REDUCING THE IMPACT OF WEIRS ON AQUATIC HABITAT

NSW DETAILED WEIR REVIEW

REPORT TO THE NEW SOUTH WALES ENVIRONMENTAL TRUST

HUNTER/CENTRAL RIVERS CMA REGION

NSW DEPARTMENT OF
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TRUST

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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

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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.

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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.

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[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.

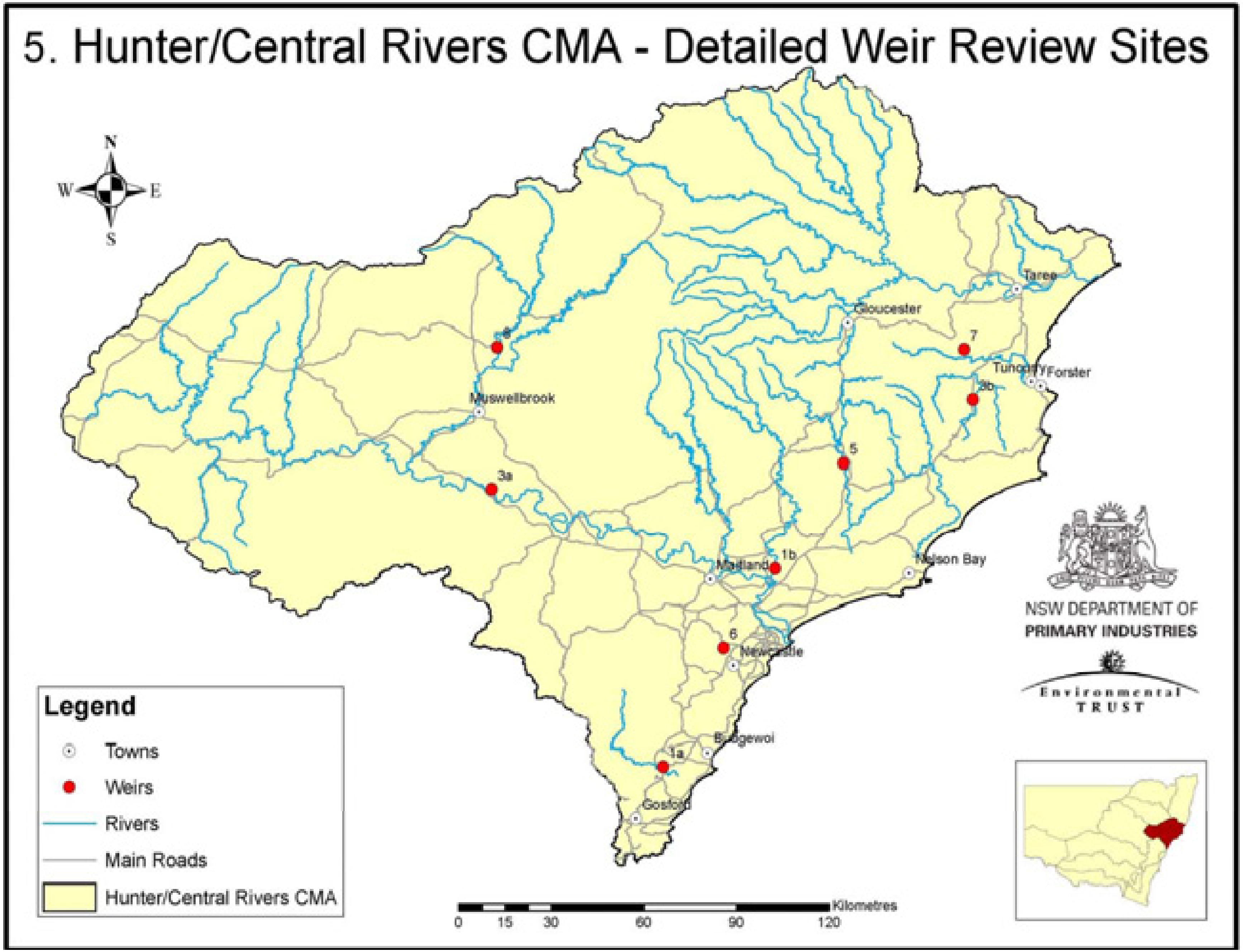
Following the initial prioritisation, a secondary prioritisation incorporating environmental and structural modification criteria was conducted to further delineate rankings. Environmental criteria incorporated aquatic and riparian habitat condition (i.e. good / fair / poor), sedimentation in the weir 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. Hunter/Central Rivers CMA - Detailed Weir Review Sites
N
W
E
S
Taree
Gloucester
7
Tuncurry
Forster
3b
Muswellbrook
5
3a
1b
6
1a
NSW DEPARTMENT OF
PRIMARY INDUSTRIES
Environmental
TRUST
Legend
Towns
Weirs
Rivers
Main Roads
Hunter/Central Rivers CMA
Kilometres
0 15 30 60 90 120

Hunter / Central Rivers 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)
1a	Wyong Weir	-33.276610	151.074060	Fixed crest (concrete)	Wyong River	Wyong and Gosford Council	Yes (Full Width Rock Ramp Fishway present)	Maintenance, Monitoring and Environmental Flow Regime	<50K	50 - 150K	60
1b	Seaham Weir	-32.710000	151.750000	Fixed crest (concrete and earth)	Williams River	Hunter Water Corporation	No (ineffective submerged orifice fishway present)	Vertical Slot Fishway	250 - 500K	50 - 150K	100
3a	Liddell Gauging Station	-32.483510	150.924320	Fixed crest water gauging structure (concrete)	Hunter River	Department of Natural Resources	No	Retrofit slope with longitudinal rock ridges	<50K	50 - 150K	200
3b	Locketts Crossing	-32.228280	152.326600	Fixed crest causeway (concrete and rock)	Coolongolook River	Great Lakes Council	No	Remove and replace with bridge	250 - 500K	150 - 250K	60
5	Stroud Water Supply Weir	-32.410056	151.949610	Fixed crest (concrete)	Karuah River	Mid Coast Water	No	Full Width Rock Ramp Fishway	50 - 150K	<50K	70
6	Barnsely Weir	-32.932110	151.589400	Fixed crest (concrete)	Cockle Creek	Lake Macquarie Council	No	Remove and replace with bridge	250 - 500K	<50K	40
7	Farm Weir at Dyers Crossing	-32.083770	152.300870	Fixed crest (concrete)	Khoribakh Creek	Unknown	No	Removal	<50K	50 - 150K	60
8	Brushy Hill Road Causeway	-32.077890	150.939970	Fixed crest causeway (concrete)	Pages River	Scone Council	No	Multiple low flow box cells or bridge	150 - 250K	250 - 500K	100

WYONG WEIR AND FISHWAY, WYONG RIVER

Figure 1. Wyong Weir and fishway during low flows, Wyong River (5/4/05, 22.5ML/day).

Figure 2. Wyong Weir and fishway during high flow event (22/10/04, ~1000ML/day).

