

REDUCING THE IMPACT OF WEIRS ON AQUATIC HABITAT

NSW DETAILED WEIR REVIEW



REPORT TO THE NEW SOUTH WALES ENVIRONMENTAL TRUST

SYDNEY METROPOLITAN CMA REGION



NSW DEPARTMENT OF
PRIMARY INDUSTRIES



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EXECUTIVE SUMMARY

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

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

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

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

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

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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 Fisheries¹ and the Department of Land and Water Conservation² 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 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 out³ events, previous occurrence of blue-green algae in the weir pool, fish caught or observed in the vicinity of the weir, licensing information, and water extraction devices linked to the works of each weir. Where possible, volume of water discharged (ML/day) on the date of the field assessment, average yearly flows, and drown out event data were acquired from the nearest Department of Natural Resources river gauge.

3.4 Field assessment

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

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

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

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

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

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

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

3.5 Prioritisation process

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

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

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

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

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

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

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

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

4. INDIVIDUAL DETAILED WEIR REVIEW REPORTS

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

5. Sydney Metro CMA - Detailed Weir Review Sites



Sydney Metropolitan CMA Summary Table

Rank	Barrier Name	Latitude	Longitude	Structure Type	Watercourse	Ownership	Operational Fishway	Recommendation	Estimated Cost of preferred option (\$)	Estimated Cost of alternative option (\$)	Potential Increase in Habitat Area (km)
1	Testers Weir	-34.004020	150.882940	Fixed crest (sandstone block and concrete)	Georges River	Campbelltown City Council	No	Partial Removal and install rock ramp	<50K	<50K	60
2	Lane Cove Weir	-33.784810	151.153350	Fixed crest (sandstone block and concrete)	Lane Cove River	National Parks and Wildlife Services	Yes (Partial Width Rock Ramp Fishway)	Structural and operational improvements to fishway and install rock ramp on downstream slope	50 - 150K	<50K	30
3	Wolli Creek Weir	-33.927720	151.132880	Fixed crest (concrete)	Wolli Creek	Rockdale and Canterbury Council	No	Retrofit slope with rock ramp fishway	<50K	50 - 150K	6
4	Pass of Sabugal Weir	-34.037940	151.003810	Fixed crest causeway (concrete)	Woronora River	Sutherland Council	No	Partial removal	<50K	50 - 150K	25
5	Hacking River Weir No. 2	-34.151450	151.027200	Fixed crest (concrete)	Hacking River	National Parks and Wildlife Services and NSW RTA	No	Partial Width Rock Ramp Fishway	150 - 250K	50 - 150K	24
6	Woollen Mill Weir	-33.785910	150.989930	Fixed crest (concrete)	Darling Mills Creek	Baulkam Hills Council and Parramatta Council	No	Partial Width Rock Ramp Fishway	50 - 150K	<50K	15
7	Wedderburn Weir	-34.105300	150.821250	Fixed crest (concrete)	Georges River	Campbelltown City Council	No	Multiple Low Flow Box Cells and bank stabilisation works	50 - 150K	250 - 500K	40

TESTERS WEIR (INGLEBURN WEIR), GEORGES RIVER



Figure 1. Testers Weir (Ingleburn Weir), Georges River (27/01/2005).

Description and Setting

Testers Weir (Ingleburn Weir) is owned by Campbelltown City Council and is located adjacent to the township of Ingleburn in the Georges River catchment, approximately 35km upstream of its mouth at Botany Bay. The structure is a fixed crest weir constructed of sandstone blocks and concrete grout, and is approximately 0.75 metres high and 11 metres across the length of the crest (Figure 1). At present there is a 1-1.5 metre breach adjacent to the left abutment. During low to medium flow conditions the weir restricts fish passage due to excessive slope gradient and minimal flow depth through the breach. During high flows the weir restricts fish passage due to headloss and excessive flow velocity through the breach. This weir resides in Ingleburn Reserve, which is frequently visited by picnickers and bush walkers.

Testers Weir is ranked as a high remediation priority within the Sydney Metropolitan CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- Although the site is located in the middle of the catchment, the upstream catchment area is approximately 300km²;
- Diverse range of native fish including a popular recreational fishery for Australian bass (*Macquaria novemaculeata*);
- Healthy instream and riparian habitat condition;
- A functioning fishway was installed on Liverpool Weir in 1997 approximately 17km downstream; and

- This site was recognised as a high priority for improving fish passage in a recent report on barriers to fish passage in the Sydney Metropolitan CMA region (Nichols and McGirr 2005).

Hydrology

No hydrological flow data has been recorded for Georges River. Drown out has been predicted to occur during large flows and major river rises that follow significant rainfall events which typically occur from winter to late autumn. It is assumed that some fish passage is possible when flow through the breach is deep enough and there is a low to medium flow velocity present (during low flow periods smaller fish species would most likely be able to negotiate the breach despite low flow depth, but would be hindered as flow depth increased due to increases in water velocity and turbulence).

Operational Details

Testers Weir was constructed in 1919 as a town water supply weir to provide a domestic water supply. Campbelltown City Council owns the structure, and today the weir pool is used for swimming and recreational fishing. Currently 13 licensed extractors draw water from the Georges River, with up to 297ML per annum being licensed for removal both upstream and downstream of the weir. The Testers Weir pool provides water for stock, irrigation, and domestic use.

At the time of inspection the weir was breached by approximately 1.2 metres on the left side (as facing downstream). The remaining weir wall was intact and did not display a lack of structural integrity.

Ecological Considerations

In 1997 a fishway was installed on Liverpool Weir approximately 17km downstream. This now allows fish passage along the Georges River to Testers Weir, meaning that Testers Weir is now the most downstream obstruction to fish passage in the Georges River.

Although some fish passage over Testers Weir is possible during high flow events, the timing of these flows may not necessarily coincide with the migrations and movements of resident fish species within the Georges River system. For example Australian bass undertake a downstream spawning migration during winter/early spring (June to September) when water temperatures are between 14-19°C. A lack of adequate drown-out flows across barriers during this time would restrict access to estuarine spawning sites. Conversely a lack of drown-out flows outside of this period reduces the ability of adult fish to undertake upstream movement following their spawning migration. It also impedes the recruitment of juvenile stocks into freshwater habitats, which occurs from late spring to early summer.

Due to the requirement of this species (and others like it) to actively move between fresh and saline habitats, any impediment to fish passage can have an immediate effect on population size, health, and distribution. Native freshwater fish species that undergo significant migrations and are known to occur in the Georges River include: long finned eel, Australian bass, freshwater mullet, bullrout, Australian smelt, striped gudgeon, and Cox's gudgeon. Introduced species including goldfish and gambusia are also known to occur in this river.



Figure 2. Georges River downstream of Testers Weir (27/01/2005).

Native freshwater fish species that undergo significant migrations and are expected to occur in the Georges River basin include: freshwater herring, Australian grayling, southern blue-eye, common galaxias, climbing galaxias, short headed lamprey and non-parasitic lamprey. Introduced species including common carp are also expected to occur in this river (Creese and Hartley 2004).



Figure 3. Georges River upstream of Testers Weir (27/01/2005).

