REDUCING THE IMPACT OF WEIRS ON AQUATIC HABITAT

NSW DETAILED WEIR REVIEW

REPORT TO THE NEW SOUTH WALES ENVIRONMENTAL TRUST

LOWER MURRAY DARLING CMA REGION

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Environmental TRUST

Published by NSW Department of Primary Industries.

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This report should be cited as:

NSW Department of Primary Industries (2006). *Reducing the Impact of Weirs on Aquatic Habitat - New South Wales Detailed Weir Review. Lower Murray Darling CMA region.* Report to the New South Wales Environmental Trust. NSW Department of Primary Industries, Flemington, NSW.

ISBN: 0 7347 1753 9 (New South Wales Detailed Weir Review)
ISBN: 978 0 7347 1827 3 (Lower Murray Darling CMA region)

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

EXECUTIVE SUMMARY

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

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

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

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

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

ACKNOWLEDGEMENTS

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

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

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

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1. INTRODUCTION

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

1.1 Project scope and setting

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

1.2 Study aims and objectives

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

The primary objectives of the project were to:

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

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

2. BACKGROUND

2.1 Fish passage in NSW

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

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

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

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

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

2.2 Barriers to fish passage

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

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

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

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

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

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

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

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

2.3 Ecological impacts of weirs

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

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

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

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

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

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

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

2.4 Policies and Legislation

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

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

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

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

3. PROJECT METHODOLOGY

3.1 Initial Weir Review

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

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

3.2 Selection of weirs for detailed review

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

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

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

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

3.3 Desktop assessment and consultation

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

3.4 Field assessment

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

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

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

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

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

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

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

3.5 Prioritisation process

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

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

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

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

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

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

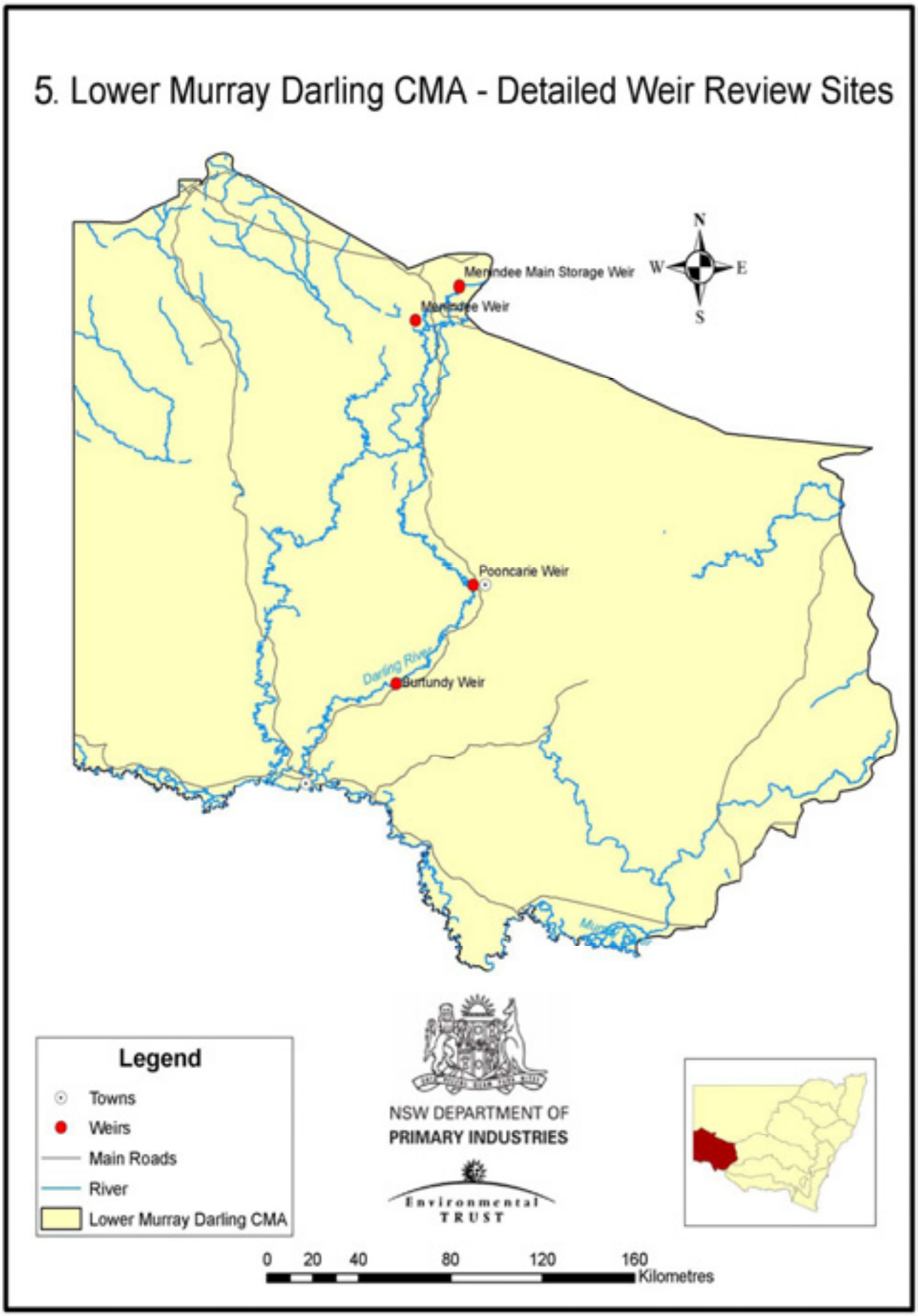
Modification criteria assessed structural use and the ease of remediating the weir. Occasionally structures were recorded during the Detailed Weir Review that were no longer used by the licensee or adjacent property owners. These obsolete weirs received a higher priority score due to the ease (e.g. low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