Description and Setting

Wyong Weir and fishway is located on the Wyong River near the township of Wyong (Figures 1 and 2). Wyong River flows into Tuggerah Lakes approximately 8km downstream. The structure is owned by Wyong Shire Council and jointly managed by Wyong and Gosford Councils under the Gosford Wyong Water Authority. Wyong Weir is a concrete fixed crest weir approximately 1.2 metres high and 40 metres across. A full width rock ramp fishway was installed in 1993, however due to the flow regime within the Wyong River, and poor design considerations at the time of construction, this fishway does not operate effectively for the majority of the time.

Wyong Weir is ranked as a high remediation priority within the Hunter Central CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- Wyong River supports a diverse range of habitat types and native fish species;
- This is a tidal barrier with approximately 60 km of unimpeded fish habitat available upstream of the weir;
- Instream habitat along Wyong River is considered in good condition; and
- Full width rock ramp fishway was installed on the structure in 1993.

Hydrology

Wyong River hydrological information was determined from gauging station 211009 near the property 'Gracemere' approximately 6km upstream. Information was sourced from the DNR office in Newcastle and uses data acquired between 12/05/1978 and 31/08/2005.

For the majority of time (80%) flows are equal to or exceed 12ML/day, while daily flows equal or exceed 100ML/day only 15% of the time. Small flows of up to 30ML/day occur 50% of the time. Overall, moderate sized flow events of 200ML/day or more occur less than 8% of the time. Highest flows occur in late autumn and early winter, while lowest flows are experienced in spring.

Effective fish passage is thought to occur when flows overtop the weir and there is sufficient depth and flow over the rock ramp. Anecdotal evidence and photographic records indicate that this takes place during flow rates of around 500ML/day, which occur less than 4% of the time. Drown out is predicted to occur during flows in excess of 1200ML/day which occurs less than 2% of the time based upon flow duration data for Wyong River.

Operational Details

Wyong Weir was constructed in 1968 as a town water supply. The structure is owned by Wyong Council and continues to be used as a town water supply today, with water being pumped to Mardi Dam via a pumping station on the upstream weir pool. Currently, 58 licensed water extractors draw water from the upstream weir pool, with up to 3120ML per annum licensed for removal.

Of this total the majority is used for irrigation purposes (2870ML per annum) while the remainder is shared amongst aquaculture, domestic, farm, and stock use. Water released from Mangrove Creek Dam via Boomerang Creek tunnel, supplements flow into the weir pool. Wyong Weir has an upstream catchment area approximately 355sqkm.

Figure 3. Wyong River downstream of Wyong Weir (5/4/05, 22.5ML/day).

Figure 4. Wyong River upstream of Wyong Weir (5/4/05, 22.5ML/day).

At the time of inspection the weir was in working condition however the condition of the fishway was extremely poor. The fishway currently has a variety of small trees, shrubs, weeds, and grasses growing between the longitudinal rock ridges, which are blocking low flows, allowing sediment to build up, and reducing the depth of channels within the fishway.

Ecological Considerations

The timing of flows adequate enough to provide fish passage at this site may not necessarily coincide with spawning migrations of resident fish species within the Wyong River system. 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 expected to occur in the Macquarie-Tuggerah drainage basin include: Australian bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian smelt, striped gudgeon, freshwater herring, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia are also expected to occur in this river (Creese and Hartley 2004).

The river contains important fish habitat components including large deep pools instream and riparian cover as well as access to estuarine spawning sites. The site has moderately vegetated banks with erosion at fixed points adjacent to the structure due to lack of adequate riparian vegetation. Much of the left hand bank has been cleared and is now dominated by exotic weed species including lantana and morning glory. Aquatic vegetation in the upstream weir pool at the time of inspection was dominated by cumbungi, duckweed, and azolla. Riparian vegetation upstream and downstream of this site was dominated by small stands of eucalypts and *Ficus* species (Figures 3 and 4).

Proposed Remediation Actions

Despite the presence of a full width rock ramp fishway, a lack of maintenance has meant that this structure is not acting effectively to pass fish. In addition, competing interests for water within the Wyong River has meant that the volume and timing of flows within this system are not completely compatible with native fish biology.

An integrated flow management regime should therefore be developed for the Wyong River to provide adequate water volumes for licensed water extractors, town water supplies and provide for the effective working of the fishway. Consultation should also explore the possibility of providing funding for the development of off stream watering points to alleviate pressure on the river and restore more natural flow regimes.

The highest flows in Wyong River occur in late autumn and early winter. These high flow periods are suitable for downstream migrations but do not cater for the recruitment of juveniles and upstream migrations of adult fish normally undertaken in late spring and early summer. Environmental flows could therefore be incorporated into the management of the upstream storages, with water potentially being released from

Mangrove Dam via Boomerang Creek tunnel during late spring and early summer to supplement natural flows and aid in the effective migration of fish species during this period. The fishway should be monitored during this phase to gauge the effectiveness of additional flows in providing fish passage.

Physical remedial actions for Wyong Weir are presented below.

- **Option 1 –** Fishway maintenance and modification

The condition of this fishway needs to be actively maintained by Wyong Council in order to provide adequate fish passage when suitable flows are present. All debris (large woody debris, living plant material, and sediment) located within the fishway needs to be removed, and the fishway channels should be monitored to ensure sediment dispersal following high flow events.

Following initial and regular maintenance of the fishway, it could be regarded as a reasonably effective high flow fishway. However to increase the time in which the fishway is operational, a low flow channel could be retrofitted into the center of the fishway to facilitate fish passage at lower flows.

This deeper section of the fishway would direct flows down the middle of the channel (centre of the fishway), thereby providing passage at lower flows. At higher flows the sides of the fishway would become more useful for fish passage, with lesser velocities experienced away from the main channel.

- **Option 2 –** Removal

The complete removal of this structure would provide the greatest benefit to the health of Wyong River and provide improvements in the availability of aquatic and riparian habitat. However the extent of upstream water extraction licenses and the use of the structure in supplying town water negates removal of the weir. Investment into the establishment, monitoring and effective working of the fishway would also be lost. Removal is therefore not an option at this time.

Projected Remediation Costs

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

Recommendation

Maintenance of the fishway, provision of a low flow channel (Option 1), and the development of an integrated flow regime are the preferred remediation actions for this site.

Due to the reliance of water extractors on the weir pool, removal of the weir is unlikely, however better management of water delivery within the system may provide for greater ecological outcomes.

Benefits Associated with Remediation

NSW DPI staff agree that the Wyong 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 the Wyong weir fishway, in excess of 60km of habitat would again become accessible to fish and other aquatic organisms.

SEAHAM WEIR, WILLIAMS RIVER, SEAHAM

Figure 1. Seaham Weir, Williams River (30/9/05, ~29ML/day)

A)

B)

Figure 2. A) Upstream entrance to submerged orifice fishway, B) Earth and rock break wall, Seaham Weir (30/9/05, ~29ML/day).

Description and Setting

Seaham Weir (Figures 1 and 2) is owned by Hunter Water Corporation and is located in the township of Seaham on the Williams River. The Williams River is a tributary of the Hunter River, the confluence of which is approximately 10km downstream near the township of Raymond Terrace. The structure is a gated weir constructed of concrete with an earth and rock break wall. It is approximately 2.5 metres high and 150 metres across.

