REDUCING THE IMPACT OF WEIRS ON AQUATIC HABITAT

NSW DETAILED WEIR REVIEW

REPORT TO THE NEW SOUTH WALES ENVIRONMENTAL TRUST

HAWKESBURY-NEPEAN 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*.

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.

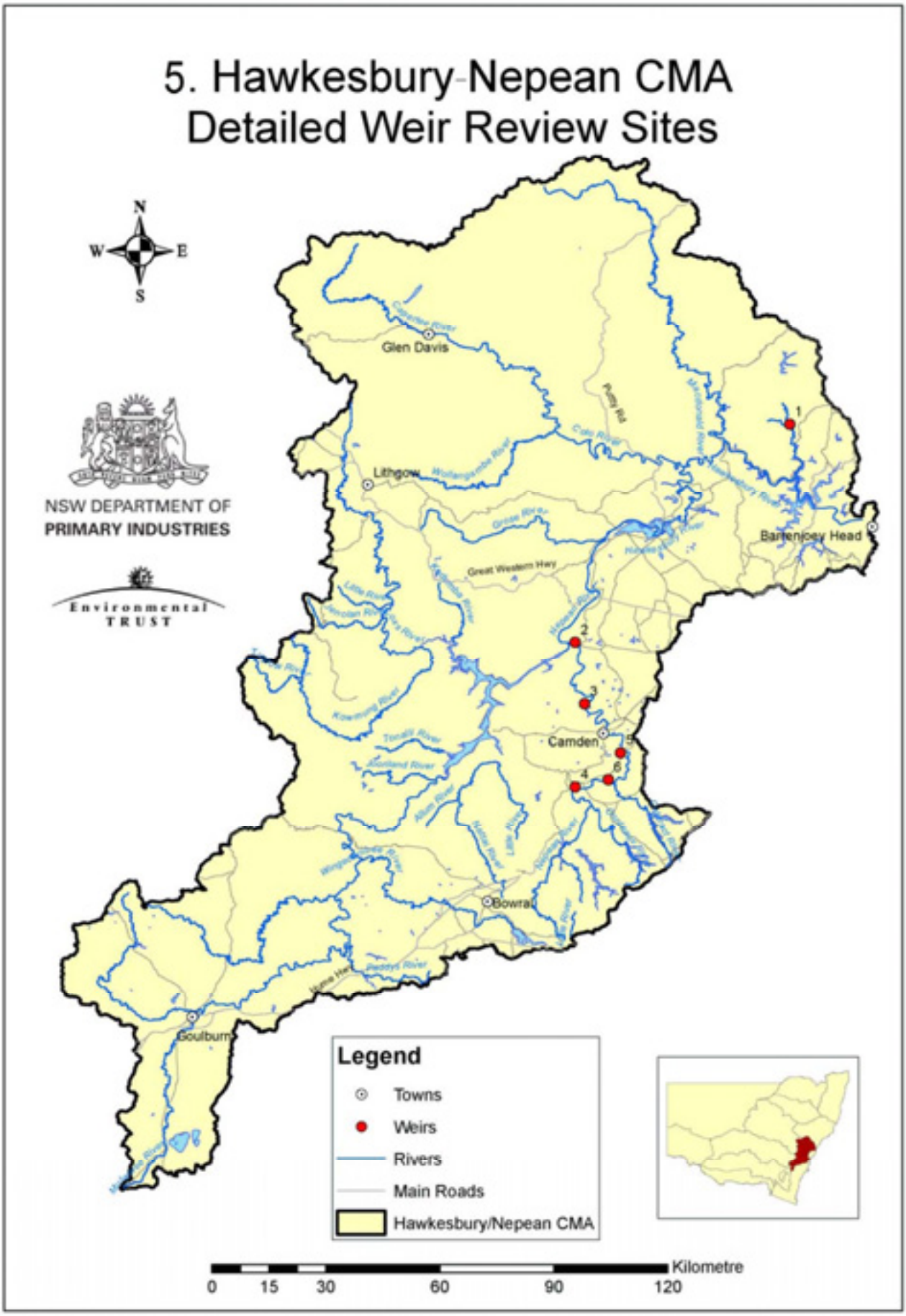
Following the initial prioritisation, a secondary prioritisation incorporating environmental and structural modification criteria was conducted to further delineate rankings. Environmental criteria incorporated aquatic and riparian habitat condition (i.e. good / fair / poor), sedimentation in the weir 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. Hawkesbury-Nepean CMA
Detailed Weir Review Sites
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NSW DEPARTMENT OF
PRIMARY INDUSTRIES
Environmental
TRUST
Glen Davis
Lithgow
Great Western Hwy
Barrenjoey Head
Camden
Bowral
Goulburn
1
2
3
4
5
6
Legend
Towns
Weirs
Rivers
Main Roads
Hawkesbury/Nepean CMA
Kilometre
0
15
30
60
90
120

Hawkesbury - Nepean 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	Lower Mangrove Creek Weir	-33.337000	151.137350	Fixed crest (concrete and steel)	Mangrove Creek	Gosford Council	No	Lower weir wall and install Fishway	50 - 150K	150 - 250K	30
2	Wallacia Weir	-33.856850	150.628060	Fixed crest (concrete)	Nepean River	Sydney Catchment Authority	No (ineffective fish ladder present)	Denil Insert Fishway	<50K	50 - 150K	135
3	Brownlow Hill Weir	-34.004810	150.650290	Fixed crest (concrete)	Nepean River	Sydney Catchment Authority	No (ineffective fish ladder present)	Partial Width Rock Ramp Fishway	50 - 150K	50 - 150K	100
4	Maldon Weir near Picton	-34.202200	150.628050	Fixed crest (concrete)	Nepean River	Private	No	Lower weir wall and install Fishway	150 - 250K	50 - 150K	50
5	Menangle Weir	-34.121000	150.735850	Fixed crest (sandstone bricks and concrete)	Nepean River	Sydney Catchment Authority	No	Partial Width Rock Ramp Fishway	50 - 150K	<50K	50
6	Douglas Park Causeway	-34.184980	150.706980	Fixed crest (concrete)	Nepean River	Wollondilly Council	No	Remove and replace with Bridge	150 - 250K	150 - 250K	36

LOWER MANGROVE WEIR, MANGROVE CREEK

Figure 1. Lower Mangrove Weir, Mangrove Creek (4/7/05, 1.41ML/day).