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

4. INDIVIDUAL DETAILED WEIR REVIEW REPORTS

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

5. Lower Murray Darling CMA - Detailed Weir Review Sites



Great Darling Anabranch

Background and Description

The Darling Anabranch is an ephemeral river that's ancestral channel extends from the Darling River south to Menindee Lakes and then 480km to the Murray River approximately 20km downstream of Wentworth (Figure 1).

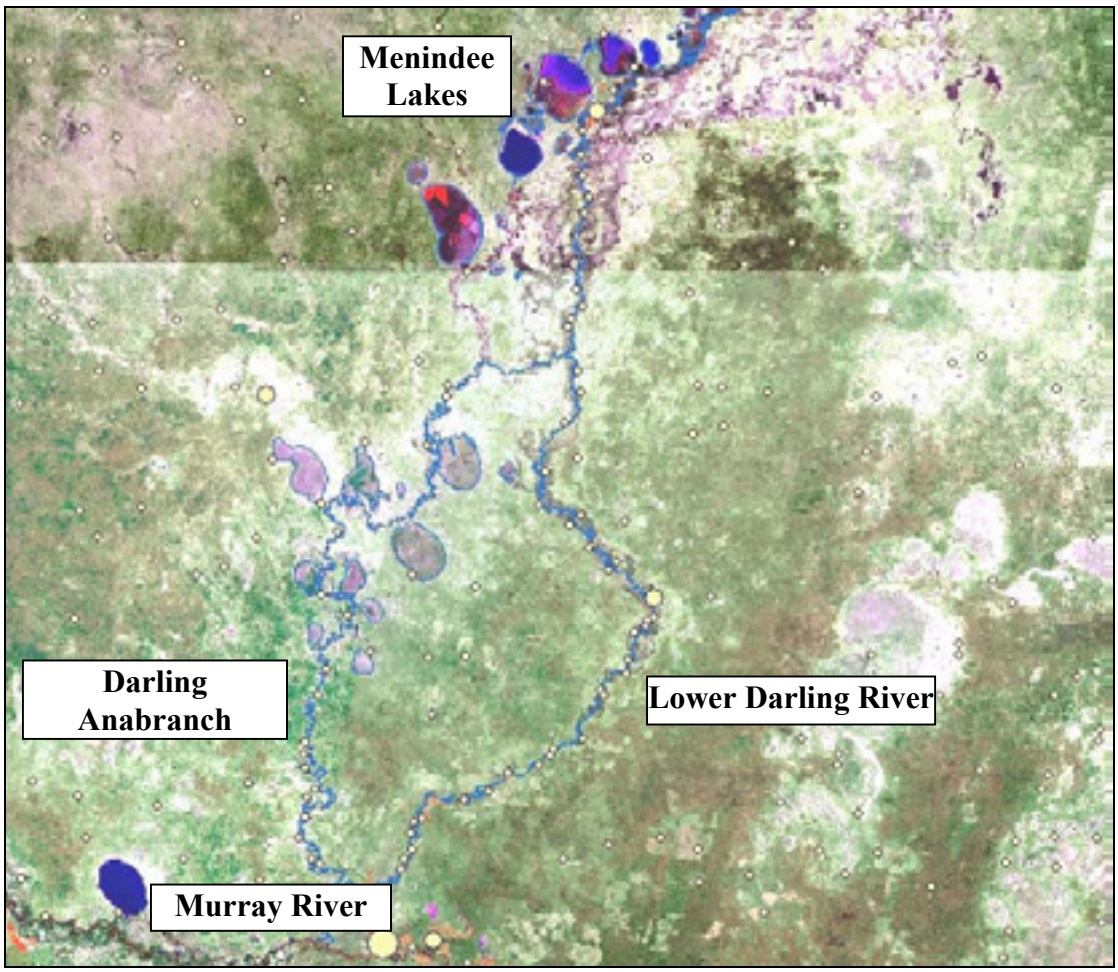


Figure 1. Darling Anabranch from Menindee Lakes in the north to the Murray River junction at Wentworth.

