The Living Murray
One River. One Life. Our Future.

Resnagging and Riparian Restoration: Hume Dam to Yarrawonga

Project Implementation Feasibility Study

June 2005

Photos: Parks Vic and DPI

NORTH EAST CATCHMENT MANAGEMENT AUTHORITY

Victoria
The Place To Be

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Department of Infrastructure, Planning and Natural Resources

Executive Summary

The *Re-snagging and Riparian Restoration - Hume Dam to Yarrawonga* Project is funded under The Living Murray's Environmental Works and Measures Program and aims to enhance native fish habitat within this reach of the river. This will be achieved through reinstating instream woody habitats and revegetating the riparian zone in priority areas. The project will enhance connectivity with existing instream habitat areas, while also demonstrating to the community the benefits of these actions on river health.

This Feasibility Study follows on from the *Hume Dam to Yarrawonga Instream and Riparian Habitat Restoration Plan 2004* (DPI, 2004). The Restoration Plan was developed as a template for the instream woody and riparian habitat rehabilitation of the Hume Dam to Yarrawonga reach of the River Murray. The Plan identified three priority areas for resnagging, and the necessary woody habitat loads required in each of these areas. A detailed Resnagging Design Plan has been developed for these three priority resnagging areas.

The aim of this report is to present the findings of a Feasibility Study, which considers the likely impacts and logistical issues associated with the implementation of the Restoration Plan's proposed program of resnagging the three priority areas.

Key issues assessed within the Feasibility Study include the benefits of resnagging activities to the ecology of the river reach and the logistics of the resnagging program, for example sources of woody habitat, and access to resnagging sites. The most cost effective methods of conducting such a large scale resnagging project are outlined in this report.

Based on the Feasibility Study it can be concluded that the implementation of the *Resnagging and Riparian Restoration – Hume Dam to Yarrawonga* project is feasible. An assessment of the logistical issues surrounding project implementation reveal that the proposal is achievable and can be managed in a cost effective manner.

Figure 3: River Murray at Priority Area 2 (photo: DPI)

Table of Contents

1 Background – Project Overview

The *Resnagging and Riparian Restoration - Hume Dam to Yarrawonga* project is funded under *The Living Murray Environmental Works and Measures Program*, which aims to rehabilitate significant ecological assets in the Murray-Darling Basin. The River Murray channel was chosen as one of six significant ecological assets, in which a suite of operational and structural works will be implemented to restore the system to healthy working condition.

The *Resnagging and Riparian Restoration – Hume Dam to Yarrawonga* project aims to provide enhanced instream habitat through resnagging and restoration of the adjacent riparian zone to secure the long-term viability of existing native fish populations between Hume Dam and Yarrawonga. To achieve this, several objectives have been identified:

1. Restore sufficient in-channel habitat through resnagging to secure the long-term viability of existing native fish populations (including Murray cod, trout cod and golden perch),

2. Restore sufficient riparian vegetation to reconstruct lateral connectivity between riparian and in-channel habitats to allow nutrient and energy transfer between these habitats, provide trees for the future recruitment of in-channel snag habitat and provide an ecologically viable riparian zone,

3. Connect the remaining small isolated patches of aquatic habitat to create large viable areas of habitat,

4. Protect the remaining intact sections of the riparian zone and connect remnant sections to create large viable areas of terrestrial habitat,

5. To demonstrate the contribution to native fish restoration that riparian and in-channel restoration can deliver as part of an integrated river rehabilitation program (demonstration reach concept),

6. To demonstrate the benefits of in-channel and riparian restoration in improving channel (main channel and anabranch) stability,

7. To apply active adaptive management principles to the project.

The first stages of the project involved an assessment of existing habitat throughout the reach. Instream woody habitats (snags) were assessed on their location, size, complexity, alignment and depth, and the riparian vegetation communities were assessed for presence/absence and connectivity. This data was presented in a Compendium of Data (DPI, 2004a, as appears in figure 1).

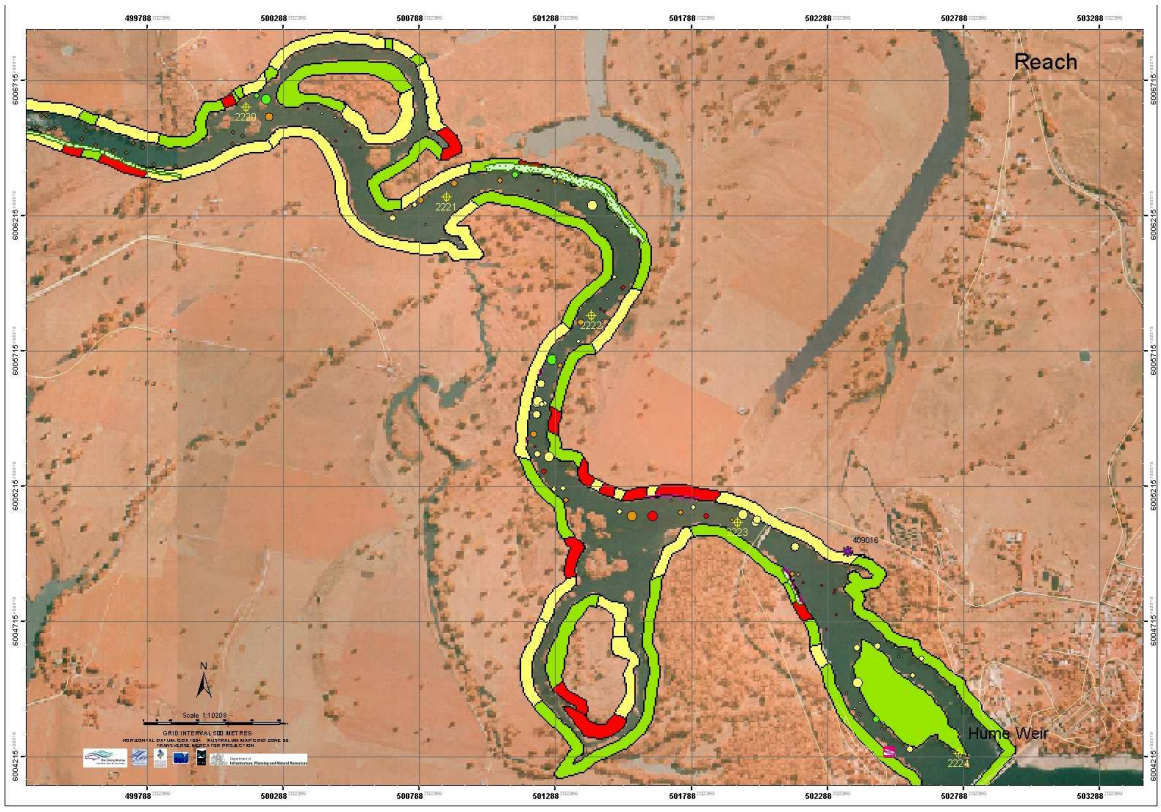

Figure 1: Output from habitat assessment as presented in Compendium of Data (DPI, 2004a)

From this data, a target instream woody habitat load was calculated. This benchmark estimates the level at which woody debris should occur to maintain native fish populations within the reach.

The resultant *Hume Dam to Yarrawonga Instream and Riparian Habitat Restoration Plan 2004* (DPI, 2004) was developed as a template for the rehabilitation of the Hume Dam to Yarrawonga reach. The Restoration Plan identified three priority areas for resnagging using data from the habitat assessment and knowledge of the number and location of woody habitats previously removed. The selection of these priority areas also took into account connectivity with existing healthy instream habitat (see section 4 for more detail).

An integral part of developing a river reach Restoration Plan was to ensure that priority actions are compliant with relevant legislation and Management Plans. The *Community Engagement and Communication Strategy 2004 – 2010* has been adopted as a key aspect of the resnagging project, to ensure efficient community and stakeholder consultation.

This Feasibility Study is the next step in the planning stages of the project, and will lead on to form the basis of an Investment Strategy for implementing on ground works commencing in the 05/06 period.

2 List of Project Partners and their Roles

The *Resnagging and Riparian Restoration – Hume Dam to Yarrawonga* project is overseen by a steering group, made up of members from various agencies, as listed in table 1.