Description and Setting

Lower Mangrove Weir is owned by Wyong Council and is located near the township of Lower Mangrove on Mangrove Creek. Mangrove Creek is a tributary of the Hawkesbury River, the confluence of which is approximately 5km downstream. The structure is a concrete and steel fixed crest weir approximately 2.5 metres high and 30 metres across. During most flow conditions the structure restricts fish passage due to excessive headloss.

The Lower Mangrove Weir is ranked as high remediation priority within the Hawkesbury Nepean River CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- Forms the tidal barrier between Mangrove Creek and the Hawkesbury River;
- The site is located in the lower end of the catchment and the upstream residual catchment area is roughly 140km^2;
- Diverse range of native fish;
- Healthy instream and riparian habitat condition; and
- Approximately 30km of habitat available upstream prior to the next barrier to fish passage.

Hydrology

Both rainfall levels and releases from Mangrove Creek Dam dictate flows in Mangrove Creek. Mangrove Creek hydrological information was determined from the gauging station located at this site (212229). Information was sourced from the Sydney Catchment Authority using data acquired between 24/5/1990 and 29/7/2005. For the majority of time (45% - 99%) there is no flow at this site.

Daily flows that equal or exceed 12ML/day occur less than 20% of the time. Flows of 33ML/day or more occur less than 10% of the time. Overall, moderate sized flow events over 100 ML/day or more occur less than 4% of the time. Highest flows occur in late autumn and winter, while the lowest flows are experienced in summer.

A drown out value for this structure has been difficult to predict given the isolated nature of the site and the controlled release of water from Mangrove Creek Dam.

Operational Details

Lower Mangrove Weir was constructed in 1977 to provide a water supply for the Gosford/Wyong area. Currently three licensed water extractor draw from the weir pool, with up to 79ML per annum being licensed for removal. The water is primarily used for irrigation and town water.

Mangrove Dam, located approximately 30km upstream has a storage capacity of roughly 195,000ML. Water for use in Gosford and Wyong townships is released from Mangrove Dam into Mangrove Creek (Lower Mangrove weir pool) and pumped approximately 10km to the Somersby Transfer System at a maximum rate of 25,376ML/month.

Ecological Considerations

Remediation of this site would allow fish passage to occur from estuarine habitats below the weir into the freshwater reaches of Mangrove Creek (upstream of the structure).

A number of native fish species require access to marine and freshwater habitats in order to complete certain stages of their life cycles. For example Australian bass migrate downstream for spawning purposes in winter and early spring, with juveniles and adults moving into freshwater environments upstream in late spring and summer. A lack of drown out flows during these times can seriously affect the ability of the species to spawn and recruit.

Native freshwater fish species that undergo significant migrations and are known to occur in Mangrove Creek include: Australian bass, long finned eel, short finned eel, Australian smelt, and striped gudgeon. Introduced species including common carp, goldfish, and eastern gambusia have also been found in this river (Creese and Hartley 2004). Although not captured during NSW DPI surveys, it is assumed that the distribution of Australian grayling, freshwater herring, and common jollytail would also be influenced by this structure.

Mangrove Creek contains important fish habitat components including estuarine habitat, large deep pools, large woody debris and cobble beds. At the time of inspection the site had well vegetated banks with erosion at fixed points upstream of the structure due to various users groups. Aquatic vegetation consisted primarily of spike rush.
Upstream riparian vegetation is dominated by banksias, eucalypts, *Ficus* spp., and casuarinas. Mangroves dominate the riparian and instream habitat downstream.

Figure 2. Mangrove Creek downstream of Lower Mangrove Weir (4/7/05, 1.41ML/day).

Figure 3. Mangrove Creek downstream of Lower Mangrove Weir showing rock and gravel barrier formed as a result of scouring following water releases (4/7/05, 1.41ML/day).

Figure 4. Mangrove Creek upstream of Lower Mangrove Weir (4/7/05, 1.41ML/day).

Proposed Remediation Actions

- **Option 1 –** Fishway

Given the location of the structure in the catchment (forming a tidal barrier in Mangrove Creek), all fishway designs are required to be designed with a slope of 1:30 to allow for the swimming ability of juvenile fish. As the structure is approximately 2.5 metres high, this means that the total length of a fishway would be approximately 70 metres. A small section of the weir crest would need to be removed to create an upstream exit and attraction flow for the fishway. Alternatively, cheater boards could be attached to the weir crest to direct flows if the alteration of the structure is not possible.

The most viable fishway option for this site would be a vertical slot design. This design could use the existing structure as a stable base, and could be dog-legged to limit the area impacted by construction on the downstream side of the structure. A disadvantage with a vertical slot fishway is that this design requires a greater volume of water to pass through the structure in order for it to work effectively.

An alternate design is a partial width rock ramp fishway, which could also be constructed on the right hand bank, and could utilise the natural gradient for part of its length. As with the vertical slot fishway, the structure would also require dog-legging to bring the downstream entrance of the fishway adjacent the weir wall to take advantage of attraction flows.

In addition, a bypass channel may also be a viable option (a bypass channel is similar to a partial width rock ramp fishway, but it is built into the bank adjacent to a structure)

- **Option 2 –** Removal/lowering of the weir wall

The complete removal of this structure would provide the greatest benefit to the health of Mangrove Creek and provide improvements in the availability of aquatic and riparian habitat. As the structure was built exclusively for Wyong Council and the instream flow and water level is dictated by upper Mangrove Creek Dam, it may be feasible to lower the weir wall to a height where water supply needs are maintained and the cost of installing a fishway is more viable. Lowering of the weir wall could be undertaken in combination with or preceding the construction of a fishway. Further discussions with Wyong Council may reveal this to be the most cost effective means of providing fish passage and maintaining the needs of the current owners.

Projected Remediation Costs

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

Recommendation

Lowering of the weir wall and construction of a rock ramp fishway is the preferred remediation action for this site. It also necessary to remove the gravel and rock barrier located approximately 20 metres downstream from the weir wall (Figure 3).