Hydrology and operational arrangements

The Darling Anabranch ("the Anabranch") receives inflows from several sources: replenishment releases from Lake Cawndilla; overland flows from the Darling River when flows exceed 10,000ML/day; backwater from the Murray River; groundwater reservoirs (particularly in the lower reaches); and overland runoff after a rain event. Prior to management of the Anabranch, the upper reaches received inflows from the Darling River on average two out of three years, but only one in eight - ten in the lower reaches. Early post European modifications to the Anabranch included the excavation of a channel from the Darling River to the Anabranch to increase the occurrence of inflow to the Anabranch. The increase in occurrence of flows from the Darling River has in part compensated for a reduction in the occurrence of inflows to the Anabranch associated with the implementation of the Menindee Lakes Scheme and increased regulation of the Lower Darling River (Earthtech 2004).

Under current arrangements 50,000ML is released annually (dependant upon availability) to service stock and domestic entitlements to 40 adjoining properties along the waterway. Of this 50,000ML, it is estimated that less than 3,000ML is consumed annually for stock and domestic purposes (Earthtech 2004).

46 instream structures (block-banks, by-washes, and road crossings) exist along the Anabranch.

Ecological significance

Aquatic vegetation is generally limited in the Darling Anabranch, with very few emergent macrophytes present. Due to the regulated nature of the flow regime, Cumbungi (*Typha domingensis*) has become the dominant species and its success has resulted in a reduction in habitat diversity and silting of drought refuges.

Some remnant aquatic flora include the common rush (*Juncus usitatus*), red myriophyllum (*Myriophyllum verrucosum*), austral mudwort (*Limosella australis*), nardoo (*Marsilea* sp.), and nitella. Filamentous green algae are also common. The spread of cumbungi has caused concerns among the local community, particularly with respect to amenity and water usage issues (Earthtech 2004).

Based on all available records there are potentially 27 species of fish, including five alien species that occur in the Darling Anabranch. The Anabranch is within the distribution range of the Aquatic Ecological Community of the Lowland Catchment of the Darling River. This community is listed as Endangered under the *Fisheries Management Act 1994*.

Current Remedial Actions

In 2004 Earthtech Engineering Pty Ltd completed the environmental impact statement for the *Darling Anabranch Stock and Domestic (non-potable) Pipeline and Reinstatement of Environmental Flows Project*. This project is still current, and will see the construction of a pipeline to deliver the 3,000ML per annum (approx) for stock and domestic purposes to properties along the Anabranch. The project would then see the removal or modification of 46 block-banks, and the delivery of an environmental flow to the Darling Anabranch that would aim to restore and maintain the ecological assets of the system. The removal or modification is aimed at remediating the impact of each site on fish migration and to assist in the delivery of the environmental flows.

As of September 2005, final designs and tendering were complete for the pipeline phase of the project. At the completion of the pipeline construction in December 2006, the Department of Natural Resources (DNR - formerly DIPNR) will progress the block-bank management and environmental flow component of the project.

Remedial Options and Recommendations

The delivery of the block-bank management and environmental flow components of the aforementioned project should be progressed as soon as possible. As the agency responsible for the management and restoration of aquatic habitats in NSW, NSW DPI should be engaged to coordinate and deliver the restoration component of the project when it commences in 2006. The roll-out of an adaptive monitoring framework is recommended to monitor the success of flow regimes and block-bank removals to deliver the ecological objectives of the project.

LOWER DARLING RIVER

Background and Description

The Lower Darling River channel commences downstream on Menindee Main Weir at Menindee and meanders generally southward to its confluence with the Murray River channel at Wentworth NSW. The Darling River flow is regulated into this reach by Menindee Main Weir, which is located approximately 39km upstream of Weir 32 on the Darling River. Menindee Main Weir regulates flow into the Menindee Lakes system and downstream into the Darling River. The Menindee Lake Regulator may also discharge into the Darling River below Menindee Main Weir depending on service and delivery requirements.

There are three weirs (Weir 32, Pooncarie Weir and Burtundy Weir) located on the main channel of the Darling River below Menindee Lakes and upstream of the Darling River confluence with the Murray River. The three structures are the most significant regulating infrastructure on the lower Darling River reach in terms of size and hydraulic impact. There is a low-level weir at “Peaka”, located approximately 20km south of the township of Pooncarie. The Darling River is also likely to have a number of unlicensed structures within the geographical area covered by this study, however they would be insignificant in size compared to the three subject weirs.