The weir restricts fish passage due to excessive head loss despite a submerged orifice fishway (Figure 2A) being located adjacent to the left abutment (this is considered to be ineffective for providing fish passage).

Seaham Weir is ranked as a high remediation priority within the Hunter Central Rivers CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- The Williams River system includes numerous upstream tributaries and in excess of 250km of possible stream habitat;
- Tidal barrier with no barriers to fish movement downstream;
- Diverse range of native fish; and
- Healthy instream and riparian habitat condition.

Hydrology

Williams River hydrological flows were determined from gauging station (210010) near Glen Martin approximately 19km upstream. Information was sourced from the DNR office in Newcastle using data acquired between 20/02/1974 and 23/08/2005.

For the majority of time (80%) flows are equal to or exceed 20ML/day. Small to medium flows of up to 94ML/day occurs 50% of the time. Overall, moderate sized flow events of 464ML/day or more occur less than 20% of the time. High flows over 1000ML/day or more occur less than 10% of the time. Highest flows occur in autumn and early winter, while lowest flows are experienced in early spring.

Operational Details

Seaham Weir was constructed in 1967 as a back up water supply to the Grahamstown Dam supply. The weir prevents saltwater intrusion upstream of the site and provides a location where flows released from Chitchester Dam and the Williams River upstream can be pumped to the Grahamstown Reservoir. Currently, 140 licensed water extractors draw from the Williams River, with up to 7180ML per annum being licensed for removal. Water skiers and recreational fisherman also utilise the weir pool. At the time of inspection the weir was in good working condition.

Environmental Considerations

Although fish passage through the gates of Seaham Weir is possible when high tides coincide with medium to high flows, the timing of these flows may not necessarily coincide with spawning migrations of resident fish species within the Williams River system. 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 Williams River include: Australian bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian smelt, freshwater herring, striped gudgeon, 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 3. Williams River downstream of Seaham Weir (30/9/05, ~29ML/day).

Figure 4. Williams River upstream of Seaham Weir (30/9/05, ~29ML/day).

In 2001, Hunter Water Corporation - in partnership with NSW Fisheries and the Department of Land and Water Conservation (now NSW DPI and Department of Natural Resources (DNR) respectively) constructed a full-width rock ramp fishway at Bandon Grove on the Williams River. This now provides unimpeded fish passage from Seaham Weir to Salisbury (approximately 25km upstream from Bandon Grove) on the Williams River and 10km of stream habitat on the Chichester River from Bandon Grove to Chichester Dam.

The Williams River contains important fish habitat components including estuarine nursery and spawning grounds, large deep freshwater pools with instream cover such as snags, macrophytes, and rocky platforms. The site has well vegetated banks with moderate erosion at fixed points adjacent to structure frequented by stock and various user groups.

Mangroves dominated downstream aquatic vegetation (Figure 3), while spike rush dominated aquatic vegetation upstream of the weir wall (Figure 4). Riparian vegetation is dominated by matt rush, eucalypts, *Ficus* spp., and small stands of casuarinas and introduced lantana. Small stands of mangroves are present downstream of the weir.

Proposed Remediation Actions

Hunter Water Corporation has recently changed management of the weir gates to improve fish passage past this site, by opening the gates during freshwater flows are present. Improved management of the gates allows for greater fish passage to occur past the structure, whilst limiting saline intrusion.

- **Option 1 –** Vertical slot fishway

Whilst fish passage has been facilitated through improved gate management, fish passage is not possible at all times. In addition, due to inadequate design and distance from sufficient attraction flows, the current submerged orifice fishway is considered to be ineffective at providing fish passage at Seaham Weir. In order to utilise attraction flow over the weir gates, a new fishway would need to be placed adjacent to the weir wall. Considering the size of the river and the diverse range of flows in the Williams River system, a vertical slot fishway is considered to be the most appropriate design.

The cost associated with the installation of a fishway at this structure is assumed to be relatively high due to the physical characteristics of the river and the height of the weir. However, the concrete construction of Seaham Weir makes an ideal anchor for this type of fishway.

- **Option 2 –** Removal

The complete removal of this structure would provide the greatest benefit to the health of Williams River and provide improvements in the availability of aquatic and riparian habitat to fish and other aquatic organisms. However the amount of water supplied to Grahamstown Dam from this site is considerable, and could not be replaced by any other means. Removal is therefore an unlikely.

Projected Remediation Costs

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

Recommendation

The construction of a vertical slot fishway (Option 1) is the preferred remediation action for this site due to the requirement of the structure to remain and hold water for supply to Grahamstown Dam.

Benefits Associated with Remediation

NSW DPI staff agree that the Williams River 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 Seaham Weir, in excess of 100km of habitat would again become accessible to fish and other aquatic organisms.

DNR RIVER GAUGING STATION 210083 - LIDDELL, HUNTER RIVER

Figure 1. Liddell River Gauging Station, Hunter River (7/4/05, ~118ML/day).

Description and Setting

The Liddell Gauging Station is owned by Department of Natural Resources and is located on the Hunter River near the township of Jerry's Plains in the Hunter River catchment. The structure is a fixed crest weir constructed of concrete approximately 1-1.5 metres high and 40 metres across. During most - all flow conditions, the weir restricts fish passage due to excessive head loss (750mm), minimal flow depth, as well as excessive velocity and gradient. The placement of rocks on the downstream edge of the slope has produced a compression wave (Figures 2A-C). This wave forms the upstream extent of fish passage. Laminal flow, high velocity, and minimal flow depth above this point prevents fish passage.

The Liddell Gauging Station is ranked as a high remediation priority within the Hunter Central CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- Hunter River supports a diverse range of habitat types and native fish species;
- This is the most downstream man made barrier to fish passage on the Hunter River (tidal influence approximately 90km downstream near the township of Maitland);
- Over 100km of aquatic habitat available upstream, including confluence with the Goulburn River; and
- Instream habitat along Hunter River is considered in good condition.

A) B) C)