The Georges River contains important fish habitat components including riffles, large deep pools and cobble beds (Figures 2 and 3). The site has well vegetated banks with minimal erosion due to a rocky substrate. At the time of inspection aquatic vegetation was not present at this site, whilst riparian vegetation was dominated by banksias, matt rush, and small stands of eucalypts.

Proposed Remediation Actions

Although Testers Weir is breached and can provide limited fish passage at low and high flows, it is recommended that fish passage remediation activities be investigated to improve the frequency of fish passage past this structure.

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

The premise behind rock ramp and vertical slot fishways is to create a series of pools separated by small steps, so that an overall slope of 1:20 is created to provide fish passage. A partial width rock ramp fishway could be installed at the breach and utilise local rock (loose sandstone) from the weir breach. The cost of a fishway at this site is somewhat exacerbated however, due to the difficulty of accessing heavy machinery to the river. The fishway design would need to be operable under a wide range of flows, also potentially increasing costs however, if some of the rock rubble could be removed from the breach a smaller, more simplistic partial width rock ramp fishway could be installed below the breach. This would both cheapen costs and significantly improve fish passage at this site.

- **Option 2 – Complete removal**

The complete removal of this structure would provide the greatest benefit to the health of Georges River and provide improvements in the availability of aquatic and riparian habitat to fish and other aquatic organisms. However, despite not being on the National or State Heritage lists, Campbelltown Council has determined that this site is considered a local heritage item. As such complete removal is very unlikely.

- **Option 3 – Modification of existing breach rubble**

As this site is considered a local heritage item by local government, and complete removal very unlikely, fish passage may be improved at the site by manipulating the existing rock rubble present at the breach.

At present the rock rubble debris forms a barrier to fish passage at low-medium flows due to a steep slope gradient at the breach. By manipulating the rock debris where the gradient is steepest, the gradient could be lowered and fish passage reinstated. Works would not compromise the heritage status of this site, as all material would remain in place (although some would be repositioned). Modification of existing breach rubble is considered the cheapest of all alternatives currently available, despite potential issues with machinery access. This is the recommended option for this site, with further discussions recommended between NSW DPI and Campbelltown Council to determine machinery access issues.

Projected Remediation Costs

Projected cost	< \$50K	\$50K - \$150K	\$150K - \$250K	\$250K - \$500K
Option 1	✓			
Option 2	✓			
Option 3	✓			

Recommendation

As this structure has been deemed to have local heritage value, modification of the existing breach rubble (Option 3) is the preferred remediation action for this site. By moving some of the existing rubble to minimise the gradient encountered across the structure, fish passage at the site will be possible for the majority of flows.

Benefits Associated with Remediation

The Georges River system is important fish habitat that should be protected, and reinstatement of fish passage along the entire system will generate substantial benefits to the ecology of the catchment. By reinstating fish passage at the Testers Weir, in excess of 60km of habitat would again become accessible to fish and other aquatic organisms.

LANE COVE WEIR, LANE COVE RIVER



Figure 1. Lane Cove Weir, Lane Cove River at moderate river flow (3/2/05).



Figure 2. Entrance to fishway at moderate river flow showing headloss, flow depth and slope gradient at low tide (3/2/2005).

Description and Setting

Lane Cove Weir and fishway (Figure 1) is located in West Chatswood on Lane Cove River and is owned by the NPWS. Lane Cove River is a tributary of the Parramatta River (Port Jackson - Sydney Harbour), the confluence of which is approximately 10km downstream. The structure is a concrete and sandstone block fixed crest weir approximately 2.5 metres high and 20 metres across. A partial width rock ramp fishway was installed against the upstream right hand bank in 1997, and extends approximately 15 metres upstream. Three box culverts form the downstream entrance to the fishway, with two of these set approximately 300mm above a natural rock platform that extends to the downstream pool. The culverts restrict fish passage due to excessive head loss and minimal flow depth at all times other than near the peak of high tide (Figure 2).

During construction of the fishway the space between boulders forming the longitudinal rock ridges in the fishway (tombstone rocks) were filled in with grout, which now acts to impede flow and fish passage during low flow conditions.

The Lane Cove Weir and fishway is ranked as high remediation priority within the Sydney Metropolitan CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- Forms the tidal barrier between Lane Cove River and Sydney Harbour;
- Recognised recreational Australian bass fishing waterway;
- The site is located in the lower end of the catchment, with an upstream catchment area of approximately 30km²;
- Diverse range of native fish;
- Healthy instream and riparian habitat condition; and
- This site was recognised as a high priority for improving fish passage in a recent report on barriers to fish passage in the Sydney Metropolitan CMA region (Nichols and McGirr 2005).

Hydrology

Due to technical difficulties with the gauging station for Lane Cove River, flow data could not be provided for this site. As with most coastal draining systems in NSW, the hydrology of the Lane Cove River catchment is one of rapid peaks and falls. At certain times of the year the weir can be overtopped as a result of large river flows, but also as a result of extremely high tides (when water moves from the estuary upstream across the weir wall).

Operational Details

Lane Cove Weir was constructed in 1938 to provide a freshwater lake in one of Sydney's most popular picnicking spots, with the fishway only being constructed in 1997. The structure is owned by the Department of Environment and Conservation (National Parks and Wildlife Service), which manages the weir pool and adjacent picnicking area as part of Lane Cove National Park for its original purpose. The weir pool extends for approximately 5km upstream. Currently one licensed water extractor draws from the weir pool, with up to 150ML per annum being licensed for removal.

At the time of inspection the condition of the weir wall was poor, with large cracks funneling freshwater through the structure on the northern side (opposite side to the fishway). NPWS have advised that, although concerned about the integrity of the structure, it has no plans to repairs on the weir wall unless it is in danger of collapse.



Figure 3. Lane Cove River downstream of Lane Cove Weir and Fishway (3/2/2005).



Figure 4. Lane Cove River upstream of Lane Cove Weir.

Ecological Considerations

At present fish passage through the Lane Cove fishway is possible when sufficient flow rates in the river coincide with high tides in the estuary, thereby limiting the effectiveness of the fishway. When flows are low in the river, water depth cannot be maintained through the fishway despite the presence of high tides, which will inundate the lower half of the fishway and entrance culvert.

Despite fish passage being possible some of the time at this site, the timing of the flows and tides allowing passage may not necessarily coincide with spawning migrations of resident fish species within the system. Native freshwater fish species that undergo significant migrations and are known to occur in the Lane Cover River include: Australian bass, striped gudgeon, long finned eel, and short finned eel. Introduced species including goldfish, carp, and gambusia are also known to occur in this river. Native freshwater fish species that undergo significant migrations and are expected to occur in the Sydney Region include: freshwater mullet, Australian smelt, and Cox's gudgeon, freshwater herring, Australian grayling, southern blue-eye, common galaxias, climbing galaxias, short headed lamprey, and non-parasitic lamprey. Introduced species including common carp and gambusia are also expected to occur in this river (Creese and Hartley 2004).

Lane Cove River contains important fish habitat components including large deep pools, large woody debris and cobble beds. The site has well vegetated banks with erosion at fixed points frequented by canoe users upstream of the structure. At the time of inspection the aquatic vegetation was primarily introduced species such as *Sagittaria* spp. and *Elodea* spp. Riparian vegetation was dominated by eucalypts, casuarinas, and *Ficus* spp (Figures 3 and 4).