Ecological significance

There are potentially 22 native fish species that may occur within the Lower-Darling channel however only 12 of these are known to occur in the system. The Lower Darling River channel maintains a relatively high abundance of golden perch (*Macquaria ambigua*) and bony herring (*Nematolosa erebi*) compared to the Murray River channel of the Lower Darling Catchment.

The Lower Darling River channel is within the distribution range of the Aquatic Ecological Community of the Lowland Catchment of the Darling River. This community is listed as Endangered under the *Fisheries Management Act 1994*.

WEIR 32

Figure 1. Weir 32 looking upstream, Darling River.

Hydrology and operational arrangements

Weir 32 is on the mainstem Darling River was constructed in 1958, is owned and managed by State Water, and is included in the portfolio of structures associated within the Menindee Lakes Storages. The weir is located approximately 39km downstream of Menindee Main Weir on the Darling River and consists of extensive sheet piling and rock fill with a drop-board system that has failed and is now filled with rock. Weir 32 provides a pumping pool for Australian Inland (providers of Broken Hill and Menindee town water supplies) and other permanent planting crops in the Menindee area. The capacity of the weir pool is approximately 3,700ML. Weir 32

Due to the nature of Weir 32 and the information available, it can be determined that passage for a range of species and size classes of fish would be feasible at discharges above 4,000ML/day. At 4,000ML/day the weir has not reached drown-out point (occurring at 7,000ML/day), however flow condition at these volumes is predicted to result in velocity and depth conditions that would permit the passage of a wide range of fish species and size classes.

From 1973 to 2002 (360 months), the mean daily discharge at Weir 32 exceeded 4,000ML/day 30% of the period time (109 times). Drown-out events (in excess of 7,000ML/day) occurred in 21% of the period time (74 months).

During the key months for fish passage (including September to November), the mean daily discharge per month exceeded 4,000ML/day for 32% of the period time (29 out of 90 months).

In 17 out of the 30 years (57% of the period time) mean daily discharges on a monthly basis in excess of 4,000ML/day were not recorded during the period of September to November from 1973 to 2002. Fish passage is therefore not feasible

during any of the key months for at least every one in two years at Weir 32, and passage at the structure during each of the key months was feasible only one in three years.

From 1992 to 1996 there was a period of 53 consecutive months when the mean daily discharge for the month did not exceed 2,900ML/day, well below the determined fish passage feasibility threshold of 4,000ML/day. From 1991 to 1996 there were six consecutive years when the mean daily discharge for each of the months September, October and November did not exceed 4,000ML/day, and fish passage was not possible.

It can be determined that Weir 32 has a significant impact on fish passage in the Darling River. The upstream habitat availability for migrating species is limited to the riverine habitat below Menindee Main Weir (39km) and potentially Menindee Lake. However, the cumulative impacts of the two structures are not relevant to quantification of Weir 32's impacts. The weir prevents the upstream migration of fish for a significant period of time and therefore could prevent the successful completion of life cycle processes for several species.

Remedial Options

- **Option 1 –** Removal of weir

The removal of Weir 32 is likely to impact upon the security of the water extraction that occurs in the weir pool. The weir pool is relatively short in length, and the proposal would require the relocation of off-take and irrigation infrastructure to the weir pool of Menindee Main Weir (Lake Wetherill). The Broken Hill water supply can alternatively be taken from Copi Hollow (Menindee Lakes system), however this is currently installed as an auxiliary alternative during drought conditions. The security of water in Copi Hollow may be higher than that of the Weir 32 pool, although water quality issues have been encountered during drought conditions and low/empty storage status of Menindee Lakes. The removal of Weir 32 would also cause unmeasured impacts on the indigenous community that currently utilise the facility.

- **Option 2 –** Installation of a fishway

The installation of a fishway would permit fish passage at discharges below 4,000ML/day. The current state of the structure does limit design options. Taking into account the current unmodified structure, a fishway could be designed to manage low flow at required velocities (less than 1.6m/sec). A partial-width rock-ramp fishway is the most viable option. Such a concept could be engineered conciliatory to the weir faces current gradient (slope). The fishway could be designed so that it drowns-out and becomes inoperable when discharge flows reach 4,000ML/day. This option should be employed if the review to be conducted by State Water concludes the weir is to be retained and subject to refurbishment.

- **Option 3 –** Modification of weir and installation of a fishway

The modification of the weir and installation of a fishway would incorporate a lowering of the crest height of the weir in addition to Option 2.
This would decrease the required discharge levels for fish passage and coincide with necessary repairs and refurbishment work at the site. A reduction in the capital costs and engineering levels for a proposed fishway could also occur if the weir was modified to achieve a lower crest height.