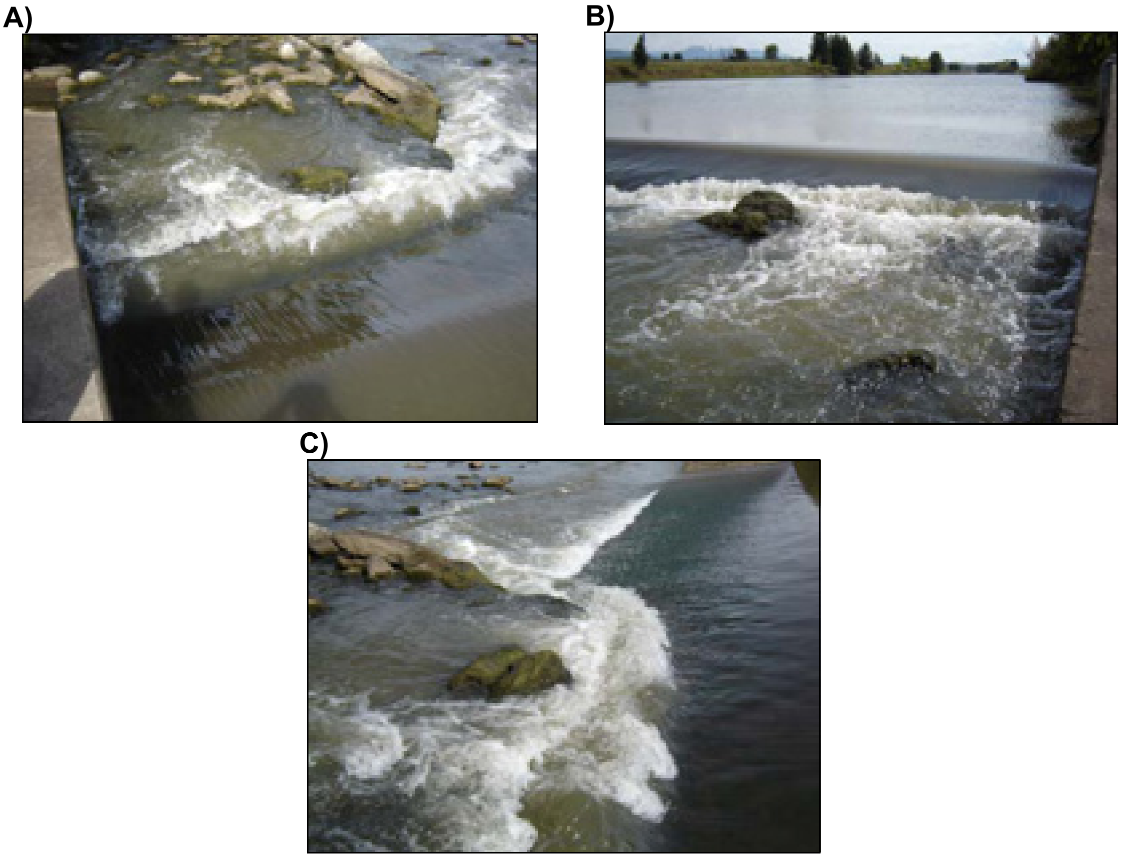


Figure 2. Compression wave above rock ramp arrangement A) looking downstream, B) looking upstream, and C) looking across structure – note attraction flow at the edge of the rock arrangement (7/4/05, ~118ML/day).

Hydrology

Hunter River hydrological flows were determined from this gauging station (210083). Information was sourced from the DNR office in Newcastle and Maitland using data acquired between 21/01/1972 and 26/08/2005. For the majority of time (80%) flows are equal to, or exceed, 131ML/day, while daily flows that equal or exceed 1000ML/day occur less than 18% of the time. Medium sized flows of up to 260ML/day occur 50% of the time. Overall, moderate sized flow events over 1900ML/day or more occur less than 10% of the time. The highest flow period for this site is during late spring and late summer, whilst the lowest flows are experienced in late autumn and early winter.

It is estimated that Liddell Gauging Station drowns out at river heights of 6.5 metres (approximately 0.75 metres above the weir crest), which correspond to flows of approximately 10,000ML/day. Flows in the Hunter River at this site reach 10,000ML/day <2% of the time.

With proposed adjustments to the left edge, effective fish passage is thought possible when flows are 100ML/day or greater, which occur up to 90% of the time.

Operational Details

Liddell Gauging Station was constructed in the early 1970's to gauge flows in the Hunter River. The structure is owned by DNR and still gauges flows today. Currently, twelve licensed water extractors draw from the weir pool, with up to 3240ML per annum being licensed for removal. At the time of inspection the gauging station was in good working condition.

Ecological Considerations

Jerry's Plains Weir, located approximately 3km upstream, has a partial width rock ramp fishway that does not provide adequate fish passage over most flow conditions. Consultation with Macquarie Generation (licensee for this site) has recognised the need to remove willows encroaching on the fishway, and to make improvements such as lining the fishway with rock groins to improve the ability of the fishway to work over a range of flows.

Liddell Gauging Station is the most downstream man made barrier to fish passage on the Hunter River. Tidal influence is approximately 90km downstream near the township of Maitland. Above Liddell Gauging Station and Jerry's Plain's rock ramp fishway, over 100km of aquatic habitat is available, including the Goulburn River. An improvised rock ramp is currently located on the left downstream bank edge of Liddell Gauging Station.

Although fish passage over this gauging site may be possible during flooding events, the timing of this may not coincide with spawning migrations of resident fish species within the Hunter River system. It is recommended that additional or environmental flows should be provided during critical periods associated with spawning migrations of resident fish species. 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 Hunter River include: Australian bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian smelt, striped gudgeon, Nepean herring, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia have also been found in this river (Creese and Hartley 2004).

The Hunter River contains important fish habitat components including large deep pools as well as access to estuarine spawning sites. This site has poorly vegetated banks with erosion at fixed points adjacent to structure due to cattle access, flooding events and lack of adequate riparian vegetation. Willows sparsely occupy the adjacent banks and have begun to encroach upon the downstream improvised rock ramp fishway. Aquatic vegetation was not observed at this site.

Figure 5. Hunter River downstream of Liddell Gauging Station showing improvised rock ramp fishway and attraction flow (7/4/05, ~118ML/day).

Figure 6. Hunter River upstream of Liddell Gauging Station (7/4/05, ~118ML/day).

Proposed Remediation Actions

- **Option 1 –** Strategically place rocks or ridges on the weir slope

Initial site assessments concluded that strategically placed rocks or ridges on the weir slope above the compression wave would sufficiently slow water velocity and increase flow depth to enable fish passage further up the structure. The effect of this on the ability of the structure to gauge flows will need to be investigated to ensure structure functionality is not lost.

It may also be necessary to redirect the rock ramp so that the downstream entrance is adjacent to the structure and can better utilise attraction flow. Currently the placement of the entrance to the fishway is set too far downstream, with fish likely to miss the entrance as they congregate around the attraction flow.

As this site is a control point for gauging flows in the Hunter River any modification would need to have minimal impact on the ability of the current structure to collect flow data and utilise past data. The viability of Option 1 as a possible option needs to be investigated further. Flow gauging results following the recent addition of a vertical slot fishway on Dalgety Weir (a control point for gauging flows in the Snowy River) could be used to help understand the impacts of modifying other flow control point structures such as Liddell Gauging Station. Further discussions between NSW DPI and DNR are required to develop a remediation plan for this structure, which incorporates the needs of all stakeholders.

- **Option 2 –** Removal

The complete removal of this structure would provide the greatest benefit to the health of Hunter River and provide improvements in the availability of aquatic and riparian habitat to native fish species. Much of the structure's current function as a flow control point as well as supplying, water for irrigation, stock, and domestic needs could potentially be met through alternative means. Recent technological advances can allow natural control to replace flow control structures such as Liddell Gauging Station, with little compromise in the data collected. In addition, there are also more sophisticated flow gauging techniques available that do not compromise fish passage. It is recommended that organisations responsible for management of these types of structures (DNR, water management bodies) should explore alternative data collection options as a matter of priority.

Projected Remediation Costs

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

Recommendation

In the short term, and due to the presence of several stakeholders at this site, Option 1 (the modification of the slope through strategic placement of rock on the weir) is the preferred remediation action for Liddell Gauging Station. Option 1 is also the cheapest option available for this site at this time.