Benefits Associated with Remediation

NSW DPI staff are in agreement that the Mangrove Creek system is important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would bring about substantial benefits to the ecology of the catchment. By reinstating fish passage at the Lower Mangrove Weir, in excess of 30km of habitat would again become accessible to fish and other aquatic organisms.

WALLACIA WEIR, NEPEAN RIVER, WALLACIA

Figure 1. Wallacia Weir, Nepean River (31/3/05, 44.55ML/day).

Description and Setting

Wallacia weir is owned by Sydney Catchment Authority and is located on the Nepean River near the township of Wallacia. Wallacia Weir is a concrete arch gravity weir approximately 5 metres high and 48 metres across, currently listed on the State Heritage Inventory. A fish "step ladder" is installed on the downstream side but is ineffective at passing fish. During most flow conditions the weir restricts fish passage due to excessive head loss (1650mm).

Wallacia Weir is ranked as a high remediation priority within the Hawkesbury Nepean CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- The site is located in the middle of the catchment on the mainstem of the Nepean River with an upstream catchment area in excess of 500km²;
- Diverse range of native fish;
- Healthy instream and riparian habitat condition; and
- Only one other man made barrier is present downstream (Penrith Weir), and it has an effective fishway installed.

Hydrology

Hydrological data at Wallacia Weir were determined from the gauging station associated with the structure (212202).

Information was sourced from the Sydney Catchment Authority office in Penrith using data acquired between 1/1/1976 and 4/10/2005. For the majority of time (80%) flows are equal to or exceed 3.75ML/day, while daily flows that equal or exceed 1000ML/day occur less than 7% of the time. Medium sized flows of up to 200ML/day occur less than 19% of the time. Overall, moderate sized flow events of 1200ML/day or more occur less than 6% of the time. Highest flows occur in late autumn, winter and early spring, while the lowest flows are experienced in summer.

Drown out has been difficult to predict given the isolated nature of this site and the relatively large height of the structure. It is assumed that this structure would drown out only on very rare occasions following prolonged heavy rain or major flooding events.

Operational Details

Wallacia weir was constructed in 1907/8 as compensation to adjacent upstream landholders for the construction of upper Nepean storage dams. The structure continues to be used today for its original purpose, with 40 licensed water extractors drawing upstream of the weir wall, and approximately 2600ML per annum being licensed for removal. At the time of inspection the condition of the weir was satisfactory.

Environmental Considerations

A fishway was recently installed on Penrith weir (next barrier downstream) and allows unimpeded fish passage along the Nepean River up to Wallacia Weir. A fishway has also recently been installed on Theresa Park Weir (next upstream barrier).

There are at least 12 major weirs on the Nepean River. Of these only six structures have had effective fishways installed (Penrith Weir, Theresa Park Weir, Mount Hunter Rivulet Weir, Cobbity Weir, Sharpes Weir and Camden Weir). Currently flow bypasses Thurns Weir and has breached Bergins Weir resulting in effective fish passage at these sites also. The remediation of Wallacia Weir in addition to other selected sites in the Nepean River would provide effective fish passage from estuarine habitats in the Hawkesbury River into the upper freshwater reaches of the Nepean River.

A number of native fish species require access to marine and freshwater habitats in order to complete certain stages of their life cycles. For example Australian bass migrate downstream for spawning purposes in winter and early spring, with juveniles and adults moving into freshwater environments upstream in late spring and summer. A lack of drown out flows during these times can seriously affect the ability of the species to spawn and recruit.

Native freshwater fish species that undergo significant migrations and are known to occur in the Nepean River include: Australian bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian smelt, striped gudgeon, freshwater herring, bullrout, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia have also been found in this river (Creese and Hartley 2004).

The river contains important fish habitat components such as large deep pools, large overhanging rocky platforms, cobble beds, and overhanging branches. The site has well vegetated banks with very minor erosion at fixed points adjacent the structure where the river is accessed by recreational fishers.

At the time of inspection aquatic vegetation was present at this site, and was dominated by salvinia, *Vallisineria* spp., and cumbungi. Riparian vegetation was dominated by casuarinas, small stands of banksias, *Ficus* spp., and eucalypts.

Figure 2. Nepean River, downstream of Wallacia Weir (31/3/05, 44.55ML/day).

Figure 3. Nepean River, upstream of Wallacia Weir (31/3/05, 44.55ML/day).

Proposed Remediation Actions

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

A Denil slot Insert fishway is considered to be the most viable fishway alternative for this site. This type of fishway involves retrofitting the existing fishway channel with U-shaped baffles will reduce velocity and turbulence present, and allow fish to ascend without undue stress. The Denil insert could be installed within the foundations of the existing fishway and potentially utilise the current slope of approximately 1:7, although this will limit the range of fish species, and size classes able to traverse the structure.

Denil fishways are cheaper than vertical slot fishways because they can be constructed on steeper slopes and thus require less materials for their construction (Baumgartner 2005). There are limitations in the use of Denil inserts however, with Larinier (1990) identifying Denil fishways as only being effective in passing fish greater than 200mm. In addition, Mallen-Cooper (2000) recommended Denil fishways be constructed on slopes no greater than 1:12, with gradients greater than this (less conservative slopes) limiting the movement of smaller fish.

It should be noted that retrofitting the existing fishway at Wallacia Weir may impact on the flow gauge associated with the structure. Calibration of flow data before, after, and during construction using additional gauging stations around the site should enable remediation of the structure to provide for fish passage, and recalibration of flow data collected.

Further investigation is required to determine the efficiency of a Denil insert at this site taking into account the current flow regime and fish species present.

- **Option 2 –** Removal

The complete removal of this structure would provide the greatest benefit to the health of Nepean River in this section of the catchment and provide improvements in the availability of aquatic and riparian habitat to fish and other aquatic organisms. Much of the structure's current function as a flow control point and for supplying water for irrigation, stock, and domestic needs could potentially be met through alternative means. In addition, it is understood that new technologies have allowed natural control points to replace flow gauging structures, with little compromise in the data collected. Calibration of existing flow gauge measurements with new measurements should allow continued data collection, with no loss in data quality following removal.

Further discussions between NSW DPI and Sydney Catchment Authority will be required in order to develop a remediation plan for this site that incorporates the needs of all stakeholders.