Proposed Remediation Actions

Negotiations with NPWS have determined that there are no issues with undertaking any of the following remedial measures to the fishway and its entrance, or to undertaking core sampling in the weir itself. Further discussions, including extensive community consultation, will be required should the de-watering of the weir pool be seen as the most appropriate alternative to fixing the leaks in the structure.

- **Option 1 – Weir structural and fishway improvements**

Leaks in the weir wall (Northern side):

In order to function correctly, it is important to maximise the flow through the fishway. At present several cracks in the weir wall on the northern side of the structure (opposite side to the fishway) enable significant volumes of water to escape, rather than pass through the fishway itself.

To minimise water loss through the structure, it is recommended that these leaks be corrected through the installation of sheet piling in the centre of the structure. Preliminary coring has been undertaken to determine weir composition, and has indicated that the visible sandstone blocks only cap the structure, with the weir generally composed of unconsolidated material. It has therefore been determined that sheet metal piling is possible to a maximum depth of 10 metres due to the unconsolidated fill material, and sand bedding.

An alternative option to fix the leaks is to de-water the weir pool (or part thereof), line the structure with geofabric and sandstone blocks on the upstream side, and allow the weir pool to refill.

This method would be extremely expensive and would impact on both the natural and social environment near the weir, to the extent of the weir pool (up to 5km upstream). Extensive community consultation would be required should this method be employed.

Headloss at fishway entrance (downstream end):

At the downstream entrance to the fishway, the shallow nature of the culverts and the ~300mm headloss at their downstream edge inhibit fish passage until tidal flow overtops this section. A way of overcoming this problem is to lower the level of that part of culvert to enable fish passage and to effectively create another resting pool at the downstream end of the fishway. Cutting into the structure at this location should not interfere with its structural integrity, as this part of the structure was constructed at the same time as the fishway.

Grout between the longitudinal rock ridges:

Wherever possible the grout between the longitudinal rock ridges along the fishway base should be removed to minimise headloss between resting pools and improve fish passage at lower flows. In addition, one of the resting pools is thought to be too small to act in the manner it is required, it is therefore recommended that the ridge rock defining this pool (approximately half way along the fishway) be removed to create a larger pool by combining with the pool adjacent.

Leaks in the fishway wall:

The longitudinal fishway wall that delineates the fishway from the river has some leaks near the downstream end of the fishway. These leaks act to attract fish, causing accumulations at this site, and decreasing movement up the fishway. It is recommended that any holes or gaps in the fishway wall should be identified and filled in conjunction with the removal of grout between longitudinal rock ridges.

- **Option 2 – Removal**

Removal is not supported by the structures owner, NPWS due to the value of the weir pool as a picnicking area and freshwater habitat, and the investment in the provision of fish passage to date (approximately \$70,000). Removal of the structure is therefore not an option at this time.

Projected Remediation Costs

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

Recommendation

Improvements to increase the effectiveness of the fishway and fix the leaks in the weir structure itself (Option 1) is the preferred remediation actions for this site due to the high recreational use of the site and significant expense applied to the provision of fish passage.

Benefits Associated with Remediation

The Lane Cove River system is important fish habitat that should be protected. Further improving fish passage within the system would generate substantial benefits to the ecology of the catchment. By improving fish passage at the Lane Cove fishway, in excess of 30km of habitat would again become accessible to fish and other aquatic organisms.

WOLLI CREEK WEIR, WOLLI CREEK, TURELLA



Figure 1. Wolli Creek Weir, Wolli Creek (9/2/05).

Description and Setting

Wolli Creek Weir (Turella Weir) is located on Wolli Creek adjacent the suburb of Turella in the Cooks River catchment (Figure 1). Wolli Creek is a tributary of Cooks River, the confluence of which is approximately 2km downstream. The structure is a concrete fixed crest weir, approximately 2 metres high and 13 metres across. During low to medium flow conditions, the weir restricts fish passage due to excessive head loss (750mm), minimal flow depth and an excessive slope gradient.

Wolli Creek Weir is ranked as a high remediation priority within the Sydney Metropolitan CMA region due to the following factors:

- The structure forms the tidal barrier in Wolli Creek, with a recreational fishing area (Botany Bay) located 2.5 - 3km downstream (confluence with Cooks River approximately 2km downstream);
- The site is located in the lower end of the catchment, with the upstream catchment area being approximately 20km²;
- A range of estuarine fish (including mullet) aggregating below structure;
- Several rehabilitation projects occurring on the surrounding lands, with local volunteers actively conducting riparian zone regeneration works upstream of site; and
- This site was recognised as a high priority for improving fish passage in a recent report on barriers to fish passage in the Sydney Metropolitan CMA region (Nichols and McGirr 2005).

Hydrology

No hydrological data has been recorded for Wolli Creek. Wolli Creek is a flood prone waterway, with a highly modified (channelised) upstream catchment collecting runoff from a basin that is nearly completely impervious (due to road sealing etc). In the last 20 months (to September 2005), three floods have been reported from this catchment. It is assumed that these floods would have drowned out Wolli Creek Weir and enabled fish passage around the structure.

Operational Details

Wolli Creek Weir was constructed in late 1800's as a road crossing and possibly as a freshwater supply for the adjacent Chinese market gardens. The structure has no formal ownership and currently serves no purpose except to maintain the upstream water level (weir pool), which preserves the health of an established freshwater riparian zone.

The site straddles the local government boundaries of Canterbury and Rockdale Council. Both local governments are assuming management of this site and are collaboratively eager to remediate fish passage.

Currently no licensed water extractors draw from the weir pool. At the time of inspection the weir was in working condition, although some cracks were evident allowing water to seep through.

Ecological Considerations

Although the upstream riparian and instream vegetation includes a range of exotic species, Wolli Creek is recognised as possessing a diverse and unique range of native plant species. Riparian vegetation adjacent the weir pool comprises introduced coral and willow trees, in addition to the introduced morning glory creeper (Figure 2). Casuarinas, common reed, and mangroves dominate the downstream riparian zone that borders the estuarine section of the creek (Figure 3).

During inspection of this structure, migratory fish species such as galaxiids and mullet were noted aggregating below this structure in large numbers (Morris *pers. obs.* 2005). Native freshwater fish species that undergo significant migrations and are expected to occur in Wolli Creek include: shortfinned eel, longfinned eel, Australian bass, freshwater mullet, bullrout, Australian smelt, striped gudgeon, Cox's gudgeon, freshwater herring, Australian grayling, southern blue-eye, common galaxias, climbing galaxias, short headed lamprey, and non-parasitic lamprey. Introduced species including goldfish, gambusia, and common carp are also expected to occur in this creek (Creese and Hartley 2004).

The river contains important fish habitat components including deep pools and channels, overhanging riparian vegetation, as well as instream woody debris. The site has moderately vegetated banks with minor erosion evident at fixed points upstream of the structure that are frequented by bush walkers. There are reinforced rock gabions on the left downstream bank, presumably to minimise undercutting of banks during flooding events.



Figure 2. Wolli Creek downstream of Wolli Creek Weir (9/2/2005).



Figure 3. Wolli Creek upstream of Wolli Creek Weir (9/2/2005).