Benefits Associated with Remediation

NSW DPI staff agree that the Hunter River 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 Liddell Gauging Station, in excess of 200km of habitat would again become accessible to fish and other aquatic organisms.

LOCKETTS CROSSING, COOLONGOLOOK RIVER

Figure 1. Lockett's Crossing, Coolongolook River (6/4/05).

Description and Setting

Lockett's Crossing is located near the township of Coolongolook in the Wallis Lake catchment. Coolongolook River and the Wang Wauk River flow into Wallis Lake, approximately 7km downstream from this site. Great Lakes Council owns the structure, which is a low level causeway constructed of concrete and rock, approximately 0.75 metres high and 25 metres across. During most flow conditions the weir restricts fish passage due to excessive headloss (300mm) and minimal flow depth across the causeway.

Lockett's Crossing is ranked as a high remediation priority within the Hunter Central CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- Coolongolook River system includes numerous upstream creeks with excess of 50km of possible stream habitat;
- This structure is a tidal barrier with no further barriers to fish passage upstream or downstream from this site;
- Diverse range of native fish; and
- Healthy instream and riparian habitat condition.

Hydrology

No hydrological data is recorded on the Coolongolook River. However hydrological data recorded in the adjacent Wang Wauk River, (situated only 5-6km away) has been used to estimate flow rates. Low flows of between 1-10ML/day occur 50% of the time, most prominently in summer. Winter and spring are characterised by high flows, but for only short periods of time.

Figure 2. Coolongolook River downstream of Lockett's Crossing (6/4/2005).

Figure 3. Coolongolook River upstream of Lockett's Crossing (6/4/2005).

Operational Details

Currently, four licensed water extractors draw water upstream from this site, with up to 182ML per annum being licensed for removal - all exclusively for irrigation. At the time of inspection the condition of the structure was reasonable with some small to medium sized leaks evident, indicating some compromise to the integrity of the structure.

Environmental Considerations

This site is the only impediment to fish passage on the Coolongolook River. Although some fish passage is possible when very large flows coincide with high tides, the timing of these events may not necessarily coincide with spawning migrations of resident fish species within the Wallis Lake system. 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 Coolongolook River include: eel tailed catfish, long finned eel, and striped gudgeon. Native freshwater fish species that undergo significant migrations and are expected to occur in the Karuah River drainage basin include: Australian bass, short finned eel, freshwater mullet, Australian smelt, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia are also expected to occur in this river (Creese and Hartley 2004).

The Coolongolook River contains important fish habitat components including large deep pools and diverse instream cover. The site has well vegetated banks with very minor erosion adjacent to the structure. Aquatic vegetation present in the upstream weir pool is dominated by spike rush, with the riparian zone being dominated by casuarinas and small stands of *Ficus* spp. and eucalypts.

Proposed Remediation Actions

- **Option 1 –** Install fishway on current structure

A fishway consultant has identified that the addition of a fishway to Lockett's Crossing in its present state would not provide fish passage for the majority of time during low flow periods. Currently the causeway leaks and allows water to pass under the structure, thus preventing low flows being channeled down a fishway. Given the expected prevalence of low flows in this catchment (approximately 50% of the time), a rock ramp or vertical slot design would not provide adequate fish passage under these conditions (Mallen-Cooper 2000).

Despite this, it may be possible to line the upstream side of the crossing with an impervious clay-core geo-textile fabric in order to minimise water leakage through the structure. This would require de-watering the site, thereby increasing construction costs and possibly reducing the viability of the option due to the lack of an assurance that low flows could be channeled down a fishway following the works. If this option was pursued, a rock ramp fishway would be the least expensive fishway type

(Mallen-Cooper 2000), due to cheaper cost of materials, and relative ease in establishing a foundation for this type of structure.

- **Option 2 –** Remove and replace with a low level bridge

Lockett's Crossing is the only available site where local residents can cross the river to access properties on the eastern downstream bank. The crossing is therefore critical, and cannot be replaced by a weir or removed completely, however the complete removal of this structure would provide the greatest benefit to the health of Coolongolook River and provide substantial improvements in the availability of aquatic and riparian habitat to fish.

The cost associated with replacing this structure with a bridge is estimated to be between $300,000 and $500,000. Despite the high cost, this is the preferred option, as it will provide unimpeded fish passage, restore natural sediment fluxes and tidal influences, and provide a safer road-crossing alternative than other available options. In addition, this option has no continued maintenance as would occur should a fishway or culvert cells be installed (Mallen-Cooper 2000).

Consultation with upstream licensed water extractors should be undertaken to identify any negative impacts of returning semi-saline conditions upstream of this site. Consultation should explore alternative water sources or methods for the provision of off-stream storages.

It should be noted that the causeway is potentially acting as a bed control structure, with considerable amount of sediment built up behind it. If the causeway is removed the destabilisation of this sediment could create bed and bank erosion adjacent to the site.

- **Option 3 –** Rebuilding the crossing as a causeway with a fishway

As the structure's integrity is beginning to be compromised, the causeway could be rebuilt with provision made for a fishway to be installed at the site.
The cost of installing a new causeway with a fishway is expected to be at least $150,000, which is a very general cost of construction for fishways (approximately $150,000 per vertical metre rise – dependant on site location, access, and various structural and hydrological constraints). Continued maintenance of the causeway would be required to ensure fish passage and to maintain the hydraulic capacity of the structure. Given that no hydrological data is available for this creek, flow data will need to be collected to verify the hydraulic parameters of the fishway (Mallen-Cooper 2000).

Projected Remediation Costs

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

Recommendation

The construction of a low level bridge (Option 2) is the preferred remediation action for this site. Cost benefit analysis of the available choices should be undertaken to assist in clarifying that Option 2 is the most viable alternative.

Benefits Associated with Remediation

NSW DPI staff agree that the Coolongolook River 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 Lockett's Crossing, in excess of 60km of habitat would again become accessible to fish and other aquatic organisms.

STROUD WATER SUPPLY WEIR, KARUAH RIVER

Figure 1. Stroud Water Supply Weir and bypass, Karuah River (6/4/05, 1490ML/day).

Figure 2. Left bank of Stroud Water Supply Weir showing natural bypass channel breach (6/4/2005, 1490ML/day).

Description and Setting

Stroud Water Supply Weir (Figure 1) is owned by Mid Coast Water and is located near the township of Stroud in the Karuah River catchment. The Karuah River flows into Port Stephens near the township of Karuah. Stroud weir is an overshot, fixed crest concrete weir, approximately 1 metre high and 40 metres across. During low to medium flow conditions, the weir restricts fish passage due to excessive head loss (500mm). During high flows a natural bypass channel has recently been formed by flow breaching around the left abutment (Figure 2).

