, and tench are also likely to be present in this waterway. This species list may vary across the basin and should be viewed as a guide only for the purpose of this review.

This site has some instream woody debris, which is an important component of fish habitat. The site is dominated by river red gum, and the lower banks either side of the structure have an established grassy understorey (Figures 4 and 5).

There is very little erosion at this site as a result of the stable bedrock, which acts to prevent bed lowering. There is some stock access to the river on the right hand bank with some minor erosion occurring as a result. This site would benefit from the establishment of off-stream watering points and riparian fencing, which would complement any fish passage remediation activities undertaken at this site.

Proposed Remediation Actions

Despite the fact that there may be limited fish passage, there remain significant periods of time when the passage of all fish will be affected. If these periods coincide with spawning migrations for particular species, the weir will continue to have a significant impact on the migratory fish community within the river. State water is in the process of reviewing their entire existing infrastructure within the Western catchment. Recommendations made as a result of this report will be further discussed with State Water to determine a solution that will improve fish passage at this site.

It should 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 when undertaking fish passage remediation works. As the weir is still required, its removal is not currently considered a viable option.

- **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 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 of fish passage at this site continues and will observe fish passage under various flow conditions, determining whether this design is applicable to other sites across NSW.

Further trials of Deelder fishlocks have been recommended by Thorncraft and Harris (2000) at other sites along the Murrumbidgee River. This includes the Berembed and Yanco Weirs, which currently have ineffective, submerged orifice fishways. As with the Balranald Weir, the Deelder fishlock design could be applied to Collarenebri Weir (No. 5), which is close to electricity supply and easily accessible from the township of Collarenebri. 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 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 option where threatened species are present, or where the weir is on the main stem of a river or a major tributary. With varying head loss the vertical slot fishway would be more effective than other fishway designs in passing a greater range of fish size classes.

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 amount is dependant on site location and access, along with various structural and hydrological constraints that may exist at the site.

- **Option 3 –** Retrofitting existing fishway with a Denil insert.

The Denil fishway is a channel incorporating U-shaped baffles that reduce velocity and turbulence so that fish can ascend without undue stress. Denil fishways are cheaper than vertical slot fishways because they can be constructed on steeper slopes, meaning less materials are needed for their construction (Baumgartner 2005). There is some scope for improvements to the existing fishway that may allow it to function more effectively. At present the weir forms a total barrier to fish passage, and only drowns out approximately 4% of the time, meaning that fish passage is not possible in all but high flow conditions that may not occur for several years consecutively. It is possible that by retrofitting the existing fishway with a Denil insert it could achieve a limited improvement in fish passage.

There are limitations with the use of Denil inserts, however, with Larinier (1990) identifying Denil fishways as only being effective in passing fish greater than 200mm in length. Mallen-Cooper (2000) recommended Denil fishways be constructed on slope no greater than 1:12, as slopes greater than this (less conservative slopes) limit the movement of smaller fish. Experimental work undertaken in NSW has shown that bony herring could ascend Denil fishways with a slope of 1:12, however their movement was greatly restricted on steeper slopes. Mallen-Cooper (2000) further recommended that Denil fishway design should not be used where adult Murray cod are present, as it has not yet been established whether this species will use the Denil design.

Therefore the existing submerged orifice fishway does not lend itself as an ideal site for installation of a Denil insert, with this option not being recommended for this site.

Recommendation

It is recommended that a fish passage options study determine the viability of accurate costings for both a fully automated Deelder fishlock (Option 1), and a vertical slot fishway design (Option 2). Further investigation into both options will enable determination of their viability and future action.

Projected Remediation Costs

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

Benefits Associated with Remediation

The Barwon River contains important fish habitat that should be protected, and the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Collarenebri Weir (No. 5) unimpeded access to in excess of 82km of potential habitat would be allowed for fish and other aquatic organisms.

LOUTH WEIR 21, DARLING RIVER

Figure 1. Louth Weir 21, Darling River (02.12.2004, 144.6ML/day).

Figure 2. Submerged orifice fishway, Louth Weir 21, Darling River (02.12.2004, 144.6ML/day).

Description and Setting

Louth Weir 21 (Figure 1) is located on the Darling River approximately 20km downstream from Louth in the Upper Darling catchment (Western CMA). The fixed crest weir is approximately 2.4 metres high and 43 metres across the length of the crest and is constructed of sheet metal pilings, concrete and rock fill, with no culverts or gates associated with the structure. There is a redundant submerged orifice fishway (Figure 2), which in its current state does not pass fish. The weir acts as a barrier to fish passage due to excessive head loss, increased turbulence, and increased velocity across the face of the structure when flows are less than approximately 9,600ML/day (Cooney 1994). At flows in excess of 9,600ML/day some fish passage by larger bodied fish may be possible