Projected Remediation Costs

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

Recommendation

Due to the number of upstream diverters using the existing weir pool, and the use of the structure as a flow gauging station, retrofitting of a Denil Insert into the existing fishway (Option 1) is the preferred remedial action to allow for fish passage at this site, and to minimise the effects of remediation on flow data collection.

Benefits Associated with Remediation

The Nepean River system is important fish habitat that should be protected, the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Wallacia Weir, in excess of 135km of habitat would again become accessible to fish and other aquatic organisms.

BROWNLOW HILL WEIR, NEPEAN RIVER

Figure 1. Brownlow Hill Weir, Nepean River (18/3/05, 27.33ML/day).

Description and Setting

Brownlow Hill Weir is located on the Nepean River (freshwater section of the Hawkesbury Nepean River), near the township of Cobbity. The structure is a concrete fixed crest weir approximately 1.8 metres high and 51.2 metres across. During low to medium flow conditions, the weir restricts fish passage due to excessive head loss (600mm). A canoe shoot is located centrally on the weir but is ineffective at passing native fish species due to headloss at each step and steepness of the overall structure. Brownlow Hill Weir is owned by the Sydney Catchment Authority and is currently listed on the State Heritage Inventory.

Brownlow Hill Weir is ranked as a high remediation priority within the Hawkesbury Nepean CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- The site is located in the middle of the catchment on the mainstem of the Nepean River;
- Diverse range of native fish;
- Healthy instream and riparian habitat condition;
- Large migratory fish populations below structure; and
- Fishways have recently been installed on Theresa Park Weir (next barrier downstream) and on Mount Hunter Rivulet Weir (next upstream barrier).

Hydrology

Hydrological flows at Brownlow Hill Weir were determined from the gauging station at Camden Weir (212216) located approximately 12km upstream. Information was sourced from the Sydney Catchment Authority using data acquired between 21/7/1989 and 6/10/2005. For the majority of time (80%) flows are equal to or exceed 11ML/day, while daily flows that equal or exceed 1000ML/day occur less than 2% of the time. Flows of up to 25ML/day occur 50% of the time.

Overall, moderate sized flow events over 80ML/day or more occur less than 20% of the time.

Flow events over 246ML/day or more occur less than 10% of the time. Highest flows in the Nepean River at this location occur in early autumn and winter while the lowest flows are experienced in mid to late summer.

Operational Details

Brownlow Hill Weir was constructed in 1907/8 to compensate adjacent upstream landholders for the construction of upper Nepean storage dams (Cataract, Cordeaux, Nepean, and Avon dams). The structure is still used today as water storage for irrigators. Currently, two licensed water extractors draw from the weir pool, with approximately 293ML per annum being licensed for removal. At the time of inspection the condition of the weir was satisfactory.

Ecological Considerations

Fishways have recently been installed on Theresa Park Weir (next barrier downstream) and on Mount Hunter Rivulet Weir (next upstream barrier). There are at least 12 major weirs on the Nepean River. Of these only six structures have had effective fishways installed (Penrith Weir, Theresa Park Weir, Mount Hunter Rivulet Weir, Cobbity Weir, Sharpes Weir, and Camden Weir). Currently flow bypasses Thurns Weir and has breached Bergins Weir resulting in effective fish passage at these sites. The remediation of Brownlow Hill Weir in addition to other selected sites in the Nepean River would provide effective fish passage from estuarine habitats in the Hawkesbury River into the upper freshwater reaches of the Nepean River.

A number of native fish species require access to marine and freshwater habitats in order to complete certain stages of their life cycles. For example Australian bass migrate downstream for spawning purposes in winter and early spring, with juveniles and adults moving into freshwater environments upstream in late spring and summer. A lack of drown out flows during these times can seriously affect the ability of the species to spawn and recruit.

Native freshwater fish species that undergo significant migrations and are known to occur in the Nepean River include: Australian bass, eel tailed catfish, long finned eel, short finned eel, bullrout, freshwater mullet, Australian smelt, striped gudgeon, freshwater herring, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia have also been found in this river (Creese and Hartley 2004).

NSW DPI site inspections have observed large accumulations of Australian bass on the downstream side of the structure, indicating that Brownlow Hill Weir is acting as a significant barrier to fish passage on the Nepean River.

The Nepean River contains important fish habitat components including large deep pools, and overhanging branches. This site has well vegetated banks with erosion at fixed points adjacent to structure frequented by stock. Aquatic vegetation was present at this site at the time of inspection and was dominated by *Vallisineria* spp. Riparian vegetation is dominated by casuarinas, small stands of banksias, eucalypts, *Ficus* spp., and common weed species.

Figure 2. Nepean River downstream of Brownlow Hill Weir (18/3/05, 27.33ML/day).

Figure 3. Nepean River upstream of Brownlow Hill Weir (18/3/05, 27.33ML/day).

Proposed Remediation Actions

Further discussions between NSW DPI, Sydney Catchment Authority, and the NSW Heritage Office will be required regardless of the option chosen in order to develop a remediation plan that incorporates the needs of all stakeholders.

- **Option 1 –** Removal

The complete removal of this structure would provide the greatest benefit to the health of Nepean River and provide significant improvements in the availability of aquatic and riparian habitat to fish and other aquatic organisms. As there are currently only two licensed weir pool extractors, much of the structure's current function could potentially be met through alternative means. However, State Heritage listing of the structure may limit the possibility for complete removal of this weir. Further discussions should occur between Sydney Water, NSW DPI, and the NSW Heritage Office regarding this option.

- **Option 2 –** Install a partial width rock ramp fishway

A partial width rock ramp fishway with a 1:20 slope could be constructed on the right hand bank. There is no ecological/hydrological reason for the location of the fishway on the right hand bank (location of the fishway dictated by access to the site). Both Theresa Park Weir (next barrier downstream) and on Mount Hunter Rivulet Weir (next upstream barrier) have partial width rock ramp fishways, therefore construction of a partial width rock ramp fishway at this site is a logical option for providing fish passage.