- **Option 4 –** Management of regulated flows

The management of regulated flows from Menindee Main Weir to target the fish passage threshold during the months of September to November relies upon water availability. This is not a long-term solution to fully mitigate the impacts of Weir 32 on fish passage, but would benefit other remediation options.

Recommendations

If Weir 32 is to be subject to refurbishment and remain in service, the provision of a fishway will be considered a priority (Option 2 or 3). Any work to sustain the serviceability of the weir will be subject to the provisions of Section 218 of the *Fisheries Management Act 1994*. The Minister for Fisheries may order the provision of fish passage at structures that are subject to modification.

If the weir is retained (refurbished) or modified at its current site, a rock ramp fishway concept could be adopted. This concept would compliment the current weir design. Rock ramp fishways can be designed to cater for a range of size classes and species and could operate across the range of regulated flows experienced at this structure. If a gated structure is incorporated or significant upgrade of the crest occurs, a vertical slot fishway may be applicable.

In the short term, Option 4 should be adopted so that environmental flows target a discharge of at least 4,000ML/day at Weir 32 to achieve some degree of fish passage prior to Options 2 or 3 being implemented.

Current Remedial Actions

Nil

POONCARIE WEIR

Figure 2. Pooncarie Weir looking upstream, Darling River.

Hydrology and operational arrangements

Pooncarie Weir is located on the Darling River adjacent to the township of Pooncarie (population 84) within the Wentworth Shire Council (hereafter WSC) local government area. The structure is licensed to WSC and was constructed in 1969 in order to secure a water supply for the township of Pooncarie. WSC has an annual water entitlement of 160ML to supply the township requirements.

The original construction of Pooncarie Weir in 1969 involved a central concrete wall, iron and limestone placed between rows of reinforced fabric on the downstream face and a grouted rock apron over downstream rock protection. A 300mm diameter pipe through the embankment is no longer evident despite the pipe being included as a condition on the weir license to ensure water passes the structure during low flows. WSC has conducted regular works at the weir, some as recently as January and December 2003. This work involved placement of large quantities of rock material onto the structure.

In 1999 WSC commissioned SMEC Pty Ltd to report on the condition of the weir structure for consideration in future management options. According to the report, the original design of the structure has the following problems:

- Depth of cut-off wall inadequate;
- Location of weir is hydraulically unsound (immediately downstream of a river-bend);
- Re-enforcement fabric is susceptible to rusting;
- The clay fill on the upstream side of the weir requires protection by way of rock pitching placed on a geotextile membrane;

- The grout rock apron only has a short life span in a flood situation; and
- The downstream rock protection is unstable (SMEC 1999).

The report determined that the weir has significant structural problems and is beyond repair (SMEC 1999). A short-term solution was recommended that involved the use of rock material.

Due to the nature of Pooncarie Weir and the information available, it can be determined that passage for a range of species and size classes of fish would be feasible at discharges above 3,000ML/day. At 3,000ML/day, the weir has not reached drown-out point, however flow condition at these volumes is predicted to result in velocity and depth conditions that could permit the passage of a wide range of fish species and size classes.

From 1973 to 2002 (360 months), the mean daily discharge per month at Pooncarie Weir exceeded 3,000ML/day 35% of the period time (128 times). Drown-out events (in excess of 5,000ML/day) occurred in 27% of the period time (97 months).

During the key months for fish passage (including September to November), the mean daily discharge per month exceeded 3,000ML/day 36% of the period time (32 out of 90 months).

In 14 out of the 30 years (47% of the period time), mean daily discharges (on a monthly basis) in excess of 3,000ML/day were not recorded during the period of September to November from 1973 to 2002. Fish passage is therefore not feasible during any of the key months for nearly every one in two years at Pooncarie, and passage at the structure during each of the key months was feasible only one in every three years.

From 1992 to 1996 there was a period of 53 consecutive months when the mean daily discharge for the month did not exceed the determined fish passage feasibility threshold of 3,000ML/day. From 1991 to 1996 there were six consecutive years when the mean daily discharge for each of the months September, October and November did not exceed 3,000ML/day.

It can be determined that Pooncarie Weir has a significant impact on fish passage in the Darling River. The upstream habitat availability for migrating species is extensive (approximately 250 km), however the weir prevents the upstream migration of fish for a significant period of time and therefore could prevent the successful completion of life cycle processes for several species.

Remedial Options

Wentworth Shire Council (licence holder of the weir) represent the stakeholders directly affected by any modification or removal options for Pooncarie Weir. Council has lobbied government departments to fund major repairs or replacement of the weir with no success. The alternative has been to carry out repairs that attempt to prolong the serviceability of the weir and protect the townships water supply. Council proposes to carry out works on an ”as needs” basis. Taking into account recent maintenance activities, this could result in the placement of rock material in instream habitats annually. This situation is not suitable from a cost benefit or ecological point of view.