Louth Weir 21 is ranked as a high remediation priority within the Western CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of threatened fish species and populations (this site is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*), and the endangered river snail (*Notopala sublineata*));
- Distributed within the Aquatic Endangered Ecological Community of the Lowland Catchment of the Darling River;
- Diverse range of native fish (High Conservation Value);
- Instream and riparian habitat condition is good;
- Improved stream connectivity: the next upstream fish passage barrier is Weir 20A, approximately 60km upstream; the next barrier downstream is Tilpa Weir 24A approximately 125km away. Both structures are owned and operated by State Water;
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Darling River upstream of Menindee are not regulated. Louth Weir 21 is located downstream of the confluences with the Warrego, Culgoa, Bokhara, Barwon and Bogan Rivers. The Barwon-Darling River headwaters originate in southeast Queensland and are fed by the Macintyre, Gwydir, Namoi, Castlereagh and Macquarie Rivers in NSW alone. The Paroo and Warrego Rivers are intermittent watercourses that feed a significant volume of water into the system during flood conditions. There are 12 other barriers to fish passage that exist upstream within NSW and include (from nearest to farthest) Weir 20A, Weir 19A, Bourke, Brewarrina (No. 15), Walgett 11A, Woorawadian (No. 10), Calmundi (No. 8), Collarenebri (No. 5), Banarway, Presbury (No. 2), Comilaroy (No. 1), and Mungindi Weirs.

The closest DNR river gauge is located within the Louth Weir pool on the Darling River (station 425004). Information referred to in this report regarding flows in the Darling River was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from State Water, DNR and NSW DPI, and describes data acquired between 29.01.1983 – 22.09.2005.

It has been determined that, in its current structural condition, the weir would allow limited fish passage when flows are in excess of 9,600ML/day with a head loss of approximately 200mm (Cooney 1994). The time weighted flow duration curve for the Darling River at station 425004 shows that flows would exceed 9,600ML/day 26% of the time based on available data between 1983 – 2005.

There are currently many licensed water extractors who utilise the upstream weir pool for varying uses including stock, domestic, irrigation and town water supplies.

Operational Details

Louth Weir 21 was built in 1974 and is owned and operated by State Water. The weir is currently used for recreation, stock, domestic, and irrigation supply for some upstream water users. The weir is constructed of concrete and metal sheet piling and possessed a submerged orifice fishway on the right hand bank. The fishway consists of 13 cells on a slope of 1:9, and is very similar in design to the non-functioning fishway at Weir 20A. At the time of the inspection the fishway on Louth Weir 21 was in a state of disrepair with none of the cells remaining intact. In its current state the weir would not pass fish at flows less than the estimated drown out value of 9,600ML/day.

Ecological Considerations

Louth Weir 21 was identified in Cooney (1994) as a priority for improving fish passage within the Barwon-Darling system. Limited fish passage may be possible for larger bodied species such as golden perch approximately 26% of the time, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Darling River. 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.

The NSW Fish and Rivers in Stressed survey (Harris and Gehrke 1997) identified as many as 30 different fish species that were expected to occur within the Darling River Basin, 14 of which were actually caught during the survey in 1996. The following native fish species are expected to occur within the Darling River Basin and potentially within the river at Louth Weir 21: Darling River hardyhead, flyspecked hardyhead, western carp gudgeon, spangled perch, Murray cod, golden perch, crimson spotted rainbowfish, bony herring, Hyrtl's tandan, flathead gudgeon, dwarf flathead gudgeon, Australian smelt, freshwater catfish, in addition to the threatened silver perch, olive perchlet, and purple spotted gudgeon. The actual distribution and conservation status of the above-threatened species within the Darling River Basin were identified in Morris *et al.* (2001). Alien species including goldfish, common carp, gambusia, and tench are also likely to be present within the waterway. This species list may vary across the basin, and should be viewed as a guide only for the purpose of this review.

The site surrounding the weir has some instream woody debris, which is an important component of fish habitat. The site is dominated by river red gum, although the lower banks, either side of the weir have very limited understorey vegetation (Figures 3 and 4), possibly as a result of prevailing drought conditions at the time of inspection.

There is very little erosion at this site due to the presence of stable bedrock, which acts to prevent bed lowering. Riparian fencing and provision of off stream watering points should be encouraged in this area and combined with any fish passage remediation works at this site.

Figure 3. Darling River downstream of Louth Weir 21 (02.12.2004, 144.6ML/day).

Figure 4. Darling River upstream of Louth Weir 21 (02.12.2004, 144.6ML/day).

Proposed Remediation Actions

Despite the fact that Louth Weir 21 may drown out several times a year, there remain significant periods of time where the passage of all fish will be affected. If these periods coincide with the spawning migrations for particular species, the weir will continue to have a significant impact on the migratory fish community within the river. It should be remembered that during structure remediation 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 and their fish passage requirements.

Tilpa Weir (No. 24), Louth Weir 21, Weir 20A, and Weir 19A are all significant structures occurring between Wilcannia Weir and Bourke Weir on the Darling River (a total distance of approximately 700km). Although these structures were built for the purposes of stock, domestic, and irrigation supply, the relatively low levels of extraction from the river may make it possible for their current uses could be met by alternative water source technology. Such alternatives would allow for a detailed assessment of the future of the weirs to be undertaken to determine if their potential removal would provide an overall benefit to the health of the Darling River.