Proposed Remediation Actions

Wolli Creek Weir currently limits fish movement from the estuarine section to the freshwater section of Wolli Creek at low to moderate flows. Remediation of fish passage at this site will improve fish recruitment within Wolli Creek and the Cooks River system, thereby improving the health of fish populations within Sydney's urban environment.

- **Option 1 – Removal**

The complete removal of this structure would provide the greatest benefit to the health of Wolli Creek and provide improvements in the availability of aquatic and riparian habitat. Removal of the structure would reinstate estuarine conditions upstream of the present weir structure however, which would lead to changes in riparian and aquatic vegetation types present. It is for this reason there is currently a lack of support for this initiative. In addition, it is also likely that important infrastructure now resides within the weir wall and may prevent the complete removal of this structure.

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

A partial width rock ramp fishway would provide adequate fish passage at this site. The benefits associated with the installation of a large structure such as this however, may be cost prohibitive, given the minimal habitat available upstream and unresolved structure ownership. In addition, minimal flows within the creek may limit the ability for this type of fishway to operate for the majority of the time, thereby reducing the cost benefit ratio for its construction.

- **Option 3 – Retrofit existing spillway (modified partial width rock ramp fishway)**

The current weir possesses a spillway near the top of the structure that has a slope of approximately 1:20. Given hydrological and monetary constraints associated with this structure and Wolli Creek itself, the most inexpensive option to provide fish passage at this site may be to retrofit the existing slope with a modified partial width rock ramp fishway.

Installation of transverse rock ridges across the spillway slope (perpendicular to the creek) will increase flow depth, reduce water velocity, and provide resting points for fish on the structure as they ascend the slope in a similar manner to a normal partial width rock ramp fishway during moderate to high flows. However, due to the hydrology of Wolli Creek, the fishway will only become operational at times of moderate-high flow. In addition, because the rock ridges can only be placed on the upstream half of the spillway, fish passage will only be possible when reasonable flows coincide with high tides. Despite these constraints, fish passage will be possible across the structure much more frequently than is currently possible.

Projected Remediation Costs

Projected cost	< \$50K	\$50K - \$150K	\$150K - \$250K	\$250K - \$500K
Option 1	✓			
Option 2		✓		
Option 3	✓			

Recommendation

Retrofitting the existing spillway with a modified rock ramp fishway (Option 3) is the preferred remedial action for this site. Retrofitting the existing spillway to provide for fish passage is the most cost effective solution for this site, but does limit the range of operation for the fishway to periods of moderate flow and at the upper end of the tidal cycle. The cost of installing a partial width rock ramp fishway that will operate in the majority of flow conditions is seen to be cost prohibitive, given the limited fish diversity present within Wolli Creek and the Cooks River. Stakeholders do not view removal of the structure as a viable option.

Canterbury and Rockdale Councils have recently applied for funding to undertake fish passage remediation works at this site, with Option 3 being the recommended action.

Benefits Associated with Remediation

NSW DPI staff agree that Wolli Creek is worth rehabilitating to improve viable fish habitat within an inner city urban environment. The reinstatement of fish passage at this site would provide substantial benefits to the ecology of the upstream catchment and its native fauna. By reinstating fish passage at this site, approximately 6km of habitat would again become accessible to fish and other aquatic organisms.

PASS OF SABUGAL WEIR/CAUSEWAY, WORONORA RIVER



Figure 1. Pass of Sabugal Weir, Woronora River (17/1/05, 6ML/day).

Description and Setting

Pass of Sabugal Weir (Figure 1) is located near Woronora Heights on the Woronora River. Woronora River is a tributary of the Georges River, the confluence of which is approximately 10km downstream. The structure is a concrete causeway 3 metres wide and approximately 40 metres across. It is built on a rocky platform and consequently its height varies between 300mm and 700mm, with flow directed both over the structure and through 400mm diameter pipes, located centrally, and on the northern side.

Immediately downstream of the structure a natural rocky platform extends approximately 100 metres forming both small pools and gentle riffles as well as producing minor natural barriers to fish passage during most low to medium flow periods.

The structure restricts fish passage at all but high flows and major river rises due to minimal flow depth over the causeway and high velocity through the submerged pipes.

The Pass of Sabugal Weir is ranked as a high remediation priority within the Sydney Metropolitan CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- Approximately 100m downstream a naturally rocky section known as “The Needles” forms the tidal barrier between Georges River and Woronora River;
- Recognised recreational bass fishing waterway;
- The site is located in the lower end of the catchment, with an upstream catchment area of approximately 100km²;
- Diverse range of migratory fish species noted aggregating below structure (downstream of the rock platform);
- Healthy instream and riparian habitat condition; and
- This site was recognised as a high priority for improving fish passage in a recent report on barriers to fish passage in the Sydney Metropolitan CMA region (Nichols and McGirr 2005).

Hydrology

Woronora River hydrological data was determined from the gauging station associated with this structure (210052). Information was sourced from the Sydney Catchment Authority (SCA) office in Penrith and used data acquired between 12/5/1992 and 6/10/2005. For the majority of time (80%) flows are equal to or exceed 3.4ML/day, while daily flows that equal or exceed 10ML/day occur less than 40% of the time. Medium sized flows of up to 30ML/day occur 10% of the time. Overall, large sized flow events over 100ML/day or more occur less than 3% of the time.

Highest flows are expected to occur from autumn to winter, while the lowest flows are experienced in summer. Both seasonal rainfall and environmental releases from Woronora Dam dictate flows in the Woronora River. Woronora Dam is managed by the SCA and is approximately 14km upstream. The dam stands 66 metres tall and 390 metres wide, with a total storage capacity of 71790ML. As a result of the size of the structure, Woronora Dam has a very large impact on the natural flow regime in the Woronora River.

Provisional environmental flow releases from Woronora Dam commenced 28 December 2002. Woronora River downstream of the dam now receives up to 50% of the inflows below 30ML/day and an annual high flow release of 800ML/day for a minimum of three days. Flows are predominantly static in their delivery, with minimal seasonal variation present.

Operational Details

The Pass of Sabugal was constructed by chain gang convicts around 1843 to provide a river crossing as part of the Old Illawarra roadway built by Thomas Mitchell between 1841 and 1843. This road provided access to Wollongong from the Menai area. The structure was named after a town in Portugal where Thomas Mitchell had served during the Napoleonic Wars.

The land this structure resides on is zoned 'SSC Environmental Protection Bushland' and has mixed ownership between Sutherland Shire Council and Department of Natural Resources (DNR). Sutherland Shire Council, DNR, Sydney Water, and the Rural Fire Service currently manage the area. There is a reliance on the weir pool for emergency access to water for fire fighting duties by local volunteer and Rural Fire Services. It also provides the only 4WD access across Woronora River for catchment management duties, and to access remote fires in the Woronora Valley. Currently no licensed water extractors draw from the weir pool.

The area around the structure is informally used for recreation purposes, especially during school holidays. The site has access from Barden Ridge to the north and Engadine to the South. Activities include bush walking, fishing, jogging, and cycling. This structure is the only way these users can cross the river in this section of the waterway during low – moderate flow periods.

A stone weir wall originally spanned the river on the upstream edge of the structure, but over time large flows have removed most of this part of the structure, with only some of the foundations and iron reinforcement still being evident. At the time of inspection the condition of the weir was considered poor with small to medium sized cracks evident.