Table 1: Project partners and their roles

Partner agency	Role
Murray Darling Basin Commission (MDBC) (incorporates River Murray Water)	The Living Murray Initiative, established by the Murray Darling Basin Commission (MDBC), aims to maximise ecological benefits for six significant ecological assets. The *Resnagging and Riparian Restoration – Hume Dam to Yarrawonga* project is one of many progressing on the River Murray Channel. The *Living Murray Environmental Works and Measures Program* provides the necessary funding for the restoration project.
North East Catchment Management Authority (NECMA)	North East Catchment Authority has been contracted by MDBC as the proponent (project manager) for the *Resnagging and Riparian Restoration – Hume to Yarrawonga* project.
NSW Department of Primary Industries (DPI - Fisheries)	NSW DPI was previously contracted to conduct an instream and riparian habitat assessment, and authored the *Instream and Riparian Habitat Restoration Plan, 2004* (DPI (2004)), which recommends priority resnagging sites. DPI has more recently been contracted to conduct this feasibility study and will develop an investment proposal for the 05/06 period.
Vic Department of Sustainability and Environment (DSE) (incorporates Arthur Rylah Institute)	ARI implemented and evaluated resnagging in the River Murray below Yarrawonga. ARI will be delivering a monitoring program for the resnagging component of the restoration project.
NSW Department of Infrastructure, Planning and Natural Resources (DIPNR)	DIPNR will be conducting a detailed riparian vegetation assessment (in conjunction with DPI), recommending priority areas for revegetation and implementing a riparian rehabilitation and protection plan, in line with the Riverworks program.

Other agencies and groups that will continue to be involved and consulted during the progression of *Resnagging and Riparian Restoration – Hume Dam to Yarrawonga* project include:

- Advisory Group on Hume to Yarrawonga Waterway Management,
- Murray Catchment Management Authority,
- Local Councils,
- Parks Victoria and NSW Forests,
- NSW Maritime, and
- the local community and waterway users through representative groups and local landholder liaison.

Further information regarding the project's compliance with existing legislation is provided in section 3.2.

3 Feasibility of Project Implementation

The *Resnagging and Riparian Restoration – Hume to Yarrawonga* project is a pioneering project, as the largest scale resnagging project to occur in the relatively short history of resnagging in south-eastern Australia.

An initial step in developing a strategic plan for resnagging in the River Murray involved a trial resnagging project. In 2001 Nicol, Lieschke, Lyon and Hughes implemented and evaluated resnagging of over 300 large river red gum snags in 14 trial sites in the Yarrawonga to Tocumwal reach of the River Murray (Nicol *et al*, 2002), see figure 2. This project developed a decision support tool for large scale resnagging, outlined practical and cost effective techniques for resnagging and assessed the response of native fish and the site characteristics and locations in which resnagging is most beneficial to native fish.

Figure 2: Resnagging in the River Murray below Yarrawonga (Photo: ARI)

While this scientific trial project provided a valuable insight into the logistics of resnagging, there were many other logistical issues that need to be addressed before large scale resnagging can be implemented. Through a series of stakeholder workshops and liaisons, some frequently asked questions arose:

- How will the resnagging design plan maximise benefits to native fish while also taking into account the concerns of other waterway users?
- Is there sufficient timber available to meet the woody habitat load requirements for the three priority reaches, and for further project expansion into the future?
- What are the most cost effective methods of relocating and reinstating timber?
- Will access through private property be a constraint for resnagging in priority areas?
- How will woody habitats be placed and secured to reduce the risk of bank erosion and “runaway snags”?

3.1 Ecological Benefits of the Project

3.1.1 Benefits for Native Fish

Instream habitat loss through removal of woody habitat (de-snagging) is one of the primary threats to native fish species, and has consequently been listed as a Key Threatening Process under Schedule 6 of the *Fisheries Management Act 1994*. Some key woody habitat – fish associations include:

- *refuges from predators and interactions between competitors,*
- *velocity refuges that minimise energy costs of swimming,*
- *spawning sites essential for successful reproduction,*
- *home range markers for territorial and migratory species, such as the Murray Cod (Maccullochella peelii peelii) and Golden Perch (Macquaria ambigua),*
- *refuge and spawning habitats in the riparian zone during overbank flooding,*
- *temperature and drought refuges formed by scouring of deep holes adjacent to large woody debris.*

(Fisheries Scientific Committee 2002)

One of the key project deliverables of the *Resnagging and Riparian Restoration – Hume Dam to Yarrawonga* project is *"the establishment of sufficient quality of habitat to sustain populations of trout cod, Murray cod and golden perch".* These large bodied native fish species have been chosen as indicator species for assessing any resultant changes in the native fish community.

Numerous research reports have demonstrated the importance of instream woody habitat for these indicator species, as well as other species including river blackfish (*Gadopsis marmoratus*) (Cadwallader, 1978; Growns *et al*, 2004; Nicol *et al*, 2002). This project will enhance woody habitat loads in this river reach with the aim of improving habitat opportunities for these native fish.

Proven benefits of resnagging in the River Murray on these native species have been documented by Nicol *et al* (2002). The scientific resnagging trial below Yarrawonga assessed whether native fish would successfully utilise reintroduced woody habitat. The results clearly demonstrated that native fish responded positively to the addition of woody habitat through resnagging.

Research has also indicated each fish species' preference of woody habitat locations within the river channel (eg position in bend, distance from bank) and characteristics (hollows and snag piles), as further discussed in section 4.2.3.

During the implementation phase, the project's Monitoring Plan will effectively gauge the benefits of resnagging for native fish in the Hume Dam to Yarrawonga reach. Results will then be fed back into the Resnagging Design Plan (see Appendix 2) as an adaptive management feature, to make best use of available knowledge.

3.1.2 River Murray System

Woody habitats play an important ecological role in rivers. They provide stable physical habitat for biota at all levels of the food chain, ranging from microscopic bacteria, fungi, algae and aquatic plants, to macroinvertebrates and fish. Woody habitats contribute to the ecological processes of productivity and respiration through the provision of sites for carbon and nutrient processing and as a basis for natural food chains. Woody habitats also play an important geomorphological role in the formation of physical features such as scour pools and channel bars (Cottingham *et al*, 2003). Over time the loss of instream woody habitat has severely impaired these important ecosystem services in the River Murray and many other rivers throughout south eastern Australia.

This project aims to restore these wide ranging functions provided by instream woody habitats by enhancing woody habitat loads, leading to a more robust and productive ecosystem.

3.2 Stakeholder Liaison Plan

A pilot stakeholder and agency liaison plan has been developed in line with the *Communication Strategy*. To ensure efficient communication of project outcomes and progress workshops and information evenings will be held and advisory material regularly updated and distributed appropriately. Stakeholder liaison will be an ongoing feature throughout the project.

3.2.1 Legislative Compliance

Works associated with the *Resnagging and Riparian Habitat Restoration Hume Dam to Yarrawonga* project will require several authorisations and approvals. Initial stakeholder, government (local and state) and agency consultation has identified key approvals required upon the progression of implementation. A number of agencies will be closely involved with the implementation stages of this project as the activities are within the scope of their jurisdictional role (see table 2).

Table 2: Authorising agencies and their roles

Agency	Legislation	Role
The NSW Department of Infrastructure, Planning and Natural Resources (DIPNR)	*Rivers and Foreshores Improvement Act*	Authorise works within 40m of waterway and within State Protected Land.
NSW Department of Primary Industries	*Fisheries Management Act 1994*	Requires consultation on protection of threatened fish species, populations and ecological communities and their habitat from harm.
Local Councils (Albury City, Greater Hume, Corowa, Wodonga, Moira)	*Environmental Planning and Assessment Act 1979* and *Local Environment Plans*	Submission of Development Applications as required.
NSW Maritime (Waterways)	*Maritime Services Act 1935* and *Navigation Act 1901*	Requires consultation for maintaining safety on all NSW navigable waters (incl River Murray channel).
NSW DEC (NPWS)	*National Parks and Wildlife Act 1974* and *Threatened*	Protection of threatened species, populations and

Agency	Legislation	Role
	Species Conservation Act 1995	ecological communities and their critical habitats. Protection of Aboriginal cultural heritage sites in NSW.
Aboriginal Affairs Victoria North East Cultural Heritage Board	*Archaeological and Aboriginal Relics Preservation Act 1972*	Protection of Aboriginal cultural heritage sites in Vic.

Consultation with other relevant agencies and groups, North East Catchment Management Authority (Vic), Murray Catchment Management Authority (NSW), Department of Sustainability and Environment (Vic) and Hume to Yarrawonga Waterway Management Advisory Group will be ongoing throughout this project. A review of related strategies and Management Plans is supplied in section 8 of the *Hume Dam to Yarrawonga Instream and Riparian Habitat Restoration Plan* (DPI, 2004).