- **Option 1 –** Construction of new low level weir and off river storage

Council would support the option of constructing a new weir structure, but does not support the option of an off river storage for providing permanent town water supply. However, taking Council's views into consideration, the option of a new low-level weir with a reduced capacity and an auxiliary off river storage may be supported. By reducing the height of the weir, suitable fish passage alternatives (fishways) become more economically feasible. The off river storage would enable the provision of the town water supply, whilst minimising the height and capacity of the new weir structure.

- **Option 2 –** Construction of a fishway on existing structure

The construction of a fishway on the existing structure would not be feasible without significant structural repairs being conducted. The regular maintenance required on the weir is testimony to the expiration of the structure. In addition, significant capital investment to provide a fishway would not be economically feasible. Other options that address the issue strategically and consider the imminent issue of the suitability of the structure are deemed more appropriate.

- **Option 3 –** Alternative water storage and removal of weir structure

The construction of an alternative storage, and removal of the existing weir structure would alleviate fish passage issues at this site. The weir pool created by Pooncarie Weir services WSC water entitlement for the township of Pooncarie as well as stock and domestic water supplies. The water security that the weir is entitled to provide is 160ML/year. Pending water licence and access arrangements, water could be sourced during off-allocation flows to fill an off-river storage.

Taking into account evaporative losses, the off-river storage would provide higher security water for Pooncarie without the inefficient annual instream works program that is currently occurring. Water quality issues that are already encountered with the instream storage may be managed more effectively with a dual supply system. Removal of the existing structure would occur as a component of Option 3.

- **Option 4 –** Management of regulated flows

The management of regulated flows from Menindee Main Weir to target the fish passage threshold during the months of September to November relies upon water availability. This is not a long-term solution to fully mitigate the impacts of Pooncarie Weir on fish passage, but could be implemented as a short term option until other options are more fully investigated.

Recommendations

The NSW Weirs Policy (August 1997) encourages all agencies and individuals that own, manage or derive benefits from weirs to address the environmental impact of weir. The principle of the policy clearly discourages the construction of new weirs. This policy, in conjunction with the significant capital cost, does not make Option 1 desirable.

The construction of an alternative storage and removal of the weir structure (Option 3) is considered the most appropriate option for alleviating the impacts of Pooncarie Weir on fish passage.

This is a significant project that would involve detailed environmental assessment and capital works. Such review is beyond the scope of this report.

It is acknowledged, however, that Option 3 will cause significant concern to stakeholder groups who historically perceive Pooncarie Weir as essential for maintaining water supply. As previously outlined the security and serviceability of the weir is not sound and a sustainable alternative that meets the ecological, social and economic requirements of stakeholders needs to be employed.

In the short term, Option 4 should be adopted so that environmental flows target a discharge of at least 3,000ML/day at Pooncarie Weir to achieve some degree of fish passage.

Current Remedial Actions

In 2004 the Lower Murray Darling CMA (LMDCMA) formed the Pooncarie Weir Working Group with a view to progress the findings of the LMDCMA Fish Passage Feasibility Study and Recommendation Report. There is some funding available to progress the construction of a fishway at Pooncarie weir, however the structure requires replacement prior to fishway investment. It is recommended that further investigation be undertaken into the feasibility of Option 3 above.

BURTUNDY WEIR

Figure 3. Burtundy Weir looking upstream, Darling River.

Hydrology and operational arrangements

Burtundy Weir is located on the Darling River approximately 500 metres downstream from Tulney Point homestead, approximately 50km north of Wentworth. Burtundy Weir was built in 1958, and is a privately owned and licensed structure (the licence is in the name of Mr Laurie Strachan, "Tulney Point Station", Wentworth, NSW).

The structure consists of a concrete wall with some rock fill on the downstream side. The concrete wall extends into the adjacent banks and has been subject to repair work in 2002. Leaks exist in the side aprons of the weir indicating some degree of structural failure.

Approximately seven properties rely on the 15km long weir pool created by Burtundy Weir for stock and domestic water supply. There are also a number of water licences servicing approximately 790 acres of permanent planting enterprises both upstream and downstream of the weir. These licences rely on the structure for security of the weir pool.

Burtundy river gauge is located approximately 400 metres upstream of the weir.

Due to the nature of Burtundy Weir, and the information available, it can be determined that passage for a range of species and size classes of fish would be feasible at discharges above 2,400ML/day. Below this discharge, depth and velocity would impede the passage of fish. At 2,400ML/day the weir has reached drown-out point. From 1973 to 2002 (360 months), the mean daily discharge per month at Burtundy Weir exceeded 2,400 ML/day 38% of the period time (136 times).