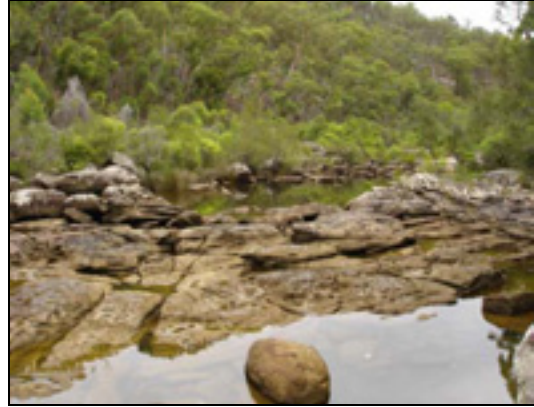


Figure 2. Woronora River looking upstream from below Pass of Sabugal Weir (17/1/2005, 6ML/day).

A)



B)



C)



D)



Figure 3. Woronora River habitat surrounding Pass of Sabugal Weir (17/1/2005, 6ML/day). A) looking downstream of “The Needles” and Pass of Sabugal Weir, B) looking upstream, 150 metres downstream of the weir, C) looking upstream at “The Needles”, 75 metres downstream of the weir, D) directly upstream of the weir.

Ecological Considerations

Although fish passage through Pass of Sabugal is possible when sufficient flow rates coincide with high tides, the timing of these flows may not necessarily coincide with spawning migrations of resident fish species within the system.

Fish surveys have been conducted in Woronora River to investigate if Macquarie Perch reside in this waterway. Although no Macquarie Perch were found, the study did find Australian smelt, long finned eel, Cox's gudgeon, striped gudgeon, flathead gudgeon, and Australian bass in Woronora River between Woronora Dam Wall and Heathcote Road (upstream of Sabugal Pass) (Bruce *et al.* 2001). Native freshwater fish species that undergo significant migrations and are expected to occur in the Woronora River include: short finned eel, freshwater mullet, bullrout, freshwater herring, Australian grayling, southern blue-eye, common galaxias, climbing galaxias, short headed lamprey, and non-parasitic lamprey. Introduced species including goldfish, gambusia, and common carp may also be expected to occur in this river (Creese and Hartley 2004).

While visiting this site the reviewer observed an unidentified species of mullet and gudgeon in the freshwater section of the river approximately 100 metres downstream of the weir, and a juvenile Australian bass 50 metres upstream of the structure (Morris *pers. obs.* 2005).

The river contains important fish habitat components including large deep pools, large woody debris, rocky overhangs, and cobble beds. The site has well vegetated banks with erosion at fixed points upstream of the structure frequented by swimmers and recreational fishers. *Sagittaria gamine* subs. *platyphylla* (introduced broad leaf emergent) was the most dominant aquatic plant and was found only upstream of the site in the weir pool. This species dominates in-stream vegetation on both banks. Riparian vegetation is dominated by eucalypts, casuarinas, and *Ficus* spp. (Figures 2 and 3).

Proposed Remediation Actions

Although Pass of Sabugal causeway does not present a barrier to fish passage at all flows, it is likely that it limits fish movement at medium flows. It is therefore recommended that this structure be remediated to allow for fish passage for the majority of flows within the Woronora River.

Fish friendly environmental flow regime

In addition to works facilitating fish passage past this structure, it is recommended that the regulated flow regime be managed in such a way to further improve fish passage and the condition of the riparian and aquatic habitat.

Environmental flows are currently released from Woronora Dam at more or less a static rate (regular flows delivered throughout the year). Whilst this provides for an overall environmental flow delivery mechanism, flows are not necessarily tuned to the requirements of migrating fish within the waterway. Therefore a fish friendly environmental flow regime that is tuned to the seasonal upstream and downstream migrations of native fish would substantially assist fish passage through "the Needles" as well as through the modified weir. It is recommended that a fish friendly delivery of environmental flows be combined with any remedial activities undertaken at the Pass of Sabugal Weir.

Discussions between NSW DPI, Sutherland Shire Council, DNR, and SCA are continuing to develop a remediation plan, which incorporates the needs of all stakeholders.

- **Option 1 – Removal**

The complete removal of this structure would provide the greatest benefit to the health of Woronora River and provide improvements in the availability of aquatic and riparian habitat to fish and other aquatic organisms. Complete removal however is not supported by the local Rural Fire Service (RFS), as they require both the weir pool and the crossing to perform emergency fire fighting duties in Woronora Valley.

- **Option 2 – Partial removal**

Due to the requirement for continued 4WD access across the Woronora River (particularly for controlling fires in remote areas), complete removal is not seen as an option for this structure. Discussions with Sutherland Shire Council, RFS, and the SCA, however have indicated that the partial removal of the structure is possible, provided access across the river is not compromised. It is proposed that a 3 metre section of the weir be removed where the central pipe is located. The lowering of this section down to the underlying bedrock will minimise the impact of the causeway on fish movement during moderate flows when the structure is accessible to fish (across the downstream rock platform and through The Needles). Approaches to the removed section will be graded to allow the continued passage of 4WD vehicles across the weir (3 metres either side). This is the preferred option for this site.

- **Option 3 – Install multiple low flow box cells**

In order to maintain access across Woronora River and allow for fish passage across the site, the current piped cells could be removed and replaced with multiple low flow box cells that are set to the level of the surrounding bedrock. This would provide fish passage during low flow conditions and would improve the ability of the structure to operate while experiencing flooding events. The cost of installing low flow cells at this site may be prohibitive however, especially considering the limited number of crossing users and the limited number of times when high flows coincide with access requirements.

Projected Remediation Costs

Projected cost	< \$50K	\$50K - \$150K	\$150K - \$250K	\$250K - \$500K
Option 1	✓			
Option 2	✓			
Option 3		✓		

Recommendation

Partial removal (Option 2), combined with the delivery of a fish friendly environmental flow regime for the Woronora River, are the preferred remediation actions for this site. At present a partnership between NSW DPI and Sutherland Council has been developed to allow for remediation of this site (implementing Option 2).

Sutherland Shire Council is at the development application stage, with NSW DPI committing funding for remediation of the structure as part of the demonstration site component of this project. Bass Sydney is undertaking fish sampling prior to, and following remediation of the structure.

Benefits Associated with Remediation

The Woronora River system contains important fish habitat that should be protected. The reinstatement of fish passage along the entire system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at the Pass of Sabugal Weir, in excess of 25km of habitat would again become accessible to fish and other aquatic organisms.

MCKELL AVENUE WEIR, HACKING RIVER, NEAR WATERFALL



Figure 1. McKell Avenue Weir, Hacking River (14/1/05).

Description and Setting

McKell Avenue Weir (also known as Waterfall causeway or Otford Weir - Figure 1) is located 4km from the township of Waterfall on the Hacking River and is jointly owned between NSW RTA and NPWS. The concrete structure is a disused road crossing that is acting as a fixed crest weir. It is approximately 3.5 metres high, 3.5 metres wide and 40 metres across. Six 600mm diameter pipes allow water to pass through the structure. During all flow conditions the weir restricts fish passage due to excessive head loss (3500mm).