3.3 Social and Economic Impacts

3.3.1 Waterway Users

Recreational Fishing

Recreational fishing is a very common recreational pursuit in the Hume Dam to Yarrawonga reach, for both local River Murray residents and visiting tourists. Any impacts of the resnagging program on recreational fishing will be beneficial, as the program aims to enhance native fish habitat, thereby leading to a more robust fish community. There are no additional recreational fishing regulations proposed as part of the resnagging program's implementation and monitoring phases. Implementing new legislated fishing closures within these waters is not considered appropriate at this stage.

Boat-based fishing issues associated with resnagging (eg navigation) are assessed below.

Commercial Fishing

The inland native commercial fishing industry in NSW has recently undergone significant changes, culminating in the cease of commercial fishing for native finfish (Murray cod and golden perch) in September 2001. Limited remaining commercial activity inland rivers is restricted to the catch of carp and yabbies.

The *Resnagging and Riparian Restoration – Hume Dam to Yarrawonga* project is not expected to have any adverse effects on the carp or yabby commercial fishery in the Hume Dam to Yarrawonga reach of the River Murray. Yabby fishing is restricted east of the Newell Highway (which incorporates the subject reach), and therefore is not an issue in this reach. Carp fishing is generally not approved in the River Murray channel, due to the associated risks of native fish bycatch. Rather, most carp fishing efforts are focused in impoundments (ponds, lakes), and as such there will be negligible impacts of resnagging on the carp fishery (A. Hodosi, pers. comm.).

Boating and Water Skiing

Priority resnagging areas (see map in section 4.1) are located away from larger townships to reduce the number of waterway users potentially affected by this project. Consultation with boating and water skiing groups will help to identify high use areas within the priority resnagging areas. This information can then be incorporated into the Resnagging Design Plan (see section 4.2) to determine where resnagging will minimise social impacts while maximising benefits to native fish.

While safe navigation has always been, and will continue to be the responsibility of licensed boat driver, this project is committed to ensuring waterway safety. NSW Maritime, the agency responsible for waterway safety in River Murray, will be actively consulted throughout the planning and implementation stages of the resnagging program. Where appropriate, signs will be posted at public boat ramps to inform waterway users of the resnagging areas, and waterway markers will indicate newly reinstated woody habitat.

During resnagging works there will be active management of boating in the reach. For example, bank resnagging may require temporary closures while cables are suspended across the river. Any interruption will be very temporary (1-2 hours at a time) and localised (less than 100m length of river), and will be well signposted and supervised on the waterway.

3.3.2 Landholders

Landholders adjacent to resnagging sites play a key role in the resnagging program and their support is required to enable access to resnagging sites. Landholders also value the river as a source of livelihood and recreation. One aspect of this Feasibility Study has been an initial consultation with many of the landholders adjacent to priority resnagging sites, with the aim of gauging their level of support for the program. In all, over 90% of landholders adjacent to priority resnagging sites have been engaged. This consultation process facilitates a better level of understanding, and a greater sense of ownership of the project, and allows for any landholder to be addressed by the project managers.

For the most part landholders at each of the proposed resnagging sites have been particularly receptive and supportive of the resnagging program, with little or no reservations. Many longer term landholders have expressed concern about the degradation of the river and their initial disapproval of the de-snagging (woody habitat removal) program. Access to resnagging sites through private land will only occur through partnership arrangements with property owners (access issues are further addressed in section 5.3).

3.3.3 Cultural Heritage (Indigenous)

Consultation with indigenous communities regarding cultural heritage sites is an important aspect of the program. Where appropriate, Cultural Heritage surveys will be conducted to determine the presence of cultural heritage sites within resnagging areas. Any cultural heritage sites discovered in the course of the works will be appropriately managed (eg protection through fencing) to prevent any undue disturbance.

3.3.4 Wider Community

The River Murray is arguably the nation's most important river, supporting numerous rural communities and providing for much of Australia's irrigated and agricultural production. The River Murray is considered an Australian icon, and there are strong cultural links between the Australian community (both past and present generations) and the river.

Resnagging and the variety of other proposed works associated with the *Environmental Works and Measures Program* will help maintain the river's iconic status and services for future generations, by conserving and restoring the ecological functions of the River Murray.

3.3.5 Demonstration Reach Principles

The concept of a "demonstration reach" has been proposed as a rehabilitation strategy by the Murray Darling Basin Commission in its recently released *Native Fish Strategy for the Murray-Darling Basin 2003-2013*. A demonstration reach is defined as:

"a river reach established for the purpose of demonstrating to the community the cumulative benefits of applying a number of interventions (eg provision of fish passage, resnagging, alien species management) for rehabilitation of native fish habitat and populations."

MDBC (2003)

The aim of a demonstration reach is to show the community the cumulative benefits of using a number of actions to achieve aquatic habitat rehabilitation, while also ensuring community and partner ownership and support for native fish management and river conservation.

There may be an opportunity to pursue a "demonstration reach" in one or all of the resnagging areas under the *Resnagging and Riparian Restoration Hume Dam – Yarrawonga* project, particularly where other river rehabilitation projects are proposed or currently occurring within the reach.

Figure 4: Boiling Down Creek (Photo:DPI)

4 Proposed Location of Resnagging

4.1 Three Priority Areas

Due to the increased waterway use and the regularity of annual irrigation flows in the River Murray, it is not feasible to reinstate the number of snags required to bring instream habitat back to original pre European levels throughout the entire Hume Dam to Yarrawonga Reach. Consequently the *Instream and Riparian Habitat Restoration Plan* (DPI, 2004) recommended three priority sites for resnagging, as indicated on the following map (figure 5).

These priority resnagging areas were identified through an analysis of the results of the instream habitat assessment (see background in section 1) and our knowledge of the number and location of woody habitats previously removed through de-snagging. Selection of these priority areas also aimed to increase connectivity through the reach by linking areas of existing healthy instream habitat.

Table 3 identifies these priority areas and gives an explanation for their selection and indicates the effort required in each priority area to restore woody habitat to the 16% woody habitat plan form area target benchmark level.

Figure 5: Priority Resnagging Areas in the Hume Dam – Yarrawonga reach of the River Murray