Whilst NSW DPI understands that these structures provide a significant social amenity, it is recommended that as a first priority an investigation into the provision of water to surrounding landholders by alternative means be undertaken. An investigation of this sort will allow determination of whether any or all of these structures can be removed without impacting surrounding landholders. If it is found to be technically feasible, detailed consultation with all stakeholders should be commenced to ascertain community attitudes towards such a proposal.

As a second (short term) measure, it is recommended that all structures have a Denil insert installed into the existing (ineffective) fishways. This will ensure that at least some of the larger bodied native fish species are able to negotiate these structures prior to drown out of the structures.

- **Option 1 –** Retrofitting existing fishway with a Denil insert.

A Denil fishway is a channel incorporating U-shaped baffles that reduce velocity and turbulence so that fish can ascend without undue stress. Denil fishways are cheaper than vertical slot fishways because they can be constructed on steeper slopes, meaning less materials are needed for their construction (Baumgartner 2005).

Mallen-Cooper (2000) recommends that Denil inserts could be considered to improve inefficient fishways where stream flows are greater than 44ML/day; small variation in head and tailwater occurs, and provided suitable trash racks are installed. It is also important that an attraction flow is created at the entrance of the fishway to direct fish movement toward the fishway.

Mallen-Cooper (2000) also recommended that Denil inserts should only be considered where the slope is equal to or less than 1:12, as slopes greater than this (less conservative slopes) limit the movement of smaller fish. The slope of the existing fishway is estimated to be in excess of 1:9, and it forms a total barrier to fish passage in the Darling River. Therefore, despite Mallen-Cooper's (2000) recommendation, there is some scope to improve the existing fishway so as to allow it to function more effectively (although still limiting the passage of smaller fish species).

Additional limitations raised concerning the use of Denil inserts include Larinier (1990) identifying Denil fishways as only being effective in passing fish greater than 200mm in length, and Mallen-Cooper (2000) further recommending that the Denil fishway design not be used where adult Murray cod are present (as it has not yet been established whether this species will use the Denil design). Further experimental work undertaken in NSW has shown that bony herring could ascend Denil fishways with a slope of 1:12, however their movement was greatly restricted on steeper slopes.

This fish passage option should be investigated further for application at Louth Weir 21 as a short term solution to fish passage remediation, whilst other options such as removal or a full width rock ramp fishway are investigated further.

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

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

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

Potentially a considerable amount of rock would need to be imported to create a fishway with a slope of 1:20. As Louth Weir 21 is 2.4 metres high, a full width rock ramp fishways would extend nearly 50 metres downstream.

Recommendation

It is recommended that alternative water source extraction technology be investigated for Louth Weir 21 to determine if its potential removal would provide an overall benefit to the health of the Darling River. If it is found to be technically feasible, detailed consultation with all stakeholders should be commenced to ascertain community attitudes towards such a proposal.

Secondly it is recommended that a Denil insert (Option 1) be installed into the existing ineffective submerged orifice fishway at Louth Weir 21, as a short term measure to improve fish passage. Should it be determined that structure removal is not possible, it is recommended that a full width rock ramp fishway (Option 2) be constructed at Louth Weir 21, to enable fish passage at a greater range of flows than is currently possible.

If Louth Weir 21 was scheduled for a complete rebuild, so that the structure was a more formalised concrete construction, it is recommended that a vertical slot fishway be installed. Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present, where the weir is on the main stem of a river, or a major tributary. With varying head loss the vertical slot fishway would be more effective than other designs in passing a greater range of fish size classes.

Projected Remediation Costs

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

Benefits Associated with Remediation

The Darling River contains important fish habitat that should be protected, and the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Louth Weir 21 it would allow unimpeded access for fish and other aquatic organisms to potential habitat in excess of 185km, either side of this site.

TILPA WEIR (No. 24), DARLING RIVER

Figure 1. Tilpa Weir (No. 24), Darling River (02.12.2004, 144.6ML/day).

Figure 2. Submerged orifice fishway, Tilpa Weir (No. 24), Darling River (02.12.2004, 144.6ML/day).

Description and Setting

Tilpa Weir (No. 24) (Figure1) is located approximately 255km upstream from Wilcannia on the Darling River in the Upper Darling catchment (Western CMA). The weir is approximately 3.5 metres high and 52 metres across the length of its crest and is constructed of sheet metal piling, concrete, and rock fill. Tilpa Weir (No. 24) is a fixed crest structure with no gates or culverts associated with it, although the structure does have a submerged orifice fishway, which does not pass fish (Figure 2). The weir acts as a barrier to fish passage when flows are less than approximately 2,400ML/day (Cooney 1994) due to excessive head loss, increased turbulence, and increased velocity across the face of the structure. Above 2,400ML/day the structure becomes drowned out with some fish passage possible.