McKell Avenue Weir is ranked as a high remediation priority within the Sydney Metropolitan CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- Although the site is located in the middle section of the catchment, the upstream catchment area is approximately 50km²;
- Diverse range of native fish species;
- Healthy instream and riparian habitat condition;
- Fish passage in the Hacking River is currently blocked by Audley Weir road crossing approximately 13km downstream, however fish passage will soon be possible past this site due to the construction of a fishway (currently at the final tender stage). The remediation of Audley Weir for fish passage, will elevate the importance of remediating this site and other man made barriers on the Hacking River located approximately 12km upstream from this site; and
- This site was recognised in the Southern Rivers Catchment Blueprint as a high priority for improving fish passage.

Hydrology

No hydrological flow data has been recorded for Hacking River. Drown out of McKell Avenue Weir has been predicted to occur only during extremely heavy flows, which are very rare in this section of the basin, although it is assumed that some fish passage is possible at these times. It should be noted that flows within the Hacking River are overall quite low, with periods of no flow causing the weir pool to dry out completely.



Figure 2. Hacking River downstream of McKell Avenue Weir (14/1/2005).



Figure 3. Hacking River upstream of McKell Avenue Weir (14/1/2005).

Operational Details

McKell Avenue Weir was constructed in 1938 as a road crossing, providing access to the Royal National Park from the township of Waterfall. As a result of construction a weir pool was also created, with an adjacent park and recreational area developed.

McKell Avenue Weir is no longer used as a road crossing due to a bridge being installed immediately downstream; its primary role today is to offer aesthetics to the adjacent recreational area and provide an emergency source of water for firefighting duties in this section of the park. No licensed water extractors exist in this section of the catchment.

Ecological Considerations

A partial width rock ramp fishway for Audley Weir is at the final tender stage. Once complete, this will allow unimpeded fish passage up to the McKell Avenue Weir.

Native freshwater fish species that undergo significant migrations and are expected to occur in the Hacking River include: short finned eel, long finned eel, Australian bass, freshwater mullet, bullrout, Australian smelt, striped gudgeon, Cox's gudgeon, freshwater herring, Australian grayling, southern blue-eye, common galaxias, climbing galaxias, short headed lamprey, and non-parasitic lamprey. 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 riffles, large deep pools and cobble beds. The site has well vegetated banks with minor erosion at fixed points adjacent to the structure that are frequented by bush walkers and people using the adjacent park. At the time of inspection, aquatic vegetation was present at this site but in very low numbers (unknown species). Riparian vegetation was dominated by eucalypts, *Ficus* spp., small stands of casuarinas, tea tree, and banksias (Figures 2 and 3).

Proposed Remediation Actions

All options outlined below will require further discussions with the structure owners (NPWS and RTA), and surrounding land managers (NPWS) before any work can be undertaken.

Given the high frequency of recreational users in the adjacent parkland, the installation of a bypass channel or partial width rock ramp fishway at this site would help to highlight the need for improving fish passage in NSW rivers and the remediation efforts being undertaken by management agencies.

- **Option 1 – Bypass channel fishway**

Given the height of the structure (approximately 3.5 metres), a bypass fishway may be a viable option for this site. There is enough space on the adjacent banks to allow construction of a channel. The upstream entrance to the channel should be positioned below a box cell installed into the structure. Below the structure, the channel could either continue downstream along the bank or connect with a partial width rock ramp fishway (slope of 1:20).

In order to allow the bypass channel to operate effectively, it may be necessary to block flow in some or all of the six piped cells to redirect flow exclusively down the channel and create attraction flows adjacent to downstream entrance. The viability of a bypass fishway at this site needs to be investigated further with NPWS and the RTA.

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

The installation of a partial width rock ramp fishway appears to be the most viable option for this site given the rocky nature of the area immediately downstream and the height of the weir.

A partial width rock ramp fishway at a slope of 1:20 would need to extend approximately 70 metres to the downstream entrance. Due to its size, a reverse leg arrangement set against the weir wall would be the most appropriate design, allowing attraction flows to guide fish to the fishway entrance, and to minimise the area downstream affected by the fishway construction.

In addition, the effective height of the structure could be lowered, and the overall length of the fishway decreased through the installation of box culvert cells in the weir itself. This would allow flows to be directed down the fishway, although would also cause a decrease in the weir pool height. Further discussions between NPWS and NSW DPI are required to determine if this is possible.

Due to the small nature of flows in the Hacking River, a full width rock ramp fishway spanning the length of the structure would not be able to operate effectively. A full width rock ramp fishway is therefore not recommended for this site.

- **Option 3 – Removal**

The complete removal of this structure would provide the greatest benefit to the health of Hacking River and provide improvements in the availability of aquatic and riparian habitat to fish and other aquatic organisms. However the reliance of NPWS on the weir pool as an emergency water supply for fire fighting excludes removal as a possibility.

Projected Remediation Costs

Projected cost	< \$50K	\$50K - \$150K	\$150K - \$250K	\$250K - \$500K
Option 1		✓		
Option 2			✓ (partial width)	
Option 3		✓		

Recommendation

The construction of a partial width rock ramp fishway (Option 2) is the preferred remediation action for this site, as it would have the least impact on both the surrounding land and the weir pool level.

Benefits Associated with Remediation

The Hacking River system is important fish habitat that should be protected. 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 McKell Avenue Weir, in excess of 24km of habitat would again become accessible to fish and other aquatic organisms.

WOOLLEN MILL WEIR, DARLING MILLS CREEK, NORTH PARRAMATTA



Figure 1. Woollen Mill Weir, Darling Mills Creek (3/2/05, 2.6ML/day).

Description and Setting

Woollen Mill Weir is located on Darling Mills Creek in North Parramatta at the junction of North Rocks Road and Windsor Road. Darling Mills Creek is a tributary of the Parramatta River, the confluence of which is approximately 700 metres downstream. There is no formal ownership of the fixed crest concrete structure, which is approximately 1 metre high and 10 metres across the crest. During most flow conditions, the weir restricts fish passage due to excessive head loss.

The Woollen Mill Weir is ranked as a high remediation priority within the Sydney CMA region due to the following factors:

- Class 2 fish habitat (known fish habitat);
- The site is located in the lower end of the catchment and the upstream catchment area is roughly 30km²;
- Lack of formal ownership and current use;
- Following remediation works on weirs located downstream on Parramatta River (2006-07 financial year) this site will become the next major impediment to fish passage; and
- This site was recognised as a medium priority for improving fish passage in a recent report on barriers to fish passage in the Sydney Metropolitan CMA region (Nichols and McGirr 2005).

Hydrology

Hydrological flows were determined from the Darling Mills Creek gauging station (213017) that is operated by the Upper Parramatta River Catchment Trust. This gauging station was installed at the weir structure itself to monitor flows following extensive flooding that occurred in Parramatta in 1986. Data was only available for a five year period (2001-2005).

It is not known what flows will drown out this structure, however significant flooding events that could have drowned out the structure occurred in August 1986, April 1988, December 1988, February 1990, and June 1991. In response to continued flooding of Parramatta City centre and surrounds, a retaining basin wall approximately 30 metres high was installed in the upper catchment in 1996 to control flooding events in the lower catchment.

Over the five year period of records (2001-2005), flows were observed to be very variable - in the range of 0 to 3424ML/day, with an average of approximately 204ML/day.