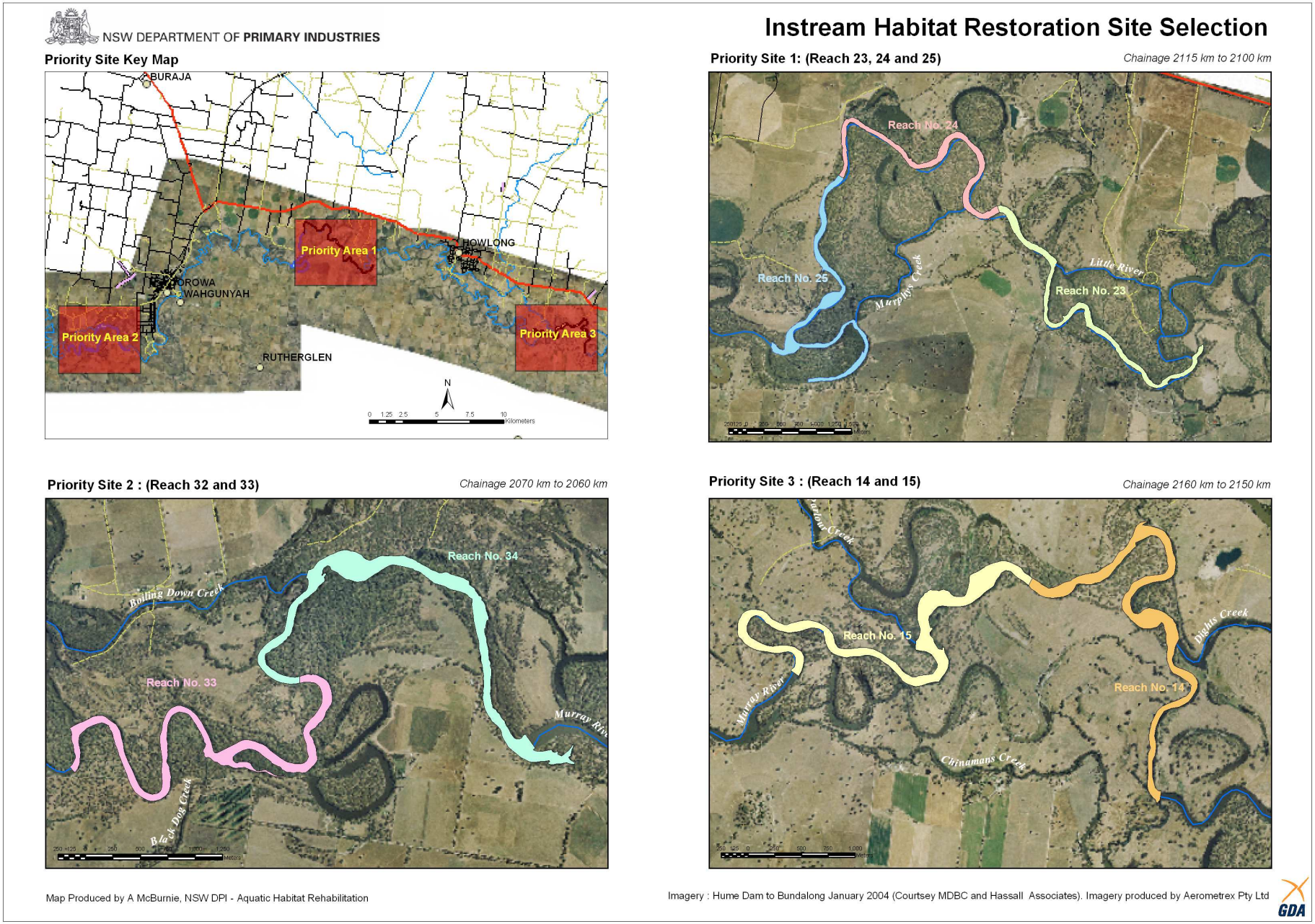

Table 3: Priority Resnagging Areas

Priority Area	Justification	Effort required
1) Reaches 23, 24 and 25	Targeted to achieve an expansion of existing suitable habitat in reaches 26 to 31. Resnagging in this 15km priority area (reaches 23, 24 and 25) would enhance the connectivity of instream habitat over a 45km stretch of the river.	Total: 2638 woody habitats (131 900m^2 planform area of woody habitat) Reach 23: 497 woody habitats Reach 24: 274 woody habitats Reach 25: 845 woody habitats
2) Reaches 32 and 33	Reaches 26 – 35 are representative of an area of best available habitat within the Hume Dam to Yarrawonga reach. Resnagging this 10km priority area (reaches 32 and 33), would achieve connectivity of instream habitat over a 60km stretch of the river (when combined with habitat restoration efforts in priority area 1). Note: this priority area is within the Boiling Down Ck demonstration reach, and is the site of a recent threatened species capture (trout cod).	Total: 204 woody habitats (10 200m^2 planform area of woody habitat) Reach 32: 62 woody habitats Reach 33: 142 woody habitats
3) Reaches 14 and 15	A 10km stretch located between two 5km reaches with % woody habitats above 10%. (below desired benchmark however relatively high within collective reach)	Total: 1518 woody habitats (75 900m^2 planform area of woody habitat) Reach 14: 662 woody habitats Reach 15: 856 woody habitats

Source: Adapted from DPI (2004)

4.2 Resnagging Design Plan

A Resnagging Design Plan has been drafted (see Appendix 2), which indicates the location of specific resnagging sites within the three priority areas. This Plan has been developed to maximise benefits to native fish populations, while taking site practicalities into account.

4.2.1 Identifying Resnagging Sites within Priority Areas

Within the three priority areas specific resnagging sites have been identified through a gap analysis. The site selection process took into account the existing woody habitat amount (planform area), complexity and location within the channel, to identify key sites where the woody habitat load should be enhanced and connectivity improved.

Site selection is at a meandering bend scale, which is consistent with the recommendation of Nicol *et al* (2002): *"…in the type of river exemplified by the study reach (the River Murray between Yarrawonga and Tocumwal), (i.e. a large, low gradient, meandering river), LWD (woody habitat) reintroduction needs to be managed at the scale of individual meander bends."*

Site selection at a meandering bend scale also allowed for site-specific practicalities to be taken into account. Attributes of potential resnagging sites were identified through an on-ground assessment (ground truthing) of the sites. These attributes included:

- water depth,

- bank height,
- riparian condition (sparsely or densely vegetated, or cleared)
- adjacent land ownership and landholder support, and
- access to the site (existing fencing and the conditions of roads into the sites).

4.2.2 Methods of Installation

Two methods will be used to place woody habitats within the channel; bank-based resnagging using the "cable dragging technique", and barge resnagging using a barge mounted excavator. Bank-based resnagging is the preferred cost effective method, to be used for most sites in all three priority areas. Where site practicalities limit the use of bank-based resnagging, barge resnagging is to be used as an alternative.

- *Bank-based resnagging*

The "cable dragging technique", as developed by Nicol *et al* (2002), provides a cost effective and quick method of reinstalling woody habitats from the bank. The technique first requires logs to placed at the top of the bank, eg with a front end loader fitted with forks (see figure 6).

Logs are then dragged into place via cables, a method based on retrieval methods used in forest harvesting. Figure 7 details the use of a cable and pulley system for resnagging.

Figure 6: A rubber tyred front end loader is a more sensitive method of putting snags into place on the bank (photo: ARI)

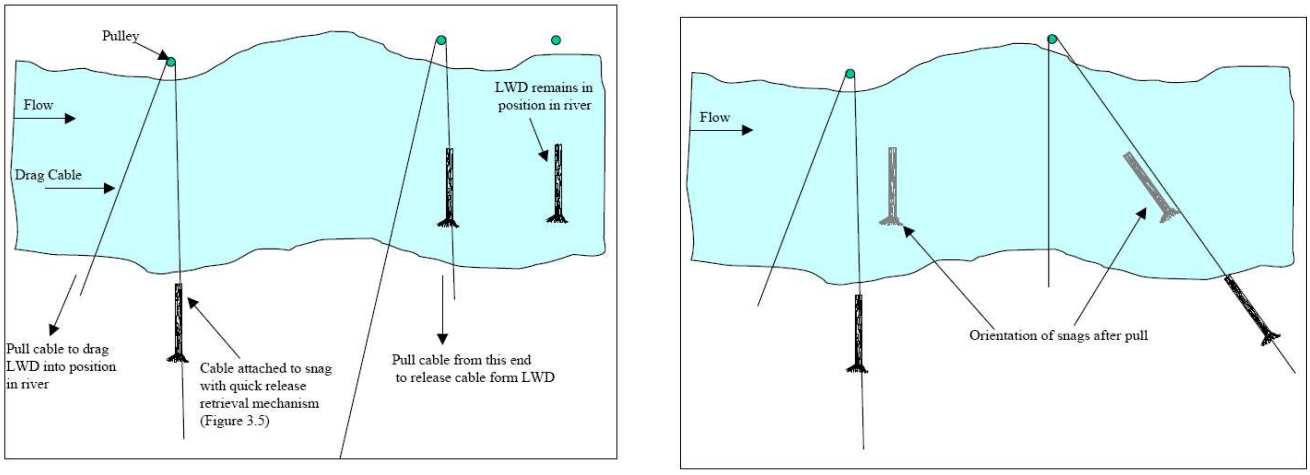

Figure 7: Diagram of bank-based resnagging cable dragging technique (Source: Nicol *et al*, 2002).

One end of the cable is attached to the log with a quick release retrieval mechanism (figure 8). The other end of the cable is then pulled by a winch, tractor or excavator into the desired position in the river. Logs can be dragged in at different angles to achieve different placement orientations. The cable is then retrieved by pulling back on the quick release mechanism, which releases the cable's dragging plate from the log, thereby leaving no foreign material on the log or in the river.

Figure 8: Quick release mechanism - a fast and efficient method of dragging snags into place (photo: ARI).

Timing: Although possible throughout the year, bank resnagging is best carried out during low flows (generally late autumn – early spring, outside the irrigation season) while banks and bed are exposed and to provide for better access to sites.

Bank-based resnagging occurs at a rate of approximately 10 snags per day.

Estimated Costs: Equipment (loader with forks, winch, 20t excavator) and labour costs for one resnagging team (4 people) are estimated at @ $2160/day + $8000 fixed cost of purchasing and maintaining cables and safety equipment.

Installation cost per snag (est) = $216 (assuming 10 snags reinstalled per day)

Note: Additional costs are associated with the transport of timber to resnagging sites (see section 5.2.1).

- *Barge resnagging*

Resnagging using a barge mounted excavator fitted with a grab (see figure 9) presents an alternative to resnagging from the bank, where site practicalities prevent the bank-based techniques from being applied.