- **Option 3 –** Install a vertical slot fishway

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

The concrete construction of the weir makes it an ideal anchor for securing the vertical slot fishway and its associated infrastructure. Adequate attraction flow would need to be created by increasing flows across the structure near the fishway during low flow periods (through cutting a notch in the weir crest near the fishway entrance). 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. The construction of a vertical slot fishway on the right hand bank is the most expensive, but most effective option for fish passage remediation at Brownlow Hill Weir. However, given that the next barriers upstream and downstream of this site have partial width rock ramp fishways installed, whose limitations will govern the fish species and size classes reaching this site, construction of a vertical slot fishway at this site may not be the most viable option.

Projected Remediation Costs

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

Recommendation

The complete removal of the structure (Option 1) is the preferred remediation action for this site, given the minimal number of diverters using the upstream weir pool. It is understood, however, that the Heritage listing of Brownlow Hill Weir may negate the possibility of removal. Therefore, following consultation with stakeholders, should removal not be a possibility, the preferred option for this site is the construction of a partial width rock ramp fishway (Option 2).

Benefits Associated with Remediation

NSW DPI staff agree that the Nepean River system is 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. By reinstating fish passage at Brownlow Hill Weir, in excess of 100km of habitat would again become accessible to fish and other aquatic organisms.

MALDON WEIR, NEPEAN RIVER

Figure 1. Maldon Weir, Nepean River (18/3/05, 20.66 ML/day).

Description and Setting

Maldon Weir is owned by Blue Circle Southern Cement Ltd and is located on the Nepean River 5-10km downstream of the Bargo, Cordeaux, and Avon River confluences with the Nepean River. The structure is a concrete fixed crest weir approximately 15 metres high and 40 metres across. During all flow conditions, the weir restricts fish passage due to excessive head loss.

Maldon Weir is ranked as a high remediation priority within the Hawkesbury Nepean CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- The site is located in the middle of the catchment on the mainstem of the Nepean River;
- Diverse range of native fish;
- Healthy instream and riparian habitat condition; and
- Large migratory fish populations below structure.

Hydrology

Hydrological flows at Maldon Weir were determined from the gauging station associated with this structure (212208). Information was sourced from the Sydney Catchment Authority office in Penrith using data acquired between 10/6/1975 and 2/9/2005.

For the majority of time (80%) flows are equal to or exceed 6.6ML/day, while daily flows that equal or exceed 1000ML/day occur less than 5% of the time. Flows of up to 15.66ML/day occur 50% of the time. Overall, moderate sized flow events of 114ML/day or more occur less than 18% of the time, with flow events of 427ML/day or more occurring less than 10% of the time. Highest flows occur in late autumn and early winter, while the lowest flows are experienced in late summer.

Due to the size of this structure, drown out is predicted to occur on very rare occasions and is thought possible only during prolonged heavy rain or major flooding events.

Operational Details

Maldon Weir was constructed in 1968 to provide a permanent fresh water supply for Blue Circle Southern Cement Ltd. This weir was critical for the operation of the cement works at the time, however pumping for the cement works now takes place approximately 300 metres downstream of the weir crest and not from the weir pool.

Currently, 15 licensed water extractors draw from the weir pool, with approximately 645ML per annum being licensed for removal. The weir pool is also utilised by recreational anglers. At the time of inspection the condition of the weir was satisfactory.

Ecological Considerations

There is over 12km of riverine habitat downstream of this structure until the next barrier (Douglas Park Weir), and 12km of riverine habitat upstream until the next barrier (Pheasants Nest Weir). There is also significant habitat available in the lower reaches of the Bargo, Cordeaux and Avon Rivers whose confluence with the Nepean is located between Maldon and Pheasants Nest Weirs.

There are at least 12 major weirs on the Nepean River. Of these, only six structures have had effective fishways installed (Penrith Weir, Theresa Park Weir, Mount Hunter Rivulet Weir, Cobbity Weir, Sharpes Weir, and Camden Weir). Currently flow bypasses Thurns Weir and has breached Bergins Weir also resulting in effective fish passage at these sites. The remediation of Maldon Weir as well as other selected sites in the Nepean River would provide effective fish passage from estuarine habitats in the Hawkesbury River to the upper freshwater reaches of the Nepean River.

A number of native fish species require access to marine and freshwater habitats in order to complete certain stages of their life cycles. For example Australian bass migrate downstream for spawning purposes in winter and early spring, with juveniles and adults moving into freshwater environments upstream in late spring and summer. A lack of drown out flows during these times can seriously affect the ability of the species to spawn and recruit.

Native freshwater fish species that undergo significant migrations and are known to occur in the Nepean River include Australian bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian smelt, striped gudgeon, freshwater herring, bullrout, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia have also been found in this river (Creese and Hartley 2004).

The river contains important fish habitat components including large deep pools, instream structure and overhanging branches. The site has well vegetated steep rocky banks with little erosion due to difficultly accessing the stream bank.

Figure 2. Nepean River downstream of Maldon Weir (18/3/05, 20.66ML/day).

Figure 3. Nepean River upstream of Maldon Weir (18/3/05, 20.66ML/day).

Aquatic vegetation was present at this site during the site inspection and was dominated by what appeared to be the introduced genus *Elodea*. Riparian vegetation was dominated by casuarinas, and matt rush, with stands of banksias, eucalypts, and *Ficus* species.

Proposed Remediation Actions

Discussions with Blue Circle Southern Cement have indicated that although water for their operations is currently being drawn downstream of Maldon Weir, they would prefer to retain the structure for future water retention purposes.

Despite wanting to retain the structure, Blue Circle Southern Cement have indicated that there may be options for lowering the structure height. If this were to occur, the cost of the Options 1 and 2 could be dramatically reduced.

- **Option 1 –** Fishway (partial width rock ramp / vertical slot)

Engineers at the cement works are interested in looking at options for fishway construction on the weir. However, the cost associated with fitting a fishway to a structure of this size would be very expensive.

Two fishway options are available for this location – a partial width rock ramp fishway or a vertical slot fishway.

Both the partial width rock ramp, and the vertical slot fishways require approximately 300 metres length to allow for fish to traverse this structure (15 metres high at a 1:20 slope). The length required could be obtained through “dog-legging” the fishway in several lengths away from the structure, then back towards it so that the downstream entrance to the fishway is near the weir base.