Small flows of up to 30ML/day occurred for the majority of the time, with sharp peaks sometimes occurring several times a month (rising to thousands of mega litres per day in only a few hours). The peaky nature of flows within Darling Mills Creek reflects the impervious (developed) nature of much of the surrounding catchment.

For the five year time period, high flow periods predominantly occurred in autumn/early winter and late spring/early summer, whilst low flow conditions occurring in late winter/early spring and late summer/early autumn.

Operational Details

Woollen Mill Weir was constructed in conjunction with a woollen mill that was established in the early 1800's. The structure has no formal ownership and does not currently serve any purpose, however both the Shire of Baulkham Hills and Parramatta City Council recognise the structure as a Local Heritage Item. Woollen Mill Weir resides on the boundary between these two councils, with the responsibility for management of the site being shared between them. No licensed extractors currently draw water from the weir pool. At the time of inspection the weir was in working condition.

Ecological Considerations

Four weirs present on Parramatta River have previously formed barriers to fish passage within the Parramatta River catchment. All four of these weirs have fishways proposed for installation, with their construction being at the tendering stage (construction in 2006-07 financial year). Once all four weirs have fishways installed, there will be unimpeded fish passage within the catchment up to Woollen Mill Weir.

Native freshwater fish species that undergo significant migrations and are expected to occur in Parramatta River and Darling Mills Creek include: shortfinned eel, longfinned eel, Australian bass, freshwater mullet, bullrout, Australian smelt, striped gudgeon, Cox's gudgeon, freshwater herring, Australian grayling, southern blue-eye, common galaxias, climbing galaxias, short headed lamprey, and non-parasitic lamprey. Introduced species including goldfish, gambausia, and common carp are also expected to occur in this creek (Creese and Hartley 2004).

Darling Mills Creek contains important fish habitat components including deep pools and overhanging branches. This site has well vegetated banks dominated by exotic species such as lantana and willows, with small stands of native *Ficus* spp. also present.



Figure 2. Darling Mills Creek downstream of Woollen Mill Weir (3/2/05, 2.6ML/day).



Figure 3. Darling Mills Creek upstream of Woollen Mill Weir (3/2/05, 2.6ML/day).

Erosion is present at fixed points, and is significant approximately 125 metres upstream, where undercutting of the left hand bank should be addressed as a matter of priority. At the time of inspection, some aquatic vegetation was present at the site, and was dominated by parrots feather (*Myriophyllum* spp.). It is recommended that in order to improve fish habitat at this site, native riparian zone plantings and bank stabilisation works should be undertaken either side of the weir.

Due to the possible use of pollutants by the woollen mill in the past, and the continued use of the surrounding area for light industry, testing of the substrate behind the weir wall is recommended prior to any works being undertaken at the site.

Proposed Remediation Actions

- **Option 1 – Full or partial removal**

The complete removal of this structure would provide the greatest benefit to the health of Darling Mills Creek and improve the availability of upstream aquatic and riparian habitat. However, this structure is considered to be a Local Heritage item by both the Shire of Baulkham Hills and Parramatta City Councils, with complete removal therefore unlikely. As an alternative, partial removal or lowering of the weir wall may be possible. Partial removal would facilitate fish movement past the site at a greater range of flows, but may compromise the integrity of the structure during high flow events. If the structure is lowered, the number of times the structure is overtopped would increase, thereby providing fish passage at the site more often. Lowering the structure would also decrease the cost of any potential fishway installed (by lessening the amount of materials required to build the fishway), and would minimise the impact on the heritage status of the site.

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

This site would be well suited to a partial width rock ramp fishway, which could utilise the rock platform on the left abutment as its foundation. It should be recognised that this option may be an expensive one for this site, due to the fair condition of the surrounding waterway. Despite the lack of formal ownership, correspondence with the Shire of Baulkham Hills has indicated that they are in the process of applying for external funds to construct a fishway at this site. Further discussions are recommended between NSW DPI, the Shire of Baulkham Hills, and Parramatta City Councils to determine the most appropriate design fishway for this site, and requirements of all stakeholders.

Projected Remediation Costs

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

Recommendation

If removal of the structure cannot be undertaken (Option 1), then the preferred remedial action for this site is the installation of a partial width rock ramp fishway (Option 2). Following remediation of the four weirs downstream on the Parramatta River, Woollen Mill Weir will increase in priority for reinstating fish passage within the Parramatta River catchment. The Shire of Baulkham Hills is currently in the process of obtaining external funds to construct a fishway at this site, it is recommended that NSW DPI work with the Shire of Baulkham Hills to determine the most appropriate fishway design for this site.

Benefits Associated with Remediation

NSW DPI staff agree that Darling Mills Creek should be rehabilitated to improve fish habitat within the creek. Improving fish passage in the middle to upper sections of this system would generate substantial benefits to the ecology of Parramatta River catchment. By reinstating fish passage at Woollen Mill Weir, in excess of 15km of habitat would again become accessible to fish and other aquatic organisms.

WEDDERBURN WEIR, GEORGES RIVER



Figure 1. Wedderburn Weir, Georges River (27/01/2005).

Description and Setting

Wedderburn Weir (Figure 1) is located near the township of Wedderburn on the Georges River. The structure is a piped road culvert constructed of concrete and is owned by Campbelltown Council. The structure is approximately 2.5 metres high and 15 metres long with seven cells approximately 1.5 metres in diameter set on an apron 20cm above streambed level. During low to medium flow conditions, the weir restricts fish passage due to minimal flow depth and excessive head loss (Figure 3B). During high flows the weir restricts fish passage due to excessive flow velocity.

Wedderburn Weir is ranked as a high remediation priority within the Sydney Metropolitan CMA region due to the following factors:

- Class 1 fish habitat (major permanently flowing waterway);
- Although the site is located in the middle of the catchment, the upstream catchment area is approximately 300km²;
- Diverse range of native fish found downstream including a popular recreational Australian bass fishery;
- Healthy instream and riparian habitat condition; and
- This site was recognised as a high priority for improving fish passage in a recent report on barriers to fish passage in the Sydney Metropolitan CMA region (Nichols and McGirr 2005).

Hydrology

No hydrological flow data has been recorded for Georges River. Drown out has been predicted to occur during large flows and major river rises following significant rainfall events which typically occur from winter to late autumn. It is assumed that some fish passage is possible during this time when flow over the structure is deep enough and there is a low to medium flow velocity present at the edge of the river.

Operational Details

Wedderburn Bridge was washed away during heavy flooding in 1986. A Bailey Bridge was installed by the army and remained until the causeway was built in mid 1987. The structure also provides a weir pool supplying water for stock, irrigation and domestic purposes. Currently 13 licensed extractors draw water from the Georges River, with up to 297ML per annum being licensed for removal.

Ecological Considerations

In 1997 a fishway was installed on Liverpool Weir, which forms the tidal barrier for the Georges River. Since installation of the fishway on Liverpool Weir, fish passage has become possible upstream to Testers (Ingleburn) Weir (located approximately 24km downstream of Wedderburn Weir) during moderate – high flows. Testers Weir acts as a barrier to fish passage at low to moderate flows due to excessive headloss and steep gradient across a breach in the structure. Opportunities for remediation of fish passage at Testers Weir will enable fish to move upstream to Wedderburn Weir.