This is the case for many resnagging sites in priority area 1, where highly vegetated and/or high unstable banks prevent resnagging from the bank (see figure 10). An ideal location to potentially launch a barge within priority area 1 has been located on private property.

A medium sized barge (~12m x 7m) mounted with a 20t excavator will be used to resnag a several sites in priority area 1 (see Resnagging Design Plan in Appendix 2). A barge this size can operate in water depths of under a metre, manoeuvred by a workboat. Woody habitats up to 5t in weight (max capacity of a 20t excavator) will be reinstated using this method.

Barge resnagging has proven to be a useful technique in East Gippsland CMA's Snowy River resnagging project, where medium sized logs of 300mm diameter and 12m length were reinstated using a 12t excavator (R. Morrison, pers. comm.).

Figure 9: Barge mounted excavator (photo: Barges Australia)

Figure 10: Example of high banks (in background) preventing bank resnagging in priority area 1 (photo: DPI)

Timing: Barges can operate in just under a metre of water, therefore barge manoeuvrability in priority area 1 will be possible during most flow scenarios.

Barge resnagging occurs at a rate of approximately 10 snags per day.

Estimated Costs: Equipment (barge, work boat, excavator with grab and loader) and labour for one resnagging team is estimated @ $3220/day + $7000 fixed cost of transporting barge (return). For detailed costs of a barge see section 5.2.1.

Installation cost per snag (est) = $322 (assuming 10 snags installed per day)

Note: Additional costs are associated with the transport of timber to resnagging sites (see section 5.2.1).

4.2.3 Woody Habitat Placement

Based on a study of the natural distribution of woody habitats in the Yarrawonga to Tocumwal reach, Nicol *et al* (2002) provides an understanding of where to place woody habitat relative to the planform geomorphology, and how to align and arrange it. The results of the study are also relevant to the Hume Dam to Yarrawonga reach, and suggest that woody habitat should be positioned in clusters that are relatively close to river banks, in the high-energy eroding parts of bends, and at a variety of angles between 0^0 and 90^0 to stream flow (as indicated in figure 11).

The placement of woody habitats in the Hume Dam to Yarrawonga reach will be based on this model, particularly in bends, where the natural location of

woody habitat was found to be relative to the curvature and length of the channel in the bend.

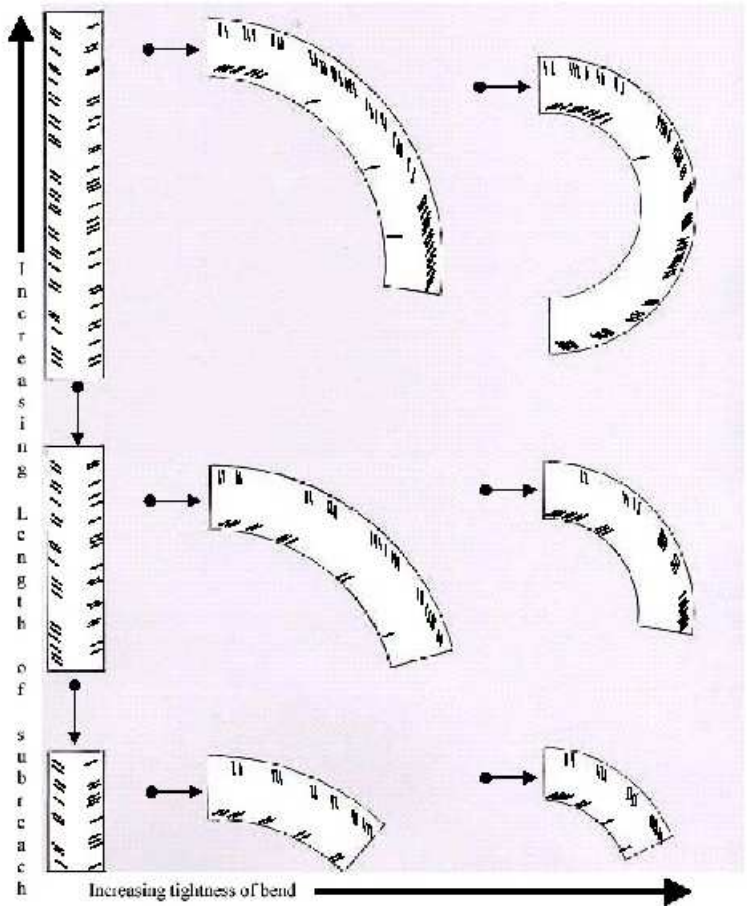

Figure 11: (from Nicol *et al*, 2002). Model of response of LWD distribution to increasing bend tightness (X Axis) and sub-reach length (Y axis). Arrows indicate direction of flow. LWD is evenly distributed on both sides of the channel in straights, but as channel curvature increases LWD is less likely to be found in the second half of the inner channel and more likely to be found in the second half of the outer channel. Note that the angles of the LWD symbols are indicative of the mean angle of LWD - in reality LWD would be arranged at a variety of angles between 0 and 90 degrees.

Resnagging can be managed in such a way that mitigates the impacts of reinstated woody habitats on erosion processes, and reduces the chances of log jams through careful planning and our knowledge of hydrological and geomorphological conditions at each resnagging site.

Woody habitats will be oriented with the direction of flow will be diverted away from the bank, within downstream arc from perpendicular to parallel. No woody habitats will be oriented in an upstream direction. The use of heavy machinery to reinstate woody habitats will be restricted to sites where the risk of any bank erosion is low. Any disturbances to the bank will be subject to remedial works (see Risk Assessment in Appendix 1).

To ensure the placement is most beneficial to native fish, site-specific work techniques will employ best knowledge of fish biological and lifecycle requirements and habitat dynamics. In the Yarrawonga to Tocumwal reach, Nicol *et al* (2002) found that trout cod were more abundant in quarter 1; Murray

cod were more abundant in quarter 1 and quarter 4; Golden perch were less specific in their distribution utilising woody habitat in quarters 1, 3 and 4. Murray cod were found to prefer areas close to the bank (within 15m of the bank), while trout cod prefer the mid river areas (>15m from the bank). Golden perch were equally abundant across the sites. Woody habitats with hollows and snag piles proved to be of particular importance. The native fish – woody habitat associations will be incorporated into the Resnagging Design Plan to ensure benefits to native fish are maximised.

4.2.4 Securing Woody Habitats

Nicol *et al* (2002) have developed guidelines for ballasting drier and less dense woody habitats with anchor boulders to avoid "run away snags". These guidelines are based on knowledge of forces such as buoyancy, weight, drag and angle to flow. This ballasting method will be used in combination with those used in other resnagging projects, for example, anchoring through the use of timber piles and/or rock anchors to secure woody habitats in resnagging projects in East Gippsland (R. Morrison, pers comm.).

The most common method of securing woody habitats through this project will be by using driven piles as ballasts (see figure 12).