Tilpa Weir (No. 24) is ranked as a high remediation priority within the Western CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of threatened fish species and populations (this site is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), and southern purple spotted gudgeon (*Mogurnda adspersa*));
- Diverse range of native fish (High Conservation Value);
- Location within the catchment (fish habitat located in the lower end of the catchment has a higher conservation need due to the higher prevalence of spawning grounds);
- Instream and riparian habitat condition (presence of instream woody debris);
- Improved stream connectivity: the next upstream barrier to fish is Louth Weir 21 approximately 125km upstream, which is owned and operated by State Water. The next barrier downstream is Wilcannia Weir approximately 255km away, which is owned and operated by the Central Darling Shire Council; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Darling River upstream of Menindee are not regulated. Tilpa Weir (No. 24) is located downstream of the confluence with Warrego, Culgoa, Bokhara, Barwon, and Bogan Rivers. The Barwon-Darling River headwaters originate in southeast Queensland and are fed by the Macintyre, Gwydir, Namoi, Castlereagh and Macquarie Rivers in NSW alone. The Paroo and Warrego Rivers are intermittent watercourses that feed a significant volume of water into the system during flood conditions. There are 13 other barriers to fish passage that exist upstream within NSW and include (from nearest to farthest) Louth Weir 21, Weir 20A, Weir 19A, Bourke, Brewarrina (No. 15), Walgett 11A, Woorawadian (No. 10), Calmundi (No. 8), Collarenebri (No. 5), Banarway, Presbury (No. 2), Comilaroy (No. 1), and Mungindi Weirs.

The closest DNR river gauge is located within the Louth Weir pool on the Darling River (station 425004). Information referred to in this report regarding flows in the Darling River was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au) and staff from State Water, DNR and NSW DPI, and describes data acquired between 29.01.1983 – 22.09.2005.

It has been determined that the weir in its current structural condition would allow limited fish passage with flows in excess of 2,400ML/day with a head loss of approximately 200mm (Cooney 1994). The time weighted flow duration curve for the Barwon River at station 425004 shows that flows would exceed 2,400ML/day 52% of the time (based on available flow data between 1983 – 2005).

There are currently many licensed water extractors who utilise the water in the upstream weir pool for varying uses including stock, irrigation, domestic, and town water supply.

Operational Details

Tilpa Weir (No. 24) was built in 1972 and is currently owned and operated by State Water. The weir currently has a submerged orifice fishway on the left hand bank that is constructed of concrete and sheet metal piling. The fishway consists of 24 cells on a slope of 1:6.9 and is very similar in design to other fishways currently on the Darling River at Weirs 19A, 20A and Louth Weir 21. At the time of inspection, the fishway was in a state of disrepair and would not pass any fish at flows less than 2,400ML/day in its current state.

Ecological Considerations

Tilpa Weir (No. 24) was identified in Cooney (1994) as a priority for improved fish passage within the Barwon-Darling system. Fish passage may be possible approximately 52% of the time when the structure is drowned out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Darling River. 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.

The NSW Fish and Rivers in Stress survey (Harris and Gehrke 1997) identified as many as 30 different fish species that were expected to occur within the Darling River Basin, 14 of which were actually caught during the survey in 1996. The following native fish species are expected to occur within the Darling River Basin, and potentially within the river at Tilpa Weir (No. 24): Darling River hardyhead, flyspecked hardyhead, western carp gudgeon, spangled perch, Murray cod, golden perch, crimson spotted rainbowfish, bony herring, Hyrtl's tandan, flathead gudgeon, dwarf flathead gudgeon, Australian smelt, freshwater catfish, in addition to the threatened silver perch, olive perchlet, and purple spotted gudgeon species. The actual distribution and conservation status of the above threatened species within the Darling River Basin were identified in Morris *et al.* (2001). Alien species including goldfish, common carp, gambusia, and tench are also likely to be present in the waterway. This species list may vary across the basin, however, and should be viewed as a guide only for the purpose of this review.

This site has some instream woody debris, which is an important component of fish habitat. The area surrounding Tilpa Weir (No. 24) is dominated by river red gum and the lower banks either side of the weir had little or no vegetation at the time of inspection, possibly as a result of prevailing drought conditions (Figures 3 and 4).

There was some minor erosion at this site at the time of inspection as a result of the lack of vegetation cover on the banks. Riparian fencing should be encouraged in this area along with provision of alternative off stream watering points, both of which could be undertaken in conjunction with any fish passage remediation works at this site.

Figure 3. Darling River downstream of Tilpa Weir (No. 24) (02.12.2004, 144.6ML/day).

Figure 4. Darling River upstream of Tilpa Weir (No. 24) (02.12.2004, 144.6ML/day).

Proposed Remediation Actions

Despite the fact that Tilpa Weir (No. 24) may drown out several times during the year, there remain significant periods of time when the passage of all fish will be affected. If these times coincide with the spawning migrations for particular species the weir will continue to have a significant impact on the migratory fish community within the river. It should be remembered that during structure remediation 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 and their fish passage requirements.