Vertical slot fishways have flexibility of operation over a wide range of head and tailwaters, but are more expensive than rock ramp fishways, and require a greater volume of water to operate effectively. Therefore, of these two designs, a partial width rock ramp fishway is likely to be the most appropriate design for this location.

A third fishway type designed for larger structures, the fishlock (12 metres or more), is not likely to be effective at this location due to the lack of depth in the downstream channel near the weir. A fishlock also requires access to electricity to operate and this may limit its applicability to this site.

Further discussions between NSW DPI and Blue Circle Southern Cement will be required in order to develop a remediation plan that incorporates the needs of the owners, and the fish passage requirements at this site.

- **Option 2 –** Removal or lowering the weir height

The complete removal of this structure would provide the greatest benefit to the health of Nepean River and provide improvements in the availability of aquatic and riparian habitat. Discussions with Blue Circle Southern Cement, have indicated that they are currently able to obtain a water supply from large pools downstream of the weir although they are reticent to remove the structure completely, as the weir pool provides a secure

water source should the downstream pools dry up. If a secure water source could be determined that would supply the cement operations, either partial or complete removal of the structure may be possible.

Lowering of the crest height would greatly reduce the cost associated with Option 1, due to the decreased length of the fishway required to maintain a 1:20 slope. Further discussions are required between stakeholders and upstream diverters to determine if lowering/partial removal of the structure would be possible.

Projected Remediation Costs

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

Recommendation

Due to the owner's requirements to retain the structure, but their ability to allow for the lowering of the weir crest, the preferred option for this site is to lower the weir wall and construct a rock ramp fishway (Option 1).

Benefits Associated with Remediation

The Nepean River system contains large areas of important fish habitat that should be protected. Reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the Nepean River catchment. By reinstating fish passage at Maldon Weir, in excess of 50km of habitat would again become accessible to fish and other aquatic organisms, including access to major tributary rivers such as the Bargo, Cordeaux, and Avon Rivers.

MENANGLE WEIR, NEPEAN RIVER, MENANGLE

Figure 1. Menangle Weir, Nepean River (18/3/05, 55.74ML/day).

Description and Setting

Menangle Weir is owned by Sydney Catchment Authority and is located on the Nepean River near the township of Menangle. The structure is a fixed crest weir constructed of sandstone bricks, approximately 3 metres high and 78 metres across. During most flow conditions, the weir restricts fish passage due to excessive head loss (2000mm). Menangle weir is currently listed on the State Heritage Inventory.

Menangle Weir is ranked as a high remediation priority within the Hawkesbury Nepean CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- The site is located in the middle of the catchment on the mainstem of the Nepean River;
- Diverse range of native fish;
- Healthy instream and riparian habitat condition; and
- Large migratory fish populations below structure.

Hydrology

Hydrological flows at Menangle Weir were determined from the gauging station associated with this structure (212238). Information was sourced from the Sydney Catchment Authority office in Penrith using data acquired between 3/7/1990 and 5/10/2005.

For the majority of time (80%) flows are equal to or exceed 10ML/day, while daily flows that equal or exceed 1000ML/day occur less than 2% of the time. Moderate sized flows of up to 40ML/day occur 50% of the time. Overall, medium sized flow events over 245ML/day or more occur less than 10% of the time. Highest flows occur in late autumn and early winter, while the lowest flows are experienced in summer.

Operational Details

Menangle Weir was constructed in 1907/8 as compensation to adjacent upstream landholders for the construction of upper Nepean storage dams. The structure is used today for its original purpose, with 20 licensed water extractors drawing from the weir pool and approximately 3686ML per annum being licensed for use. The weir pool is also utilised by recreational anglers and boating enthusiasts. At the time of inspection the condition of the weir was satisfactory.

Environmental Considerations

A fishway was recently installed on the next barrier downstream (Mount Hunter Rivulet Weir) and over 30km of mainstem river is available upstream until the next man made barrier (Douglas Park Weir).

There are at least 12 major weirs on the Nepean River. Of these only six structures have had effective fishways installed (Penrith Weir, Theresa Park Weir, Mount Hunter Rivulet Weir, Cobbity Weir, Sharpes Weir and Camden Weir). Currently flow bypasses Thurns Weir and has breached Bergins Weir, resulting in effective fish passage at these sites. The remediation of Menangle Weir in addition to other selected sites in the Nepean River would provide effective fish passage from estuarine habitats in the Hawkesbury River into the upper freshwater reaches of the Nepean River.

A number of native fish species require access to marine and freshwater habitats in order to complete certain stages of their life cycles. For example Australian bass migrate downstream for spawning purposes in winter and early spring, with juveniles and adults moving into freshwater environments upstream in late spring and summer. A lack of drown out flows during these times can seriously affect the ability of the species to spawn and recruit.

Native freshwater fish species that undergo significant migrations and are known to occur in the Nepean River include: Australian bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian smelt, striped gudgeon, freshwater herring, bullrout, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia have also been found in this river (Creese and Hartley 2004).

The river contains important fish habitat components including large deep pools, and overhanging branches. The area surrounding the weir has well vegetated banks with erosion at fixed points adjacent the structure due to stock and recreational fisher access to the river. Aquatic vegetation was present at this site at the time of inspection and was dominated by *Vallisineria* species. Riparian vegetation was dominated by casuarinas, small stands of banksias, eucalypts, *Ficus* spp., and common weed species.

There is evidence of significant erosion at the weir structure itself, with undermining of the weir evident on the left side of the structure.

Minor erosion of the banks is also occurring downstream of the site. The base of the weir appears to be resting on exposed bedrock, which may also prove a barrier to fish further downstream during periods of low flows.

Figure 2. Nepean River downstream of Menangle Weir (18/3/2005, 55.74ML/day).

Figure 3. Nepean River upstream of Menangle Weir (18/3/2005, 55.74ML/day).

Proposed Remediation Actions

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

The most appropriate fishway design for this weir would be a partial width rock ramp fishway. The general principle for a fishway is to create a series of small steps and resting pools with an overall slope of 1:20 that will enable fish to traverse the structure. A reverse dog leg design should be incorporated into the design to locate the fishway entrance near the base of the weir structure to utilise the attraction flow passing over the weir wall and.