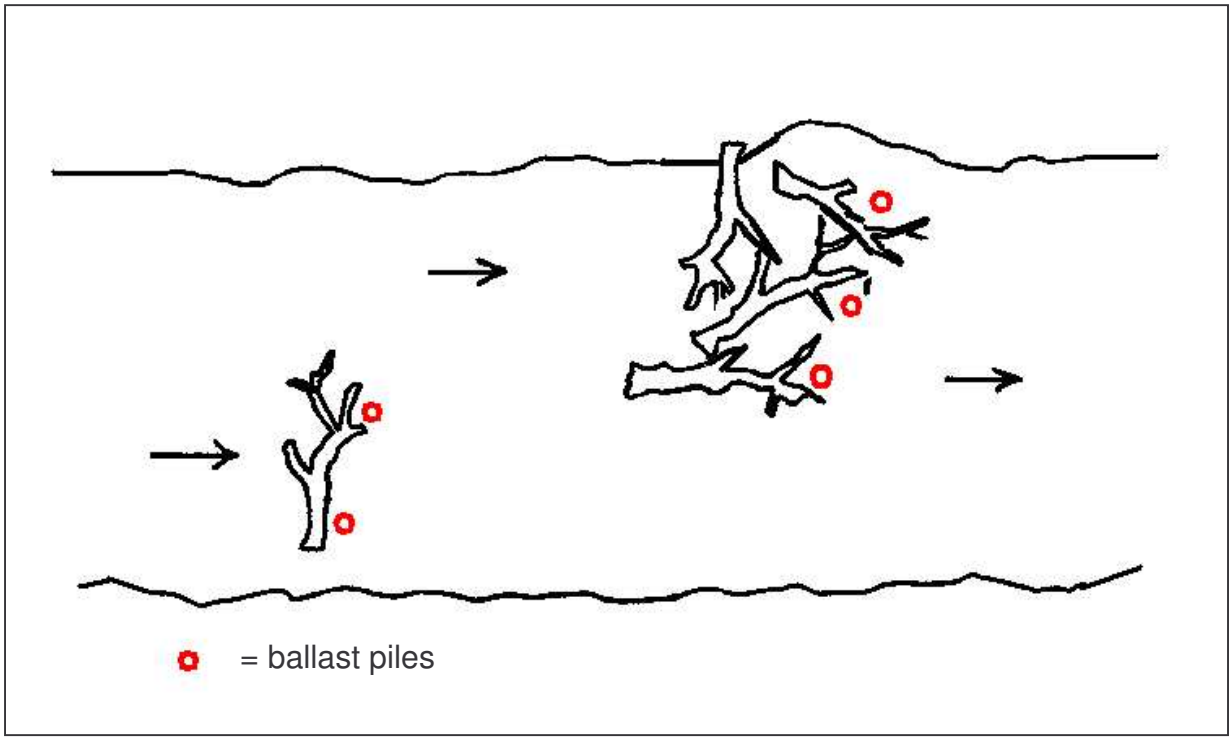

Figure 12: Method of securing woody habitats

The level at which securing is required will be assessed on site, dependent on the condition and size of each individual woody habitat and the site practicalities. For example, higher density green timber is likely to require less ballasting than lower density timber. Similarly, larger logs with intact root masses and/or branches are more likely to remain in place with minimal or no ballasting, compared with smaller, less complex timber that may tend to float without intervention.

4.3 Timeframe

Proposed works in the 05/06 period will be scheduled, as indicated below. During this period one third of the resnagging benchmark will be achieved.

Activity	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Stakeholder Liaison/ Compliance												
Timber transportation												
Bank resnagging (during low flows)												
Barge resnagging (during higher flows)												
Site rehabilitation												

Resnagging in 05/06 is to be followed by a roll out of seasonal resnagging at priority areas over the following two financial years – 06/07, 07/08.

4.4 Resourcing

Resnagging is to be carried out by one operational team (4 people) on a seasonal basis. This allows for better coordination of site access and timber availability and transport. The resnagging team will also be able to learn from previous experiences as resnagging works progress, and adapt management techniques accordingly.

4.5 Further Expansion of the Project

Following the resnagging of the three priority areas, this project could potentially be expanded to other areas along the River Murray channel and anabranches. This will be reassessed by the steering committee once resnagging of the three priority sites has been completed and evaluated.

5 Logistical Issues

The following section addresses the logistical issues associated with large scale resnagging of a large lowland river.

5.1 Sources of Timber for Woody Habitat

Using the riparian zone and/or floodplain as a large scale source of timber for re-snagging is not considered a ecologically sound option, given their important ecological and geomorphological roles (Cottingham *et al*, 2003). Rather, the *Resnagging and Riparian Restoration – Hume Dam to Yarrawonga* project aims to source timber from alternative sources such as development sites, road and bridge construction sites. Felled trees are often otherwise used for firewood or woodchips.

The target benchmark woody habitat level, as identified in the *Instream and Riparian Habitat Restoration Plan* (DPI, 2004) is 16% plan form area. To reach these levels in the priority areas, an equivalent of approximately 4300 woody habitats are required (table 3).

A sufficient amount of timber will be able to be sourced for resnagging in the three priority areas over the course of the project 2005 - 2008. Significant woody habitat sources (as listed in table 4, and pictured in figure 13) have already been stockpiled and are awaiting resnagging in the 05/06 period. At this point in time stockpiled sources account for over 20% of the required woody habitat load.

Table 4: Timber sourced for use in the resnagging project

Timber Source	**Estimate of woody habitat available (planform area m^2)**	**Approx distance to nearest resnagging site**
Snags washed up on GMW managed infrastructure ➢ Yarrawonga Weir	300	50km
Trees felled for road bridge developments ➢ Albury National Highway ➢ Corowa bridge ➢ Cobram-Barooga bridge	 10 000 600 3000	 30km <10km 80km
Trees felled for other floodplain developments ➢ Subdivision (Wodonga) ➢ Pivot irrigator constructions (Yarrawonga and Mulwala) ➢ Earthworks (Yarrawonga) ➢ Levee works (Cobram) ➢ Land clearing (Shepparton) ➢ Other	 200 4000 1000 4000 6000 12 000	 25km 50km 50km 80km 150km 10-50km
Hazard reduction in Parks Vic managed camping/recreation areas (eg. Richardson's Bend, Shaw's Flat, Lumby's Bend and Stanton's Bend)	3000	<5km
Total **Average Distance (per m^2 woody habitat)**	**44 100m^2**	 **53.3km**

Other sources of woody habitat will become available for resnagging during the course of the project. These other sources include:

- *Other floodplain developments*

Consent Authorities have been engaged, and a request has been made to notify DPI (Fisheries) in the event of the approval of any future developments requiring the removal of large trees. These developments may include road works, housing projects, and land clearing. To date, letters have been sent to local councils, regional DIPNR and DSE offices and the project managers of known upcoming developments (eg Goulburn Valley Highway projects, Wodonga railway bypass, Norske Skog waste water facility upgrade).

- *Engineered snag piles*

Engineered artificial woody habitat will be constructed using smaller timber debris (ie heads of trees) and purchased timber piles @ $30 ea (excluding cost of installation).

- *DIPNR Riverworks*

Instream erosion control structures such as timber groynes and other bed-control devices can be extended to include submerged complexes that can act as a surrogate to natural woody habitats. Further investigation into the habitat attributes provided by instream structures is due to occur in 2005, through an assessment of the association of native fish and different types of constructed instream structures.

- *State Forest*

Local State forest areas often have a significant amount of unwanted timber left over from their logging and culling operations (ie defective timber not suitable for milling). Usually this timber is sold for firewood.

Initial discussions with forest managers, Parks Vic (DSE) or NSW Forests, indicate that this timber will be put aside for the resnagging project.

- *Hazard reduction in Crown Land*

Parks Vic and NSW Forests managed land within the subject reach will provide a feasible source of woody debris for resnagging through their hazard reduction program (reducing the risks of harm to campers through the removal of high risk limbs and trees). Hazard reduction would provide a local source of timber that would not require relocation. This would require further discussion with local land management officers, to ensure compliance with the Reserve Management Plan or equivalent.

Figure 13: Stockpiles of timber to be re-snagged

- *Desnagged timber**

This includes originally desnagged woody habitats located on river banks adjacent to resnagging sites. Several landholders have indicated that there are numerous de-snagged snags on their properties (around 20 snags have been identified to date). It is feasible to reinstate these woody habitats back into the channel, given their close proximity to resnagging sites.

- *Timber from Lake Mulwala and/or Hume**

Floating timber to be removed for navigational purposes and standing dead trees. Initial discussions with impoundment managers (GMW) have indicated access to this timber for resnagging would not be a contentious issue, subject to environmental compliance.

* The use of such timber would be subject to site specific assessments of impacts on threatened species (eg ground dwelling parrots and Bush Stone-curlew) and would be dependent on access for heavy machinery and/or barge.

- *Natural woody habitat recruitment*

The recruitment of snags from riparian vegetation is a natural riverine process associated with the lifecycle of trees and natural meandering and erosion processes. The level of natural snag recruitment will be enhanced in the long term by the riparian revegetation aspect of the project.

- *Redgum regrowth*

Redgum regrowth on the River Murray floodplain has been enhanced as a result of the higher regularity of regulated irrigation flows and the associated elevated water table. This has resulted in dense stands of redgum regrowth in certain areas, which would otherwise (during the course of a natural flow regime) have experienced a higher mortality of redgum saplings. In places this regrowth is rendering the land unsuitable for farming purposes, unless the regrowth is slashed or otherwise removed.

There is an opportunity to establish a tender arrangement with affected landholders involved in the current easement program. Under this arrangement landholders may agree to preserve these areas of regrowth for ecological purposes. Once preserved, there is potential for less desirable trees in these dense stands to be culled (ie certain trees be removed to reduce impacts of competition between trees). Culling would aim to encourage the development of more complex branching trees, which would be more beneficial as woody habitat in the longer term. Culled trees would also have the potential to be used in river restoration as woody habitat, depending the trees are of sufficient size when culled.

The establishment of such a regrowth preservation agreement is to be further investigated in 05/06 by the steering group.