Stroud Water Supply Weir is ranked as a high remediation priority within the Hunter Central CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- The Karuah River upstream posesses well in excess of 150km of stream habitat and many small confluence's and tributaries branch from this river including the Mammy Johnson, Ward and Telegherry Rivers;
- Downstream length is approximately 40km until the area of tidal influence, with no other barriers to fish migration downstream;
- The next barrier on the Karuah River is a box culvert road crossing on Cherry Tree Road approximately 34km upstream from this site. This site has been classed as a high priority for remediation works in a NSW DPI road crossing survey;
- Stroud Weir is located in the middle to lower end of the catchment within a total upstream catchment area over 4700km^2;
- Diverse range of native fish; and
- Healthy instream and riparian habitat condition.

Hydrology

Karuah River hydrological flows were determined from the DNR gauging station 209003 located at Booral approximately 10km downstream. For the majority of time (period of record 05/07/1973 to 24/08/2005) (80%) flows are equal to or exceed ~ 29ML/day, while daily flows equal or exceed 1339ML/day only 8% of the time. Overall, moderate sized flow events of 380ML/day or more occur less than 20% of the time. Highest flows occur in late autumn and early winter, while lowest flows are experienced in late spring and early summer.

Drown out has been difficult to predict given the isolated nature of this site. It is assumed that this structure would easily drown out on following prolonged heavy rain or major flooding events.

Operational Details

Stroud weir was constructed in 1900 as a water supply for the township of Stroud. The structure is owned by Mid Coast Water and still used today as a town water supply weir. There are approximately 64 water access licenses operating on the Karuah River with 3,360ML per annum in water entitlements.

Of this volume, about 3,000ML is used for irrigation, 320ML for town supply, 25ML for stock, and 100ML for domestic and other farming purposes. At the time of inspection the weir was in good working condition.

Figure 3. Karuah River downstream of Stroud Weir (6/4/2005, 1490ML/day).

Figure 4. Karuah River upstream of Stroud Weir (6/4/2005, 1490ML/day).

Environmental Considerations

Although fish passage around Stroud Weir is possible during 6% of flow events, the timing of these flows may not necessarily coincide with spawning migrations of resident fish species within the Karuah River system.

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 Karuah River include: Australian bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian smelt, striped gudgeon, 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 Karuah River contains important fish habitat components including estuarine nursery and spawning grounds, large deep freshwater pools with instream cover such as snags, macrophytes and rocky platforms. The site has well vegetated banks with moderate erosion at fixed points adjacent to structure frequented by stock. Aquatic vegetation was not observed during inspection as the river was under a medium to high flow event. Riparian vegetation is dominated by matt rush, eucalypts, *Ficus* spp., with small stands of casuarinas and introduced lantana (Figures 3 and 4).

Proposed Remediation Actions

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

An inexpensive option for this site is to develop the natural rock bypass channel on the left bank created under medium to high flows as illustrated in Figures 1 and 2. As this channel is only deep enough to provide fish passage during flows of around 1400ML/day, which occur only 6% of the time, it would be necessary to lower the upstream entrance and formalise the channel to facilitate fish passage during low flow periods. Longitudinal rock ridges and a more defined channel wall could also be added to the bypass channel to ensure appropriate flow velocities, and to create a partial width rock ramp fishway with resting pools on a slope of 1:20. The partial width rock ramp fishway entrance would also need to be brought back toward the weir structure in order to maximise the possibility of fish moving past the structure (fish are more likely to encounter the fishway entrance when it is located closer to the weir wall. A small section of the weir crest adjacent to the channel could be cut to provide attraction flow closer to the downstream entrance. It should be noted that the bypass channel resides on natural bedrock.

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

Recent negotiations with Mid Coast Water have determined that a full width rock ramp fishway would be the most effective remediation option for this site given the variable flows experienced within the Karuah River. The fishway will be built with an overall slope of 1:20, with a central low flow channel allowing fish passage prior to flooding flows.

A small section in the centre of the weir crest will need to be removed to form the upstream exit/entrance and provide a concentration of flow down the low flow channel. Due to the presence of bedrock downstream of the structure and relatively small size of the structure, a full width rock ramp fishway at this location would be relatively cost effective. This is the preferred option for this site.

- **Option 3 –** Removal

The complete removal of this structure would provide the greatest benefit to the health of Karuah River and provide improvements in the availability of aquatic and riparian habitat. Mid Coast Water have recently undertaken a yield analysis for their water storages, and have indicated that this weir is still required for town water supply. Although Mid Coast Water are supportive of appropriate improvements that will allow fish passage at this site, removal is not an option at this time.

Projected Remediation Costs

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

Recommendation

A full width rock ramp fishway (Option 2) is the preferred option for this site and is the remediation option being undertaken by Mid Coast Water and NSW DPI as part of the demonstration site component of this project (works beginning early July 2006).

Benefits Associated with Remediation

NSW DPI staff agree that the Karuah River 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 Stroud Weir, in excess of 70km of habitat would again become accessible to fish and other aquatic organisms.

BARNSLEY WEIR, COCKLE CREEK, BARNSLEY

Figure 1. Barnsley Weir, Cockle Creek (5/4/05).

Description and setting

Barnsley Weir (Figure 1) is located approximately 1km from the township of Barnsley on the mainstem of Cockle Creek. The weir is constructed of concrete and measures 0.85 metres high by 20 metres wide. There is one piped cell approximately 400mm in diameter which is heavily blocked by sediment and debris. Water cascades over the crest of the weir, with fish passage being restricted due to cell blockage and excessive headloss (65mm) during low-flow conditions. The weir drowns out following medium to large sized flooding events during which fish passage is possible.

Prioritisation of weirs in the Hunter Central CMA region has highlighted Barnsley Weir as a high remediation priority within the Hunter Central CMA region due to the following factors:

- Cockle Creek supports a diverse range of habitat types and native fish species;
- This is a tidal barrier with many upstream confluences including Diega Creek, Burkes Creek and Slatey Creek;
- Approximately 30km of unimpeded fish habitat is available upstream of the weir; and
- Instream habitat along the Cockle Creek is considered in good condition.

Hydrology

No hydrological flow data is recorded on the Cockle Creek. Anecdotal evidence has suggested that drown out flows occur around 2-3 times per year following torrential downpours.

Operational Details

Barnsley Weir was constructed in the late 1920's for a local colliery to supply water for cooling purposes. The colliery has since ceased operations and the structure is being used as a road crossing by local residents and tourists (the structure is now managed by Lake Macquarie Council under a licensing agreement with DNR). Westside Wallsend and Rhonda Collieries dominate upstream land use. Few private landholders reside adjacent to the creek upstream of this structure.

Environmental Considerations

Although fish passage is possible when high tides coincide with high flow events, the timing of these flows do not necessarily coincide with spawning migrations of resident fish species within the Cockle Creek system. 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 expected to occur in the Macquarie-Tuggerah drainage basin include: Australian bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian smelt, striped gudgeon, freshwater herring, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia are also expected to occur in this river (Creese and Hartley 2004).

The river contains important fish habitat components including large pools and diverse instream structure. The site has well vegetated banks with some erosion at fixed points adjacent to the structure. Previous site visits by NSW DPI have identified *Vallisneria* sp. (ribbonweed) as the dominant upstream aquatic vegetation. Mangroves, casuarinas, and *Ficus spp*. dominate downstream riparian vegetation, whilst casuarinas and eucalypts dominate upstream riparian vegetation. Water quality along Cockle Creek is described as variable due to the high incidence of flooding events and dry periods.