Given the current location of flows across the weir, the left hand side of this structure appears the most appropriate position for a fishway at this site. A rock platform is present on the downstream side of the weir with a channel present on the left hand side, which would act as a suitably stable base for the fishway, and allow for low flows to be directed down the fishway. However, the left hand side of this structure is also in urgent need of structural maintenance. This may impact on the ability of the fishway to be situated at this location, although repairs to the weir wall may be possible during construction of the fishway.

Alternatively, if the fishway were to be located on the right hand side, site access is greater, and the site is more visible (bordering a public reserve). In order to direct flows down the fishway, “cheater boards” (hardwood boards that act to slightly raise the weir pool level) will need to be attached to the weir crest on the left hand side of the structure. Placement of the partial width rock ramp fishway on the left hand side does not address the issue of structural maintenance of the left hand side however.

Further discussions between NSW DPI, Sydney Catchment Authority, and State Heritage will be required in order to determine remediation options that are satisfactory to all stakeholders.

- **Option 2 –** Removal

The complete removal of this structure would provide the greatest benefit to the health of Nepean River and provide improvements in the availability of aquatic and riparian habitat. However, as the structure is listed on the State Heritage Inventory, the complete removal of this weir is not likely to be possible. Further discussions between NSW DPI, Sydney Catchment Authority, and State Heritage are required to determine if this option is viable.

Projected Remediation Costs

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

Recommendation

Due to the structure's heritage listing complete removal if unlikely, with partial removal or lowering of the weir crest requiring further investigation to determine if it is possible. The construction of a partial width rock ramp fishway (Option 1) is therefore the preferred remedial action for this site, as this will have minimal impact on the structure itself, whilst reinstating fish passage.

Benefits Associated with Remediation

The Nepean River system is important fish habitat that should be protected, with reinstatement of fish passage along the entire system generating substantial benefits to the ecology of the catchment. By reinstating fish passage at Menangle Weir, in excess of 50km of habitat would again become accessible to fish and other aquatic organisms.

DOUGLAS PARK WEIR, NEPEAN RIVER

Figure 1. Douglas Park Weir, Nepean River (18/3/05, ~ 20.66ML/day).

Description and Setting

Douglas Park Weir is owned by Wollondilly Council and is located on the Nepean River near the township of Douglas Park. The structure is a concrete fixed crest weir approximately 0.8 metres high and 40 metres across. A road causeway was subsequently added to the top of the weir structure at a later date. During most flow conditions, the weir restricts fish passage due to excessive head loss (600mm), minimal flow depth and high gradient across the structure (Figure 1).

Douglas Park Weir is ranked as a high remediation priority within the Hawkesbury Nepean CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- The site is located in the middle to upper part of the catchment on the mainstem of the Nepean River;
- Diverse range of native fish;
- Healthy instream and riparian habitat condition; and
- Large migratory fish populations below structure.

Hydrology

Hydrological information for Douglas Park Weir was determined from the gauging station at Maldon Weir (212208) located approximately 10km upstream.

Information was sourced from the Sydney Catchment Authority using data acquired between 10/6/1975 and 2/9/2005.

For the majority of time (80%) flows are equal to or exceed 6.6ML/day, while daily flows that equal or exceed 1000ML/day occur less than 5% of the time. Flows of up to 15.66ML/day occur 50% of the time. Overall, moderate sized flow events over 114ML/day or more occur less than 18% of the time. Flow events over 427ML/day or more occur less than 10% of the time. Highest flows occur in late autumn and early winter while the lowest flows are experienced in late summer.

Drown out of the weir below the causeway has been predicted to occur during flows in excess of 550ML/day which occurs approximately 9% of the time based upon flow duration curves for Nepean River. It is assumed that fish passage is possible during this time.

Operational Details

Douglas Park Weir was constructed prior to the 1960's with box culverts added to the structure in early 1960's. The structure is still used today as water storage for irrigators and a road crossing for the local township of Douglas Park. Currently, five licensed extractors draw water from the upstream weir pool, with approximately 470ML per annum being licensed for removal. At the time of inspection the condition of the weir was satisfactory.

Ecological Considerations

The next barrier downstream is Menangle Weir approximately 24km away, whilst the next barrier upstream is Maldon Weir approximately 16km away. There are at least 12 major weirs on the Nepean River. Of these only six structures have had effective fishways installed (Penrith Weir, Theresa Park Weir, Mount Hunter Rivulet Weir, Cobbity Weir, Sharpes Weir, and Camden Weir). Currently flow bypasses Thurns Weir and has breached Bergins Weir resulting in effective fish passage at these sites. The remediation of Douglas Park Weir in addition to other selected sites in the Nepean River would provide effective fish passage from estuarine habitats in the Hawkesbury River into the upper freshwater reaches of the Nepean River.

A number of native fish species require access to marine and freshwater habitats in order to complete certain stages of their life cycles. For example Australian bass migrate downstream for spawning purposes in winter and early spring, with juveniles and adults moving into freshwater environments upstream in late spring and summer. A lack of drown out flows during these times can seriously affect the ability of the species to spawn and recruit.

Native freshwater fish species that undergo significant migrations and are known to occur in the Nepean River include: Australian bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian smelt, striped gudgeon, freshwater herring, bullrout, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia have also been found in this river (Creese and Hartley 2004).

Figure 2. Nepean River downstream of Douglas Park Weir (18/3/05, ~ 20.66ML/day).

Figure 3. Nepean River upstream of Douglas Park Weir (18/3/05, ~ 20.66ML/day).

The river contains important fish habitat components including large deep pools, and overhanging branches. The site has well vegetated banks with erosion at fixed points adjacent to structure frequented by recreational fishers and boating enthusiasts (Figures 2 and 3). Boats are launched above and below the weir on adjacent sandy banks.

Aquatic vegetation is present at this site and is dominated by swamp barnyard grass. Riparian vegetation is dominated by casuarinas, privet, small stands of banksias, eucalypts, *Ficus* spp., and common weed species.

Recent discussions with Wollondilly Council have suggested that there may be both European and Aboriginal Heritage issues associated with this site. This should be clarified prior to the commencement of any proposed works.