5.1.1 Wood Condition

The various sources of timber for resnagging will result in a range of wood conditions and types (eg green wood from newly cleared vegetation, dry wood that has been stockpiled for some time, and submerged timber from relocated sources). These varying wood conditions are all beneficial for fish habitat, considering the wide range of conditions woody habitat would naturally enter the river, including whole live trees and dead dry branches that from mature trees.

In an assessment of the colonization rates of macroinvertebrate and algal species on resnagged wood types (green, dry/dead and submerged wood), Nicol *et al* (2002) recorded little difference in the time taken to establish and aquatic ecosystem function after resnagging using either green or dry/dead wood. Submerged wood was found to re-establish ecosystem functions in a shorter time period.

5.2 Relocation of Woody Debris to Resnagging Sites

Timber for the resnagging project has been sourced from a variety of local sources, as detailed in section 5.1, thereby reducing the effort and associated costs of long distance transportation.

At priority area 2, for example, the amount of timber on-site (eg. existing stockpiles, redundant bridge piles and remaining desnagged snags) is sufficient to meet the required instream woody habitat load (~200 snags). This prevents the need for additional timber to be transported to this site.

While there are various nearby sources available for resnagging at priority areas 1 and 3, the relocation of additional timber is inevitable. For the program to be more efficient in terms of relocation cost and effort, woody habitats should be reinstated in the priority area closest to their original location to prevent unnecessary transport costs. For example, it is more logical to use timber from the Albury National Highway project for priority area 3. Similarly, timber from further downstream (eg. Yarrawonga weir, Cobram – Barooga bridge, Cobram levee works), should be used for priority area 1.

This will also provide some degree of habitat benefit to be delivered to each of the resnagging sites in the short term, rather then concentrating all effort in priority area 1, which requires the largest amount of timber, then moving on to priority area 2 and then finally 3.

5.2.1 Transport Options

An assessment of various modes of transport is essential to determine which is most practical and cost efficient. A transportation and handling plan will be developed with contractor / transport company to ensure compliance with OH&S requirements for safe and efficient transport of timber from its source to the resnagging site (see Risk Assessment in Appendix 1).

Various transport methods have been assessed, as follows:

- *Truck*

Trucking the timber by road presents the most efficient mode of transporting the timber, with the ability to directly transport timber from its source (eg stockpile) to its resnagging site. In most cases, truck loads will consist of a number of logs (est 8-10), with the exception of the largest and more complex logs, for which loads may be of only 2-3. Transportation by truck should utilise the method which is most practical for the size, complexity and type of timber to be relocated (ie tip truck for smaller logs and root masses and/or low loader for larger more complex timber).

Timber transport via road is subject to load mass and size requirements of RTA/Vic Roads. Loads are to be kept within load size/mass requirements, to avoid the need for road traffic permits, and additional costs of oversized and pilot vehicles. This will be achieved by cutting timber to within maximum transportable size requirements prior to loading.

Estimated costs:

Costs associated with transporting timber (snags) have been calculated (tables 5 and 6) based on a fixed cost of loading, distance to be transported, dependent on the snags size:

- **Small snag**: short sections and root balls weight <1t ea
- **Medium snag**: trunks and branches 1-5t ea
- **Large snag**: larger trunks >5t ea with rootballs and/or braches intact

Table 5: Estimated costs of transporting snags by truck

Snag size	Approx total no of snags in each size category	Approx no of snags transported per load	Fixed loading/ unloading cost	Transport cost per load*	Transport costs per snag per km*	Load / unload costs	On road transport costs
Small	3000	10	$800	$6/km	$0.60	$240 000	$90 000
Medium	2500	4	$800	$6/km	$1.50	$500 000	$187 000
Large	300	2	$1000	$6/km	$3	$150 000	$45 000

* Based on average 50km transport distance

Table 6: Estimated timber transport costs per snag by varying distances

	Timber size		
Distance (km)	**Small**	**Medium**	**Large**
5	$83	$208	$515
10	$86	$215	$530
20	$92	$230	$560
50	$110	$275	$650
100	$140	$350	$800
150	$170	$425	$950
200	$200	$500	$1100
250	$230	$575	$1250
300	$260	$650	$1400

- *Barge*

Barges were once frequently used for freight transport along the River Murray. Since the improvement of road infrastructure, the use of barges is now an inefficient mode of transport. There are currently no known full time barge operators within this reach of the River Murray. Temporary barges are used for bridge construction and weir maintenance, etc. These barges are typically brought in by road.

When considering a barge as an alternative to a truck for timber transportation, the distance travelled by water far exceeds the distance travelled by land, due to the extensive meandering of the main channel, and the time taken to negotiate the channel. For example, the distance from Albury to Corowa by road is 62 km, while the distance by river is approx 115km.

Furthermore, unless timber stockpiles are located on the banks of the River Murray, transport by barge would require double handling, to firstly relocate the timber over land (eg by truck) to the barge mooring point then to reload the timber onto the barge.

While the use of a barge for long distance transport of timber has been found is unpractical, the use of a barge is more appropriate for other aspects of the project, for example, the harvesting of standing and/or floating timber from Lake Hume and Mulwala. Resnagging using a barge mounted excavator is proposed as a method of resnagging, as discussed in section 4.2.2.

Estimated costs: Various barge companies have provided quotes for the hire and mobilisation costs, including the costs of a workboat and deckhand, as detailed in table 7.

Table 7: Quotes for the use of a barge for resnagging

Company	Barge specs	Initial mobilisation costs	Hire cost (per week)	Other
Barges Australia	Two 12.2m x 3.35m steel pontoons fitted together	$6000 (Syd-River Murray-Syd)	Barge and boat hire: $2000 Loader: $2282 Labour: $3300 **Total: $7582**	Easily transportable by road Can carry 20t excavator (plus timber – max snag size 5t)
Gippsland Lakes Barges Services	12m x 4.5m steel barge	$19 300 (Gippsland-River Murray-Gippsland) Transport by road requires oversize road permits	**Total: $9082** (incl barge, boat, loader and labour)	Previously used in Snowy River resnagging project More expensive to transport by road – single barge Limited to 12t excavator (plus timber – max snag size 2.5t)
State Water	10m x 12m steel barge located at Hume Dam	>$20 000 Transport by road requires oversize permits + repairs + costs of disposal	Barge hire: $0 Workboat: $660 Loader: $2282 Labour: $3300 **Total: $6242**	Previously used in Hume Dam remediation works - larger than necessary for resnagging works Currently in state of disrepair - relocation and operation would require major structural and maintenance works Under an agreement with State Water barge would be free of charge, however would require disposal after completion of works

- *Helicopter*

Relocating timber by air to resnagging sites presents time efficient, yet expensive, mode of transport. The excessive costs associated with the use of a helicopter, and the helicopter's limited carrying capacity prevents the use of this method of transport (see table 8 below).

Table 8: Approx costs of three types of helicopters (B. Rees, pers comm.)

Type	Max lift capacity	Hire cost (per day)	Additional flying costs (per hour)	Other comments
Ericson Aircrane	8-9 tonne	$20 000 + loader $500 per day	> $5000	Does not take into account additional cost of transport out to Australia
Mill 8 Lift Chopper	5 tonne	$15 000 + loader $500 per day	$5000	" "
Bell 205	1800kg	$5000 + loader $500 per day	$2000	Locally based at Essendon Airport (Melbourne)

- *Comparative Prices of Transport Options*

Table 9: Comparative prices of transport options – assume 10 medium sized logs are to be relocated a distance of 50km from Lake Mulwala to Site 1 (near Rutherglen)

Mode of transport	Fixed cost of loading/ unloading per trip	Distance to be travelled per trip (time taken)	Cost per km (per load)	No of trips required	Estimated total cost
Road (Truck)	$800	50km by road (1 hour)	$6	4 logs per load = 3 trips	$2400 + 900 = $3300
River (Barge)	$7000	65km by river (~8 hours)	$10.00	10 logs per load = 1 trip	$7000 + 650 = $7650
Air (Helicopter)	$10000	40km by air (0.5 hour)	$50.00	1 log per load = 10 trips	100000 + 20000 = $120 000

Note: each of the above options require the use of a front end loader for loading and unloading timber. These costs, plus the costs of labour, have been factored in the associated costs presented in the table.

Based on the comparative prices presented above in table 9, and the logistical issues discussed in section 5, trucking timber by road is the most practical option for relocating timber from stockpiles to resnagging sites.

5.3 Access to River at Resnagging Rites

Land ownership on the banks of the River Murray adjacent to priority resnagging sites is a combination of private ownership and Crown reserve, frontage or State Forest (NSW or Vic).