Tilpa Weir (No. 24), Louth Weir 21, Weir 20A, and Weir 19A are all significant structures occurring between Wilcannia Weir and Bourke Weir on the Darling River (a total distance of approximately 700km). Although these structures were built for the purposes of stock, domestic, and irrigation supply, the relatively low levels of extraction from the river may make it possible for their current uses could be met by alternative water source technology. Such alternatives would allow for a detailed assessment of the future of the weirs to be undertaken to determine if their potential removal would provide an overall benefit to the health of the Darling River.

Whilst NSW DPI understands that these structures provide a significant social amenity, it is recommended that as a first priority an investigation into the provision of water to surrounding landholders by alternative means be undertaken. An investigation of this sort will allow determination of whether any or all of these structures can be removed without impacting surrounding landholders. If it is found to be technically feasible, detailed consultation with all stakeholders should be commenced to ascertain community attitudes towards such a proposal.

As a second (short term) measure, it is recommended that all structures have a Denil insert installed into the existing (ineffective) fishways. This will ensure that at least some of the larger bodied native fish species are able to negotiate these structures prior to drown out of the structures.

- **Option 1 –** Retrofitting existing fishway with a Denil insert.

The Denil fishway is a channel incorporating U-shaped baffles that reduce velocity and turbulence so that fish can ascend without undue stress. Denil fishways are cheaper than vertical slot fishways because they can be constructed on steeper slopes, meaning less materials are needed for their construction (Baumgartner 2005).

Mallen-Cooper (2000) recommends that Denil inserts should only be considered where the slope is equal to or less than 1:12, as slopes greater than this (less conservative slopes) limit the movement of smaller fish. The slope of the existing fishway is estimated to be in excess of 1:6. Experimental work undertaken in NSW has shown that bony herring could ascend Denil fishways with a slope of 1:12, although their movement was greatly restricted on steeper slopes, with passage of some other fish species being possible up to a slope of 1:4. There is therefore some scope for improvements to the existing fishway by retrofitting it with a Denil insert to allow it to function more effectively.

Unlike the other submerged orifice fishways that exist on the Darling River, the one at Tilpa Weir (No. 24) is in reasonable condition. According to the flow duration curve for the Darling River at this site, the weir potentially drowns out during 52% of flows.

Therefore, although it may not provide fish passage at all flows, the option of Denil inserts should be considered to allow fish passage at this site at a higher percentage of flows.

Mallen-Cooper (2000) recommends that Denil inserts could be considered to improve inefficient fishways where stream flows are greater than 44ML/day; small variation in head and tailwater occurs, and provided suitable trash racks are installed. It is also important that an attraction flow is created at the entrance of the fishway to direct fish movement toward the fishway.

There are limitations with the use of Denil inserts however, with Larinier (1990) identifying Denil fishways as only being effective in passing fish greater than 200mm in length. Mallen-Cooper (2000) further recommended that Denil fishway design should not be used where adult Murray cod are present, as it has not yet been established whether this species will use the Denil design.

This fish passage option should be investigated further for application at Tilpa Weir (No. 24) as a short term solution to fish passage remediation, whilst other options such as removal or a full width rock ramp fishway are investigated further.

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

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

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

Potentially a considerable amount of rock would need to be imported to create a fishway with a slope of 1:20. As Tilpa Weir (No. 24) is 3.5 metres high, a full width rock ramp fishways would extend approximately 70 metres downstream.

Recommendation

It is recommended that alternative water source extraction technology be investigated for Tilpa Weir (No. 24) to determine if its potential removal would provide an overall benefit to the health of the Darling River. If it is found to be technically feasible, detailed consultation with all stakeholders should be commenced to ascertain community attitudes towards such a proposal.

Secondly it is recommended that a Denil insert (Option 1) be installed into the existing ineffective submerged orifice fishway at Tilpa Weir (No. 24), as a short term measure to improve fish passage. Should it be determined that structure removal is not possible, it is recommended that a full width rock ramp fishway (Option 2) be constructed at Tilpa Weir (No. 24), to enable fish passage at a greater range of flows than is currently possible.

If Tilpa Weir (No. 24) was scheduled for a complete rebuild, so that the structure was a more formalised concrete construction, it is recommended that a vertical slot fishway be installed. Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present, where the weir is on the main stem of a river, or a major tributary. With varying head loss the vertical slot fishway would be more effective than other designs in passing a greater range of fish size classes.

Projected Remediation Costs

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

Benefits Associated with Remediation

The Darling River contains important fish habitat that should be protected, with the reinstatement of fish passage along the entire system generating substantial benefits in the ecology of the catchment. By reinstating fish passage at Tilpa Weir (No. 24) unimpeded access for fish and other aquatic organisms would be provided to in excess of 378km of potential habitat either side of this site.

WEIR 19A, DARLING RIVER

Figure 1. Weir 19A, Darling River (01.12.2004, 144.6ML/day).

Figure 2. Defunct fishway, Weir 19A, Darling River (01.12.2004, 144.6ML/day).