During the key months for fish passage (including September to November), mean daily discharge per month exceeded 2,400ML/day 40% of the period time (36 out of 90 months). In 14 out of the 30 years (47%), mean discharges on a monthly basis in excess of 2,400ML/day were not recorded during the period of September to November from 1973 to 2002. Fish passage is therefore not feasible at Burtundy Weir during any of the key months for nearly one in every two years.

From 1992 to 1996 there was a period of 50 consecutive months when the mean daily discharge for the month did not exceed 2,400 ML/day. From 1991 to 1996 there were six consecutive years when the mean daily discharge for each of the months September, October and November did not exceed 2,400ML/day and fish passage was not possible.

It can be determined that Burtundy Weir has a significant impact on fish passage in the Darling River. The upstream habitat availability to migrating species is extensive but limited to the riverine habitat below Pooncarie Weir. The weir prevents the upstream migration of fish for a significant period of time and therefore could prevent the successful completion of life cycle processes for several species.

Remedial Options

- **Option 1 –** Removal or modification of the weir

The removal of Burtundy Weir would compromise the storage capacity and water supply for exiting users. This would not be seen as a suitable option as it would result in significant economic and social impacts. Modification of the weir to lower its vertical height (and therefore reduce the flow volume required to achieve fish passage) would also cause similar impacts. The vertical height and storage capacity of the weir is relatively low.

- **Option 2 –** Construction of a fishway on existing structure

The installation of a fishway is feasible at Burtundy Weir. The structure is located on a rock bar, and the relatively low vertical height lends itself to the application of a rock ramp fishway. The surveyed height of crest to downstream bed level is approximately 1400mm. As an indicative guide, a rock ramp concept constructed on a grade of 1:20 would result in a structure less than 30 metres in length. Such a structure could require approximately 200 cubic metres of material.

The incorporation of a full-width rock-ramp as and alternative to a partial-width ramp style fishway may reduce engineering and construction costs, however an exponentially large amount of material would be required. This concept would involve managing the discharge from the width of the weir crest across a grade of material at an appropriate slope rating (1:20). This work could also be adopted as a refurbishment technique that would stabilise the structure and resolve current structural issues. The limitation of this concept is that fish passage would still require discharge volumes high enough to ensure adequate depth across the crest. The channelling of flow into a ramp type structure allows adequate depths to be maintained at low flows.

- **Option 3 –** Management of regulated flows

The management of regulated flows from Menindee Main Weir to target the fish passage threshold during the key months of September to November relies upon

water availability. This is not a long-term solution to fully mitigate the impacts of Burtundy Weir on fish passage but could be implemented as a short term option until other options are fully investigated.

Recommendations

The installation of a fishway (Option 2) is feasible at Burtundy Weir and would avoid the outlined economic and social issues associated with removal of the structure. Unlike Pooncarie Weir, Burtundy Weir is structurally reasonably sound, and execution of capital works would be sustainable and cost effective.

The options of a partial width rock ramp fishway or stream wide grading structure (full width rock ramp fishway) would need to be detailed by commissioning the design of the structure. Any further works to the weir will be subject to the provisions of Section 218 of the *Fisheries Management Act 1994*, which allows the Minister for Fisheries to require a fishway to be constructed in the course of altering or modifying a weir.

In the short term, Option 3 should be adopted so that environmental flows target a discharge of at least 2,400ML/day at Burtundy Weir to achieve some degree of fish passage.

Current Remedial Actions

A partial width rock ramp fishway will be designed and constructed at Burtundy Weir in 2006 by the LMDCMA.

Lower River Murray (Lower Murray-Darling Catchment)

Background and Description

The Lower River Murray channel within the Lower Murray-Darling catchment commences at the confluence of the Murrumbidgee River in the east and flows west to the South Australian border, west of Lake Victoria. Within this regulated river channel, there are six major weirs (Weirs 7-11 and Weir 15) that regulate flow and maintain a differential head that blocks the passage of migratory fish species. As of November 2005, five out of these six weirs will have operational fishways that will permit the passage of a range of fish species across a wide range of flows.

There are also two regulators on Frenchman Creek and Rufus River that regulate flow into Lake Victoria. These are also significant barriers to the migrations of native fish.