Proposed Remediation Actions

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

A partial or full width rock ramp could be installed below this structure and either utilise the slope of the weir as part of the foundation for the upper section of the fishway or retrofit the current slope with longitudinal rock ridges to provide appropriate flow depth and water velocity across the structure. The cost of a full width rock ramp fishway will be greater than that of a partial width rock ramp, and may therefore not be as cost effective as other options. In addition, it should be noted that the sandy substrate surrounding the site may increase costs for installation of a fishway due to the need for greater foundation work for the structure.

- **Option 2 –** Removal

The complete removal of this structure would provide the greatest benefit to the health of Nepean River and provide improvements in the availability of aquatic and riparian habitat. However, as the structure is the only means by which local residents can access their properties, complete removal of this weir may not be possible.

- **Option 3 –** Replacement of the weir with a bridge

There may be the possibility of replacing this causeway and weir with a bridge structure. The expense of this is likely to be comparable to the cost of an effective fishway design and construction, although cost benefit analysis against Option 1 should be undertaken prior to works being undertaken. If a bridge is built at this location a Doolan Deck arrangement may be an appropriate design.

A Doolan Deck Bridge comprises precast concrete and timber panels that are moved out over the river bed and placed on struts and support beams installed on each bank. This type of structure is relatively easy and quick to install, and often has a similar cost to installation of culvert cells for smaller waterways.

Further discussions between NSW DPI and Wollondilly Council will be required in order to develop a remediation plan, which incorporates the needs of all stakeholders.

Projected Remediation Costs

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

Recommendation

The construction of a bridge and the removal of this structure is the preferred remediation option for this site (Option 3). If further information reveals that the cost of bridge is too expensive, or that the structure must be retained, a rock ramp fishway (Option 1) is the next preferred option for this site.

Both Option 2 and 3 require investigation into the potential effects structure removal may have on upstream diverters. Bed level surveys are likely to be required prior to removal to determine the depth of pumping pools, and if Option 2 and 3 are viable.

Benefits Associated with Remediation

NSW DPI staff are in agreement that the Nepean River system is important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at Douglas Park Weir, in excess of 36km of habitat would again become accessible to fish and other aquatic organisms.

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7. APPENDICES

Appendix A: Detailed Weir Assessment Proforma

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

PRELIMINARY QUESTIONS Fish Passage

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

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

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

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

Date of review:

Name of Reviewer:

Contact phone No:

SECTION 1 OWNERSHIP AND LICENCE INFORMATION

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

Name of weir:

General directions, landmarks etc:

Name of nearest town:

Grid Reference:

Name of Watercourse:

Catchment Management Area:

Local Government Area:

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

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

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

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

Owner of land on which structure is built

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

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

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

Plan Number…….

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

Position Title: Owner name:

Office Address:

Phone: Mobile:

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

Licence No: .....

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

Licensing Office: .....

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

SECTION 2 STRUCTURAL AND OPERATIONAL DETAILS

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

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

Concrete ☐

Earth & rock ☐

Sheet piling ☐ with rock fill ☐ or other ……

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

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

2b ***Structure dimensions:***

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

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

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

Fixed Crest Structure ☐ Adjustable release structure ☐

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

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

..... release frequency

..... duration

..... season of opening

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

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

Yes / No

Please provide brief details:

.....

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

.....

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

working ☐ unserviceable ☐ decommissioned ☐

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

immediate maintenance ☐ modification ☐ replacement ☐

Please provide details:

SECTION 3 WEIR/BARRIER USE

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

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

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

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

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

List Users;

1 …….. 2 ……

3 …….. 4 ……

4 …….. 6 ……

(For more users please use separate sheet)

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

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

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

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

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

…….

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

…….

…….

SECTION 4 WEIR SETTING

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

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

(m)

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

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

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

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

(km) Structure name and/or type

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

(km) Structure name and/or type

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

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

Please provide details:
……..

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

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

Upper *Middle* *Lower*

SECTION 5 HYDROLOGY INFORMATION

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

…..... (m)

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

……(m)

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

Yes / No (m)

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

Yes / No Yes / No

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

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

Comments:
…..

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

…..... (per year) OR don't know

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

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

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

Yes / No / don't know

Please describe:
…..

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

SECTION 6 GEOMORPHIC INFORMATION

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

Yes / No / don't know

Comments:

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

Intact ☐ minor erosion ☐ extensive erosion ☐

Please describe:

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

Intact ☐ minor erosion ☐ extensive erosion ☐

Please describe:

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

Intact ☐ minor erosion ☐ extensive erosion ☐

Please describe:

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

Yes / No / don't know

Please describe:…….

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

…..... (m)

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

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

(Please provide details……..

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

Yes / No Please describe

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

Yes / No

Please describe:

……

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

Yes / No / don't know

SECTION 7 ECOLOGICAL CONSIDERATIONS

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

Yes / No structure type: …..

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

Yes / No / don't know

Comments:

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

……
……

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

……
……

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

Yes / No

Comments:
……

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

Yes / No/ don't know

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

……. season ……. (frequency)

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

Well vegetated ☐ moderately vegetated ☐ poorly vegetated ☐

Dominant species present (including native and introduced):

……

Please comment on native riparian vegetation and introduced plant species:

……

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

Yes / No

Comments:

……

……

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

<5% ☐ 5-10% ☐ 10-30% ☐ <30% ☐

Dominant species present (including native and introduced):

……

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

Yes / No / Don't know

Comments
……

……

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

Yes / No / partial one side / both sides

Comments:
……

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

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

Comments:

….

SECTION 8 RECOMMENDATIONS

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

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

Comments:

….

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

Comments:

….

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

……

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

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

Comments:

……

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

Please describe:

….

….

(vi) **Is the weir remote/difficult to access?** Yes / No

If Yes, please describe access/location (Is there all weather access?)

……

……

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

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

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

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

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

=

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

……

……

……

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

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

……

……

(II) ESTIMATED COST OF PROPOSED WORKS

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

Comments (Include supporting literature and correspondence)

……

……

……

……

8e No action recommended

Comments (Include supporting literature and correspondence)

……

……

……

……

SECTION 9 ADDITIONAL INFORMATION

For further information:

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

Appendix B: Weir Prioritisation Scheme for NSW Coastal CMAs

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

Appendix C: Weir Prioritisation Scheme for NSW Inland CMAs

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


aquatic habitat rehabilitation
making more fish
...naturally