Description and Setting

Weir 19A (Figure 1) is located approximately 44km downstream of the township of Bourke on the Darling River in the Upper Darling catchment (Western CMA). The weir is approximately 4.5 metres high and 50 metres across the length of the crest. Weir 19A is a fixed crest structure constructed of sheet metal piling and concrete, and has no gates or culverts associated with it. There is a redundant submerged orifice fishway (Figure 2), which in its current state does not pass fish, and as a consequence, the weir acts as a barrier to fish passage until the structure is drowned out at approximately 8,500ML/day (Cooney 1994). When flows are less than this the weir restricts fish due to excessive head loss, increased turbulence, and increased velocity across the face of the structure.

Weir 19A is ranked as a high remediation priority within the Western CMA region due to the following factors:

- Class 1 fish habitat - major permanently flowing waterway and presence of threatened fish species and populations (this site is within the expected distribution of silver perch (*Bidyanus bidyanus*), olive perchlet (*Ambassis agassizii*), purple spotted gudgeon (*Mogurnda adspersa*) and the endangered river snail (*Notopala sublineata*));
- Distributed within the Aquatic Endangered Ecological Community of the Lowland Catchment of the Darling River;
- Diverse range of native fish (High Conservation Value);
- Instream and riparian habitat condition (presence of instream woody debris);
- Improved stream connectivity: the next upstream barrier to fish passage is Bourke Weir approximately 44km upstream, which is owned and operated by Bourke Shire Council; the next barrier downstream is Weir 20A approximately 105km away, which is owned and operated by State Water; and
- Low frequency of drown out (flow at which fish passage is possible, where head loss and velocity are minimal).

Hydrology

Flows within the Darling River upstream of Menindee are not regulated. Weir 19A is located downstream of the confluence with Warrego, Culgoa, Bokhara, Barwon, and Bogan Rivers. The Barwon-Darling River headwaters originate in southeast Queensland and are fed by the Macintyre, Gwydir, Namoi, Castlereagh and Macquarie Rivers in NSW alone. The Paroo and Warego Rivers are intermittent watercourses that feed a significant volume of water into the system during flood conditions. There are ten other barriers to fish passage that exist upstream of this site in NSW and include (from nearest to farthest) Bourke, Brewarrina (No. 15), Walgett 11A, Woorawadian (No. 10), Calmundi (No. 8), Collarenebri (No. 5), Banarway, Presbury (No. 2), Comilaroy (No. 1), and Mungindi Weirs.

The closest DNR river gauge is located within the Bourke Weir pool on the Darling River (station 425003). Information referred to in this report regarding flows in the Darling River was sourced from the DNR website (URL: http://waterinfo.dlwc.nsw.gov.au), and staff from State Water, DNR and NSW DPI, and describes data acquired between 01.06.1980 – 22.09.2005.

The weir is preventing fish passage during most flow conditions. It has been estimated that the weir in its current structural condition would allow limited fish passage with flows in excess of 8,500ML/day a head loss of approximately 110mm (Cooney, 1994). The time weighted flow duration curve for the Barwon River at station 425003 shows that flows would exceed 8,500ML/day 27% of the time (based on available flow data between 1980 – 2005).

There are currently many licensed water extractors who utilise the water in the upstream weir pool for varying purposes including stock, irrigation, domestic, and town water supply.

Operational Details

Weir 19A was built in 1966 and is owned and operated by State Water. The weir is a static structure, with no moving parts such as release gates requiring maintenance apart from the submerged orifice fishway on the right hand bank. The fishway is constructed of concrete and metal sheet piling and consists of 12 cells with a slope in excess of 1:6. At the time of the inspection the fishway was in a state of disrepair, with no noticeable attraction flow to direct fish to the fishway.

Ecological Considerations

Weir 19A was identified in Cooney (1994) as a priority for improved fish passage within the Barwon-Darling system. Limited fish passage may be possible approximately 27% of the time when the structure is near drown out, however the timing of these flows may not necessarily coincide with spawning migrations of all or any of the resident fish species within the Darling River. If the weir only drowns out for short periods of time, fish may only be able to utilise these fish passage opportunities if they are residing directly downstream of the weir and are waiting to move upstream. This is often not the case however, with some fish only beginning to migrate on cues such as rising water levels. If the structure is 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.

The NSW Fish and Rivers Stress survey (Harris and Gehrke 1997) identified as many as 30 different fish species that were expected to occur within the Darling River Basin, 14 of which were actually caught during the survey in 1996. The following native fish species are expected to occur within the Darling River Basin, and potentially within the river at Weir 19A: Darling River hardyhead, flyspecked hardyhead, western carp gudgeon, spangled perch, Murray cod, golden perch, crimson spotted rainbowfish, bony herring, Hyrtl's tandan, flathead gudgeon, dwarf flathead gudgeon, Australian smelt, freshwater catfish, in addition to the threatened silver perch, olive perchlet, and purple spotted gudgeon. The actual distribution and conservation status of the above threatened species within the Darling River Basin are identified in Morris *et al.* (2001). Alien species including goldfish, common carp, gambusia, and tench are also likely to be present in the system. This species list may vary across the basin, however, and should be viewed as a guide only, for the purpose of this review.