Overall aquatic health would be improved by revegetation of the riparian zone along Cockle Creek, with priority being given to disturbed or cleared banks. This would help to alleviate pressure on downstream water quality from the build up of sediments behind the weir wall.

Figure 2. Cockle Creek downstream of Barnsley Weir (5/4/2005).

Figure 3. Cockle Creek upstream of Barnsley Weir (5/4/2005).

Proposed Remediation Actions

- **Option 1 –** Install box culvert with low flow cell

The single 400mm diameter pipe cell is inadequate to pass flows and provide for fish passage. At present the pipe is blocked with sediment and debris on the upstream side, blocking fish passage and flows through the structure. Should this cell be cleared of debris, it would still possess high linear velocities through the structure, and its 65mm headloss would continue to limit fish passage.

In the short term it is recommended that built up sediment and debris be removed from the culvert to improve flows through the structure. Further works are required to improve fish passage, however.

As this structure is no longer required to create a water source for the Collieries, but remains required as an access point across Cockle Creek, it is recommended that box culverts with low flow cells be installed into the structure to provide fish passage, improve flow through the structure, and improve public safety at the site (by minimising water movement across the road surface).

Low flow cells are set into the stream bed, allowing some of the surrounding sediment to migrate into the cells. Movement of sediment into the cells lessens behavioural reluctance of fish to enter the culvert, whilst the lower setting of the cells enable low flows to pass the structure, ensuring that they are operable at all times.

Prior to any works being conducted at the site, it is recommended that the sediment behind the weir wall be analysed for excessive heavy metal deposits that may have resulted from the colliery operations.

- **Option 2 –** Remove and install a bridge

The complete removal of this structure would provide the greatest benefit to the health of Cockle Creek, improving fish passage and access to available aquatic and riparian habitat, as well restoring natural sediment fluxes within the creek. A long-term objective for this site should be the complete removal of this structure and the installation of a bridge. Prior to removal, the sediment built up behind the structure should be analysed for pollutants and disposed appropriately. Taking into account the cost of installing a new causeway (~$150,000-$200,000) and continued maintenance, it is considered that the installation of a bridge (~$300,000) is a more viable and worthwhile option.

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. As the channel widens significantly downstream of the crossings present position, the cost of a bridge may increase if the location is moved to alternative sites downstream.

Projected Remediation Costs

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

Recommendation

The construction of a bridge (Option 2) is the preferred remediation action for this site. If the costs associated with installing a bridge are unfeasible, it is recommended that Option 1 be investigated further.

Benefits Associated with Remediation

NSW DPI staff agree that Cockle Creek provides important fish habitat that should be protected, and that the reinstatement of fish passage along the entire system would provide substantial benefits to the ecology of the catchment. Reinstating fish passage at Barnsley Weir would provide unimpeded access for fish and other aquatic organisms to habitat in excess of 40km.

DYER'S CROSSING WEIR, KHORIBAKH CREEK

Figure 1. Dyer's Crossing Weir, Khoribakh Creek (5/4/05)

Description and Setting

Dyer's Crossing Weir is located on Khoribakh Creek near the township of Nabiac in the Wallamba River catchment. Khoribakh Creek flows into Wallamba River approximately 2km downstream from this site. This weir is currently unlicensed and ownership is yet to be confirmed. Local council does not acknowledge ownership, whilst the right and left banks are under private ownership. The structure itself is an overshot concrete weir, approximately 1.4 metres high and 15 metres across. During most flow conditions the weir restricts fish passage due to excessive head loss (1000mm).

Dyer's Crossing Weir is ranked as a high remediation priority within the Hunter Central CMA region due to the following factors:

- Class 2 moderate fish habitat (known fish habitat);
- Abundant upstream habitat including Firefly, Champion Kings Flat and Kooloombakh Creeks, with over of 40km of unimpeded stream habitat;
- Diverse range of native fish; and
- Healthy instream and riparian habitat condition.

Hydrology

No hydrological data is recorded on the Khoribakh Creek. Anecdotal evidence suggests that drown out flows occur around 2-3 times per year, at which time fish passage would be possible at the site.

Figure 2. Khoribakh Creek directly downstream of Dyer's Crossing Weir (5/4/2005).

Figure 3. Khoribakh Creek directly upstream of Dyer's Crossing Weir (5/4/2005).

Operational Details

At the time of inspection the weir was in working condition. Currently five licensed water extractors draw water upstream of this site, with up to 209ML per annum being licensed for removal. Licenses are exclusively for irrigation and farming, and previous studies have identified that this weir pool may be have used as an emergency fire fighting water supply. The weir pool is currently being used as a natural barrier for cattle grazing on the left bank.

Environmental Considerations

There are three high priority road crossings that impede fish passage on the Wallamba River downstream of Dyer's Crossing. These sites include Wellers Lane Crossing (approximately 4km downstream from Dyers Crossing), Dargavilles Road Crossing, and Clarkson's Crossing. Clarkson's Crossing will be addressed in the near future as part of joint project between Great Lakes Council, Greater Taree Council, DNR, and NSW DPI. Following remediation of Clarksons Crossing, the next fish passage barriers upstream of the site will increase in priority, leading to further remediation works.

Upstream of Dyer's Crossing there is over 40km of unimpeded aquatic habitat, including the tributaries of Firefly, Champion Kings Flat and Kooloombakh Creeks.

Native freshwater fish species that undergo significant migrations and are expected to occur in the Wallamba River catchment include: short finned eel, long finned eel, Australian bass, freshwater mullet, bullrout, Australian smelt, striped gudgeon, Cox's gudgeon, freshwater herring, southern blue-eye, and common galaxias. Introduced species including goldfish, gambusia, and common carp are also expected to occur in this river (Creese and Hartley 2004).

The river contains important fish habitat components including deep pools and diverse instream cover. The site has well vegetated banks with very minor erosion upstream of the structure. Aquatic vegetation was not noted in the upstream weir pool. Riparian vegetation is dominated by *Ficus* spp., matt rush with small stands of eucalypts and introduced lantana.

Proposed Remediation Actions

- **Option 1 –** Remove weir

The complete removal of this structure would provide the greatest benefit to the health of Khoribakh Creek and provide substantial improvements in the availability of aquatic and riparian habitat for fish. Option 1 is the preferred option for this site, as it will provide unimpeded fish passage and restore natural flow and sediment fluxes. In addition, this option requires no continued maintenance compared to Option 2 (a fishway), which would require regular removal of debris from the fishway channel.

In regard to additional use of the weir pool, consultation with the Operations Officer for Taree District Rural Fire Brigade have concluded that there are far more reliable local water sources than the Dyer's Crossing weir pool, therefore the weir pool is no longer required for fire fighting duties.

In addition, initial consultation with the adjacent landholder on the left upstream bank has concluded that if funding for fencing on his property could be provided, and assistance in maintenance of fences is provided following flooding events, he would support removal of the weir wall.

Consultation with upstream licensed water extractors should be undertaken to identify any negative impacts of lowering the available water level for extraction upstream at this site. Discussion should explore possible alternative water sources or compensation for the construction of off-stream storages.