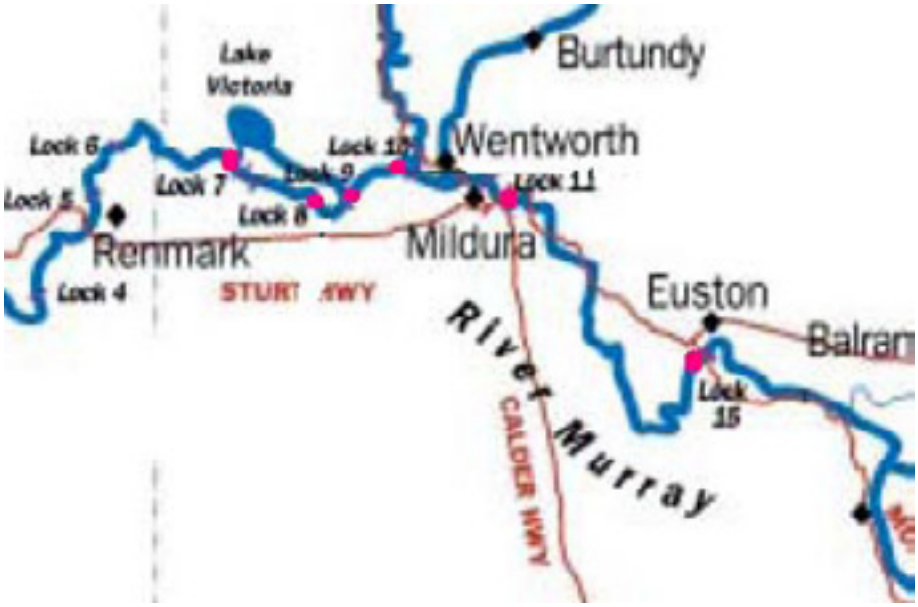


Figure 1. The Lower River Murray extending from the confluence of the Murrumbidgee River in the east to the South Australian border in the west.

Ecological significance

The Aquatic Ecological Community in the natural drainage system of the Lower Murray River catchment is listed as threatened under the *Fisheries Management Act 1994*. The community includes all native aquatic species of finfish, crustaceans, molluscs, worms, and insects endemic to the rivers, creeks, streams, lagoons, anabranches, billabongs, lakes and floodplains of each drainage system.

Current Remedial Actions

In response to the decline in the health of the River Murray system, the Murray-Darling Basin Ministerial Council (MDBC) in April 2002 agreed to a $150 million, eight-year program of structural and operational measures to improve the environmental health of the River Murray system. This program is known as the Environmental Works and Measures Program and is presented under the auspice of "The Living Murray" Initiative.

The Environmental Works and Implementation Program funds the “sea to Hume Dam” Fish Passage Program. This program addresses the objectives of the MDBC’s Native Fish Strategy (2003) by providing migratory fish passage at all locks and weirs between the sea and Hume Dam to support the recovery of native fish populations.

Specific environmental outcomes to be achieved through the “sea to Hume Dam” fish passage program include:

- overcome barriers to fish migration to increase the number and diversity of native fish moving along the river channel;
- provision of improved opportunities for breeding and recruitment to sustain existing native fish populations; and
- provision of carp management measures to reduce the impacts of this introduced pest upon aquatic habitats and native fish populations.

As at November 2005, fishways have been constructed at Weirs 7 and 8 near the South Australian border. Vertical slot fishways have recently been completed at Weir 9 near Lake Victoria and Weir 10 at Wentworth. The existing denil fishway at Weir 15 (Euston) has been refurbished and upgraded for improved fish passage.

Outside of NSW, at the barrages located between Lake Alexandrina and the Southern Ocean in South Australia, two prototype fishways have been installed in the Tauwitcherie Barrage structure, a third is nearing completion at Goolwa Barrage, and the design of a fourth will shortly be completed.

For the remaining fishways at Weirs 1 to 6 (in South Australia) and Weir 11 (at Mildura) completion is scheduled by 2013. With the exception of Mildura Weir, the construction of each fishway is accompanied by the upgrading of the ‘navigable pass’ at each site. It is anticipated that the fishway program will be extended to include modification or removal of other major obstructions to fish movement throughout the River Murray system including structures on auxiliary river channels such as on Mullaroo Creek (Victoria), within the Chowilla Floodplain (South Australia), on the regulators at Lake Victoria and Menindee Lakes, as well as works for Stevens Weir on the Edward River (New South Wales).

A “four-State” team in conjunction with the Fish Passage Reference Group is combining their expertise and resources to undertake a monitoring program associated with the “sea to Hume Dam” fish passage program. The four-State cooperative effort involves:

- New South Wales Department of Primary Industries (NSW DPI);
- Victorian Department of Sustainability and Environment (DSE);
- Queensland Department of Primary Industry (Q DPI); and
- South Australian Research and Development Institute (SARDI).

The monitoring program has been designed to determine benefits to fish migration and changes in the abundance and diversity of native fish populations along the river channel. The program will also serve to determine the effectiveness of the newly constructed fishways, and to inform the design and implementation of new fishway designs elsewhere in the Murray-Darling Basin.

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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