This site has some instream woody debris, which is an important component of fish habitat.

The area surrounding the weir is dominated by river red gum, with the lower banks either side of the weir having limited understorey vegetation, possibly as a result of drought conditions being experienced at the time of inspection (Figures 3 and 4). Despite the lack of understorey vegetation, there is very little erosion at this site due to the presence of stable bedrock, which acts to prevent bed lowering.

Figure 3. Darling River downstream of Weir 19A (01.12.2004, 144.6ML/day).

Figure 4. Darling River upstream of Weir 19A (01.12.2004, 144.6ML/day).

Proposed Remediation Actions

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

Tilpa Weir (No. 24), Louth Weir 21, Weir 20A, and Weir 19A are all significant structures occurring between Wilcannia Weir and Bourke Weir on the Darling River (a total distance of approximately 700km). Although these structures were built for the purposes of stock, domestic, and irrigation supply, the relatively low levels of extraction from the river may make it possible for their current uses could be met by alternative water source technology. Such alternatives would allow for a detailed assessment of the future of the weirs to be undertaken to determine if their potential removal would provide an overall benefit to the health of the Darling River.

Whilst NSW DPI understands that these structures provide a significant social amenity, it is recommended that as a first priority an investigation into the provision of water to surrounding landholders by alternative means be undertaken. An investigation of this sort will allow determination of whether any or all of these structures can be removed without impacting surrounding landholders. If it is found to be technically feasible, detailed consultation with all stakeholders should be commenced to ascertain community attitudes towards such a proposal.

As a second (short term) measure, it is recommended that all structures have a Denil insert installed into the existing (ineffective) fishways. This will ensure that at least some of the larger bodied native fish species are able to negotiate these structures prior to drown out of the structures.

- **Option 1 –** Retrofitting existing fishway with a Denil insert.

The Denil fishway is a channel incorporating U-shaped baffles that reduce velocity and turbulence so that fish can ascend without undue stress. Denil fishways are cheaper than vertical slot fishways because they can be constructed on steeper slopes; meaning less materials are needed for their construction (Baumgartner 2005). At present this structure forms a total barrier to fish passage, and only drowns out approximately 27% of the time alienating fish within the Darling River for the majority of the time. It is possible that by retrofitting the existing fishway with a Denil insert it would achieve an increase in fish passage (although still limiting the passage of smaller fish species).

Mallen-Cooper (2000) recommends that Denil inserts could be considered to improve inefficient fishways where stream flows are greater than 44ML/day; small variation in head and tailwater occurs, and provided suitable trash racks are installed. It is also important that an attraction flow is created at the entrance of the fishway to direct fish movement toward the fishway.

There are limitations with the use of Denil inserts however, with Larinier (1990) identifying Denil fishways as only being effective in passing fish greater than 200mm in length. Mallen-Cooper (2000) recommended Denil fishways be constructed on slope no greater than 1:12, as slopes greater than this (less conservative slopes) limit the movement of smaller fish (the slope of the existing fishway is estimated to be in excess of 1:6). Experimental work undertaken in NSW has shown that bony herring could ascend Denil fishways with a slope of 1:12, however their movement was greatly restricted on steeper slopes. Mallen-Cooper (2000) further recommended that Denil fishway design should not be used where adult Murray cod are present, as it has not yet been established whether this species will use the Denil design.

- **Option 2 –** Vertical slot fishway

Vertical slot fishways are considered one of the most effective fishway designs and is the preferred option where threatened species are present, where the weir is on the main stem of a river, or a major tributary. With varying head loss the vertical slot fishway would be more effective than other designs in passing a greater range of fish size classes.

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 dependent on site location and access, as along with various structural and hydrological constraints.

The vertical slot fishway could be constructed on the right hand bank where the redundant submerged orifice fishway exists. Adequate attraction flow would need to be created by increasing flows through the fishway during low flow periods to enable migrating fish to locate the fishway entrance. Attraction flows could be achieved by lowering (notching) the concrete weir wall at the fishway's upstream exit to create a low flow channel that preferentially directs water through the fishway. This is the preferred option for fish passage remediation at Weir 19A.

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

An alternative to the vertical slot fishway is the construction of a full width rock ramp fishway, which would also provide fish passage for a greater range of fish species and size classes over a greater range of flows than is currently possible.

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

Potentially a considerable amount of rock would need to be imported to create a fishway with a slope of 1:20. As Weir 19A is 4.5 metres high, a full width rock ramp fishways would extend nearly 90 metres downstream.

Recommendation

It is recommended that alternative water source extraction technology be investigated for Weir 19A to determine if its potential removal would provide an overall benefit to the health of the Darling River. If it is found to be technically feasible, detailed consultation with all stakeholders should be commenced to ascertain community attitudes towards such a proposal.