Due to the requirement of some native fish to actively move between fresh and saline habitats, any impediment to fish passage can have an effect on population size, health and distribution. Native freshwater fish species that undergo significant migrations and are known to occur in the Georges River include: long finned eel, Australian bass, freshwater mullet, bullrout, Australian smelt, striped gudgeon, and Cox's gudgeon. Introduced species including goldfish and gambusia are also known to occur in this river. Native freshwater fish species that undergo significant migrations and are expected to occur in the Georges River basin include: freshwater herring, Australian grayling, southern blue-eye, common galaxias, climbing galaxias, short headed lamprey, and non-parasitic lamprey. Introduced species including common carp are also expected to occur in this river (Creese and Hartley 2004).

The Georges River contains important fish habitat components including riffles, large deep pools and cobble beds. Although the site has moderate to well-vegetated banks upstream and downstream of the site (Figures 2, 3A, and 4), extensive erosion is evident in and around the downstream weir pool. This eroded sediment has gradually filled in the downstream channel, allowing a dense stand of cumbungi (bulrush) to develop and severely reduce the available aquatic habitat (Figure 4).

At the time of inspection, aquatic vegetation at this site was dominated by cumbungi with some introduced water hyacinth present in the upstream weir pool. Eucalypts, banksias, and exotic weeds dominated riparian vegetation.



Figure 2. Habitat directly downstream of Wedderburn Weir showing dense stands of cumbungi blocking channel (27/01/2005).



Figure 3. Wedderburn Weir, Georges River (27/01/2005) showing A) habitat downstream of structure, B) apron with 200mm headloss and minimal flow depth (downstream side).



Figure 4. Georges River upstream of Wedderburn Weir (27/01/2005).

Proposed Remediation Actions

- **Option 1** – Remove apron and install low flow box cells

Figures 1 and 3B show that fish passage at this site is blocked by the presence of the downstream apron (low flow depth) and pipe culverts (creating linear water velocities through the structure at times of flow and minimal flow depth at low flow periods).

To minimise the effect of the structure on fish passage, it is recommended that two or more low flow box culvert cells be installed into the structure, and the downstream apron removed. Provision of low flow cells will direct flow through one or two cells, enhancing water depth through the structure at low flows and allowing some of the surrounding substrate to settle in the culvert itself (minimising potential behavioural barriers as a result of change of substrate type). Removal of the downstream apron will aid allowing fish to reach the culvert so that they may pass through, in addition to minimising behavioural aversion to the site.

In addition to works on the structure itself, it is also necessary to rehabilitate the aquatic habitat in the downstream weir pool to prevent further bank erosion, destabilisation, and scouring on the downstream edge during flooding events.

- **Option 2** – Remove and replacement with a bridge

The complete removal of this structure would provide the greatest benefit to the health of Georges River and provide improvements in the availability of aquatic and riparian habitat to fish and other aquatic organisms. However this is the only crossing on the Georges River available to residents of Wedderburn, which therefore negates the possibility of complete removal without provision of another crossing point.

Removal of the existing structure and replacement with a standard bridge may not be financially viable however. Given the narrow width of the river channel at this site, a prefabricated Doolan Deck Bridge (~\$300,000) may be a viable option for this site. 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.

It is therefore recommended that a cost benefit analysis against Options 1 and 2 should be undertaken to identify the most effective and economically viable option for this site.

Projected Remediation Costs

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

Recommendation

The removal of the apron and installation of multiple low flow box cells (Option 1) is the preferred remediation action for this site, although a cost benefit analysis for the installation of a Doolan Deck Bridge is also recommended.

Installation of a structure such as a Doolan Deck Bridge may minimise future expenditure on the site, such as ongoing maintenance issues.

Benefits Associated with Remediation

The Georges River system contains important fish habitat that should be protected. Reinstatement of fish passage along the entire Georges River system would generate substantial benefits to the ecology of the catchment. By reinstating fish passage at the Wedderburn Weir, in excess of 40km of upstream 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 modification replacement
maintenance

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 register at <http://www.heritage.nsw.gov.au>.

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

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

SECTION 4 WEIR SETTING

4a (i) What is the stream classification of the watercourse at the weir location? (please refer to appendix 2)
(ii) How wide is the watercourse upstream of the weir pool (beyond the influence of the weir)?
 (m)
(iii) Is the watercourse a tributary, anabranch, or floodrunner?

4b (i) What is the total catchment area upstream of the weir?
 (sq. km)
(ii) What is the proportion of the catchment controlled by the weir (upstream to the next river bed obstruction include natural and artificial).
 %

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

(km) Structure name and/or type

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

(km) Structure name and/or type

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

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

Please provide details:

.....

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

.....

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

Upper Middle Lower

SECTION 5 HYDROLOGY INFORMATION

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

..... (m)

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

.....(m)

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

Yes / No (m)

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

Yes / No Yes / No

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

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

Comments:

.....

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

..... (per year) OR don't know

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

If yes where is the information held or located?

.....

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

Yes / No / don't know

Please describe:

.....

(iii) **Has there been any changes to groundwater levels in the vicinity of the weir pool?**

Yes / No / don't know

SECTION 6 GEOMORPHIC INFORMATION

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

Yes / No / don't know

Comments:

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

Intact [] minor erosion [] extensive erosion []

Please describe:

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

Intact [] minor erosion [] extensive erosion []

Please describe:

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

Intact [] minor erosion [] extensive erosion []

Please describe:

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

Yes / No / don't know

Please describe:.....

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

..... (m)

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

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

(Please provide details.....)

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

Yes / No Please describe

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

Yes / No

Please describe:

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

Yes / No / don't know

SECTION 7 ECOLOGICAL CONSIDERATIONS

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

Yes / No structure type:

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

Yes / No / don't know

Comments:

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

.....
.....

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

.....
.....

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

Yes / No

Comments:

.....

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

Yes / No/ don't know

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

..... season (frequency)

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

Well vegetated moderately vegetated poorly vegetated

Dominant species present (including native and introduced):

.....

Please comment on native riparian vegetation and introduced plant species:

.....

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

Yes / No

Comments:

.....

.....

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

<5% 5-10% 10-30% <30%

Dominant species present (including native and introduced):

.....

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

Yes / No / Don't know

Comments

.....

.....

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

Yes / No / partial one side / both sides

Comments:

.....

(ii) Do stock have access to the river?

Yes / No / partial one side / both sides

Comments:
.....

SECTION 8 RECOMMENDATIONS

8a Removal Option YES / NA (please circle)

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

Comments:
.....

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

Comments:
.....

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

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

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

Comments:
.....

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

Please describe:
.....

(vi) Is the weir remote/difficult to access? Yes / No
If Yes, please describe access/location (Is there all weather access?)

.....

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

8b Fishway options YES/NA (please circle)

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

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

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

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

8c Modification of Structure to allow for fish passage

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

.....

(II) ESTIMATED COST OF PROPOSED WORKS

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

Comments (Include supporting literature and correspondence)

.....
.....
.....
.....

8e No action recommended

Comments (Include supporting literature and correspondence)

.....
.....
.....
.....

SECTION 9 ADDITIONAL INFORMATION

For further information:

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

Appendix B: Weir Prioritisation Scheme for NSW Coastal CMAs

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

Appendix C: Weir Prioritisation Scheme for NSW Inland CMAs

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