It should be noted that the weir is potentially acting as a bed control structure, with considerable amounts of sediment built up behind it. Due to relatively high frequency of large flows in this creek (the structure being overtopped approximately 2-3 times per year), this sediment would be quickly dispersed following removal of the structure, however sediment composition should be investigated to identify any potential negative impacts should the structure be removed (such as presence of heavy metals).

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

A partial width rock ramp could be installed at this site however, without flow data it is difficult to determine what range of flows the fishway will be required to work under. Anecdotal evidence suggests small to medium sized flows are fairly consistent. A partial width rock ramp fishway would be built to form an overall slope of 1:20, with a series of short steps leading to resting pools that allow fish to traverse the structure.

If it is determined that upstream diverters will be negatively affected by the removal of the weir, lowering of the weir crest may be possible, without affecting weir pool storage greatly, and decreasing the cost of constructing a fishway at the site.

Projected Remediation Costs

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

Recommendation

The removal of this structure (Option 1) is the preferred remediation action for this site due to its lower cost and greater benefit to the environment. Discussions should be held with upstream diverters to determine potential impacts on their water supply, however if impacts are negligible, or options become available for provision of offstream storages, Option 1 should be implemented. If the weir pool is still required following investigations, Option 2 is the preferred option for this site.

Benefits Associated with Remediation

NSW DPI staff agree that the Khoribakh 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 Dyer's Crossing Weir, in excess of 60km of habitat would again become accessible to fish and other aquatic organisms.

BRUSHY HILL ROAD CROSSING, PAGES RIVER

Figure 1. Brushy Hill Road causeway, Pages River (7/4/05, ~ 4ML/day).

Description and Setting

The Brushy Hill Road causeway is owned by Upper Hunter Shire Council and is located near the township of Aberdeen on the Pages River. The Pages River is a tributary of the Hunter River, the confluence of which is located approximately 8km downstream. The causeway is constructed of concrete and large boulders and is approximately 1.5 – 2 metres high and 75 metres across. During most flow conditions, the weir restricts fish passage due to excessive head loss (1500mm), minimal flow depth, and excessive velocity through the two box cells located in the middle of the structure.

The Brushy Hill Road causeway is ranked as a high remediation priority within the Hunter Central CMA region due to the following factors:

- Class 2 fish habitat (known fish habitat);
- Pages River supports a diverse range of habitat types and native fish species;
- This is the most downstream man made barrier to fish passage on the Pages River, although there is at least one man made barrier located downstream on the Hunter River (Liddell Gauging Station);
- Over 30km of aquatic habitat available upstream;
- Instream habitat along Pages River is considered in fair condition; and
- A full width rock ramp fishway installed on the next structure downstream (Jerry's Plains Weir).

Hydrology

Pages River hydrological flows were determined from a gauging station (210052) located at Gundy approximately 12km upstream. Information was sourced from the DNR office in Newcastle using data acquired between 26/10/1972 and 12/09/2005. For the majority of time (80%) flows are equal to or exceed 4.5ML/day, while daily flows that equal or exceed 100ML/day occur less than 23% of the time. Medium sized flows of up to 30ML/day occur 50% of the time. Overall, large flow events over 300ML/day or more occur less than 9% of the time. Highest flows occur in late winter to late spring, while the lowest flows are experienced in summer and early autumn.

Operational Details

Brushy Hill Road Causeway was constructed in 1956 to provide a crossing over the Pages River following a flood in 1955, which washed the previous causeway away. The structure is owned by Upper Hunter Shire Council and is still used today for its original purpose. Currently, 82 licensed water extractors draw from the Pages River, with up to 4606ML per annum being licensed for removal. At the time of inspection the crossing was in good working condition.

Ecological Considerations

Jerry's Plains rock ramp fishway, located approximately 90km downstream, provides adequate fish passage during most flow conditions. Consultation with Macquarie Generation, the licensee for this site, has recognised the need to remove any willows encroaching on the fishway and line the ramp with rock groins to improve the ability of the fishway to function over a range of flows.

Liddell Gauging station is the most downstream man made barrier to fish passage remaining on the Hunter River, and next barrier downstream of Brushy Hill Road Crossing. Tidal influence is approximately 90km further downstream near the township of Maitland.

Although fish passage through Brushy Hill Causeway may be possible during major river rises and flooding events the timing of this may not coincide with the frequency of spawning migrations of resident fish species within the Hunter River Catchment. 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 Hunter River downstream of the confluence with the Pages River include: Australian Bass, eel tailed catfish, long finned eel, short finned eel, freshwater mullet, Australian Smelt, striped gudgeon, Nepean herring, and common jollytail. Introduced species including common carp, goldfish, and eastern gambusia have also been found in this river (Creese and Hartley 2004).

A) **B)**

Figure 2. Cell entrance showing A) headloss and cell size downstream, and B) upstream cell entrance (7/4/05, ~ 4ML/day).

Figure 3. Downstream cell entrance showing headloss and cell size (7/4/05, ~ 4ML/day).

A) **B)**

Figure 5. Pages River looking A) downstream, and B) upstream (7/4/05, ~ 4ML/day).

This site has poorly vegetated banks with erosion at fixed points adjacent the structure (due to cattle access, flooding events, and lack of adequate riparian vegetation). Aquatic vegetation was not observed at this site.

Proposed Remediation Actions

Fish passage in the Pages River would be improved through remediation of Brushy hill causeway. Further discussions between NSW DPI and Upper Hunter Shire Council will be required in order to develop a remediation plan, which incorporates the needs of all stakeholders.

- **Option 1 –** Installation of multiple low flow box cells, or partial removal and replacement with small bridge.

The least expensive option is to remove the current cells and replace them with multiple box culverts and low flow box cells. This would provide fish passage during low flow conditions and would improve the ability of the structure to operate during flood events.

Alternatively a section of the causeway could be removed and replaced with a small bridge. This would provide greater fish passage than box culverts alone, and increase user safety during flooding conditions. Cost of installation is likely to be greater than box culverts alone, however.

- **Option 2 –** Complete removal and installation of a bridge

The complete removal of this structure would provide the greatest benefit to the health of Pages River and provide improvements in the availability of aquatic and riparian habitat. The current function of the structure as a crossing could still be met through the installation of bridge. It should be noted that the causeway is potentially acting as a bed control structure, with bed stability requiring investigation prior to undertaking works that may disturb the sediment behind the structure.

Projected Remediation Costs

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

Recommendation

Both options are reasonably expensive due to the size of the structure, however the installation of multiple box culverts with low flow cells (Option 1) is the preferred remedial action for this site. Installation of multiple low flow cells will allow additional flow to pass through the causeway, thereby decreasing high water velocities currently experienced as water is forced through inadequate sized culverts. A decrease in water velocities, and provision of low flow cells will allow fish passage to be possible over a greater range of flows than is currently possible, whilst maintaining vehicle access across Pages River.

Benefits Associated with Remediation

NSW DPI staff agree that the Pages 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 the Brushy Hill Road causeway, in excess of 100km 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	

<u>Appendix C: Weir Prioritisation Scheme for NSW Inland CMAs</u>

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