Secondly it is recommended that a Denil insert (Option 1) be installed into the existing ineffective submerged orifice fishway at Weir 19A, as a short term measure to improve fish passage. Should it be determined that structure removal is not possible, it is recommended that a vertical slot fishway (Option 2) be constructed at Weir 19A, to enable fish passage at a greater range of flows than is currently possible.

Projected Remediation Costs

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

Benefits Associated with Remediation

The Darling River contains important fish habitat that should be protected, and the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Weir 19A, unimpeded access to potential habitat in excess of 149km would be provided to fish and other aquatic organisms, both upstream and downstream from this site.

6. REFERENCES

Baumgartner, L.J. (2003). Fish passage through a Deelder lock on the Murrumbidgee River, Australia. NSW Fisheries Final Report. 34pp.

Baumgartner, L.J. (2005). *Effects of Weirs on Fish Movements in the Murray – Darling Basin.* Thesis Submitted for the Degree of Doctor of Philosophy. University of Canberra, Canberra, Australia.

Cooney, T. (1994). North-west weirs and fish passage report. NSW Department of Water Resources, (Technical Services Report No. TS 93.069).

Fairfull, S. and Witheridge, G. (2003). Why do fish need to cross the road? Fish passage requirements for waterway crossings. NSW Fisheries, Cronulla, 16pp.

Gehrke, P.C. and Harris, J.H. (2001). Regional-scale effects of flow regulation on lowland riverine fish communities in New South Wales, Australia. *Regulated Rivers: Resource Management*. 17: 369-391.

Gehrke, P.C., Gilligan, D.M., and Barwick, M. (2001). Fish communities and migration into the Shoalhaven River: before construction of a fishway. NSW Fisheries Final Report Series, no. 26.

Harris, J. (2001). Fish passage in Australia: experience, challenges and projections. ***In:*** Keller, R.J. and Peterken, C. (eds) *Third Australian Technical Workshop on Fishways*. Clayton: Monash University, pp 1-17.

Harris, J., Edwards, E., and Curran, S. (1992). Bourke Weir fish passage study. NSW Fisheries Research Institute unpublished report, Sydney.

Harris, J. and Gehrke, P.C. (1997). *Fish and rivers in stress. The NSW rivers survey.* NSW Fisheries Office of Conservation and the Cooperative Research Centre for Freshwater Ecology. Cronulla.

Larinier (1990). Experience in France: fish pass design criteria and downstream migration problems. ***In:*** '*Proceedings of the International Symposium on Fishways '90 in Gifu.'* (Ed. S. Komura.) pp. 65-74. (Publications Committee of the International Symposium on Fishways '90: Gifu, Japan.)

Mallen-Cooper, M. (1994). Swimming ability of adult golden perch, *Macquaria ambigua* (Percicthyidae), and adult silver perch, *Bidyanus bidyanus* (Teraponidae), in an experimental vertical slot fishway. *Australian Journal of Marine and Freshwater Research.* 45: 191-198.

Mallen-Cooper, M. (2000). *Review of fish passage in NSW*. Fishway Consulting Services, St. Ives Chase.

Marttin and Graaf (2002). The effect of a sluice gate and its mode of operation on mortality of drifting fish larvae in Bangladesh. Management and Ecological Note. ***In:*** *Fisheries Management and Ecology.* 9: 123 – 125.

Morris, S.A., Pollard, D.A., Gehrke, P.C., and Pogonoski, J.J. (2001). *Threatened and potentially threatened freshwater fishes of coastal New South Wales and the Murray Darling Basin.* Report to Fisheries Action Program and World Wide Fund for Nature. NSW Fisheries Final Report Series No. 33. 169 pp.

NSW Fisheries (2002). Initial weir and floodgate review. Report for the State Weir Review Committee. NSW Fisheries, Ballina.

NSW Fisheries (2003). Policy and guidelines for fish friendly waterway crossings. Fishnote Series NSWF1181, NSW Fisheries, Cronulla NSW.

Pethebridge, R., Lugg, A., and Harris, J. (1998). Obstructions to fish passage in New South Wales south coast streams. Final Report Series 4, Cooperative Research Centre for Freshwater Ecology and NSW Fisheries, Cronulla, NSW.

Smith, A.K, and Pollard, D.A. (1998). Policy and guidelines. NSW Fisheries Office of Conservation, Sydney. 76 pp.

Thorncraft G.A. and Harris J.H. (1996). Assessment of rock-ramp fishways. Report for the Environmental Trusts, NSW Environmental Protection Authority, Border Rivers Commission, Department of Land and Water Resources, and Wyong Council. Fisheries Research Institute, Cronulla.

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

Williams, R.J., Watford, F.A. and M.A. Taylor (1996). *A summary of aspects of FRDC project 94/041 "Restoration of estuarine fisheries habitat" relevant to tidal obstructions in New South Wales estuaries.* NSW Fisheries Research Institute, Cronulla, NSW, 109pp.

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