Most adjacent landholders have been engaged and the proposed resnagging project discussed in detail. The brochure *"Instream and Riparian Restoration – Hume Dam to Yarrawonga"* has provided landholders with additional information about the project, with the aim of fostering support for this river rehabilitation project.

The majority of landholders engaged during the investigation phase of this report have expressed support for the project (as discussed in section 3.3.2). Permission has been granted to access most resnagging sites via private roads or across paddocks (as shown in Resnagging Design Plan, see Appendix 2). Where appropriate (ie bank resnagging sites) there has also been discussion of access for heavy machinery and short term stockpiling of timber to be used as snags. Some concerns about the damage to private roads and bridges have been discussed with the landholders. These include safety issues, bridge capacities and damage to tracks and roads by heavy machinery.

Additional works associated with access for resnagging include:

- Temporary removal and/or adjustment of property fences to allow for heavy machinery access (eg truck and excavator).

Cost: $9000 (1km total length of fencing required (in sections) @ $9 per meter (incl materials + fencing contractor)

- Small scale track work at some sites to allow for heavy machinery access (eg some minor resurfacing and temporary drainage crossings).

Cost: resurfacing and temporary crossings $50 000 (10 sites @ $5000 ea (materials, plant and labour))

- Track maintenance (for those extensively used) after resnagging project.

Cost: $19 000 (materials (rock fill) + 100 hours grader hire @ $90/hour)

- Further safety assessment of private bridges (to determine load capacity, etc). If any bridges are found to be unsafe, alternative site access options would be considered.

Cost: $10 000 (10 bridges. Bridge assessor: 10 days @ $1000/day)

There are only a small number of adjacent landholders (5 in total) who have indicated that they do not support the project and access through their property is not appropriate at this time. However, this does not significantly impact on the project as proposed resnagging in these areas can either be carried out from a barge or from the opposite bank.

5.4 Resnagging Site Rehabilitation

While all care will be taken to minimise disturbance to the riparian zone during resnagging activities (eg preferred use of rubber tyred front end loader rather than excavator where possible and /or use of barge in sensitive areas), some disturbance through heavy machinery access is inevitable. Remediation will be undertaken as required.

Cost: Small scale soil battering works $9000 (100 hours bobcat hire @ $90/hour)

Localised revegetation and fencing at resnagging sites $15 700 (incl plants, tree guards, planting, fencing)

6 Conclusions and Recommendations

A Resnagging Design Plan has been developed as a proposed resnagging program in key sites in the Hume Dam to Yarrawonga reach (see Attachment 2). This Plan is due to roll out over three years 2005 - 2008, achieving benchmark woody habitat loads in the three priority areas, as identified in the *Restoration Plan* (DPI, 2004). Sites were selected through a gap analysis, to determine where resnagging will be most beneficial to native fish, while also giving consideration to site practicalities.

Two resnagging methods are proposed; bank-based resnagging using the "cable dragging technique", and barge resnagging using a barge mounted excavator. As the most cost effective method, bank-based resnagging is the preferred method, and is to be used at most resnagging sites in all three priority areas. Where site practicalities such as high banks or dense riparian vegetation limit the use of bank-based resnagging, barge resnagging is to be used as an alternative (see section 4.2.2).

The Feasibility Study has assessed a variety of logistical issues associated with large scale resnagging in the Murray River:

- **Sourcing Timber**: A sufficient amount of timber will be sourced for resnagging in the three priority areas over the next three financial years through various sources of existing stockpiles, future development sites, State Forest hazard reduction and forest culling operations, desnagged timber and, if necessary, timber from water impoundments and purchased piles to make up the remainder woody habitat load requirement (see section 5.1).
- **Transport**: Timber can be cost effectively transported from its source to the closest priority area (see section 5.2). An assessment of the transport options has concluded transport by road (truck) is the most cost effective. Resnagging will utilise stockpiled timber at its closest priority area, for increased efficiency in reducing transport effort required, while also delivering habitat enhancement to all three sites in the short term.
- **Access**: The majority of resnagging sites have good to excellent access for bank-based resnagging. A small number of sites will require small scale track works to enable access for heavy machinery. Any short term disturbance to private infrastructure during the course of the project (fence modification and track degradation) will require additional maintenance works following the completion of resnagging at that site. Over 90% of landholders adjacent to resnagging sites have been engaged, and the majority are supportive of the project (see sections 3.3.2 and 5.3).
- **Minimising Environmental Impacts**: Resnagging will result in an enhancement of instream habitat, while minimising impacts on the riparian zone and bank stability. Resnagging can be managed in such a way that ensures no net increase of bank erosion (eg knowledge of the site's hydraulic and geomorphic attributes and angling woody habitats appropriately). Where appropriate, woody habitats will be secured through necessary means. Any disturbance to sites will also be rehabilitated through a site rehabilitation plan (revegetation and soil battering).

- **Social Impacts**: The Resnagging Design Plan minimises social impacts through considering the needs of waterway users (fishers, boaters) and adjacent landholders. Active consultation with the community will occur throughout the implementation of the resnagging program.

Based on the Feasibility Study it can be concluded that the implementation of the *Resnagging and Riparian Restoration – Hume Dam to Yarrawonga* project is feasible. An assessment of the logistical issues surrounding project implementation reveal that the proposal is achievable and can be managed in a cost effective manner.

Adaptive management principles will be integrated throughout implementation stages of the resnagging program. This will allow for new knowledge that comes to hand to be incorporated into the project (eg. If the results of monitoring reveal those more successful resnagging designs, or if a new resnagging method comes to light).

Continuation of the resnagging program beyond the three priority sites will be reassessed following the completion and evaluation of the resnagging of the three priority sites.

7 Acknowledgements

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Personal Communications

Reg Morrison (East Gippsland CMA)

Anthony Hodosi (NSW DPI Fisheries)

Brian Rees (Vic Department of Sustainability and Environment – Fire Management)

Appendix 1 - Risk Assessment

Issue	*Potential impact*	*Likelihood*	*Mitigation Measure(s)*
Sourcing timber for resnagging	➢ Insufficient timber available for resnagging project	Medium	➢ Investigate all possible timber sources, in the short and long term ➢ Correspond with agencies responsible for regulating tree clearing ➢ Opportunistically source timber over the course of the project. Purchase timber where required. ➢ See section 5.1
Storage of timber for resnagging	➢ Insufficient storage sites for timber before works ➢ Difficulty in accessing stockpiles for relocation ➢ Stockpiled timber subject to collection for firewood	Low Low Medium	➢ Stockpiling to occur on private or crown land with permission of landholder ➢ Ensure stockpiles are located in areas that can be accessed by heavy machinery for transportation at a later date ➢ Positioning of signs to indicate wood is not to be used for firewood, positioning of stockpiles in low profile locations where possible. ➢ see section 4.1.1
Overland transport of timber to resnagging sites	➢ Loads exceed road requirements ➢ Inadequate road safety while transporting timber	Low Low	➢ Ensure timber is cut to within maximum RTA/Vic Roads load requirements when transporting (size, weight) ➢ Engage reputable transportation company, ensure compliance with road regulations. Develop Transportation and Handling Plan. ➢ see section 4.1.3
Access to resnagging sites	➢ Difficulty in gaining access to river at resnagging sites	Medium	➢ Assess river access at priority sites, work with local landholders to gain access to sites within private land and identify heavy vehicle access points ➢ Resnagging design plan to take site practicalities into account ➢ Use of barge where bank resnagging is not practical ➢ see section 4.1.5
Location of resnagging sites	➢ Conflict with waterway users (waterskiiers, boaters, fishers) about woody habitat placement	Medium	➢ Work with stakeholders to develop resnagging design plan ➢ Identify the waterway's frequently used areas and comprimise on those

			that are inappropriate for resnagging ➢ Keep stakeholders informed on progress of project and works areas and commencement dates
Use of heavy machinery on riparian zone	➢ Reduced bank stability	Low	➢ Instruct heavy machinery operators in exercising care when operating heavy machinery in the riparian zone. ➢ Keep heavy machinery away from unstable banks. Use rubber tyred loader (rather than excavator) where possible.
	➢ Damage to riparian vegetation	Medium	➢ Ensure heavy machinery access is restricted to areas not requiring removal of significants stands of vegetation ➢ Use of barge instead of bank resnagging in sensitive areas (ie those with high banks and/or highly vegetated areas)
	➢ Degradation of site during resnagging	High	➢ Undertake site rehabilitation after resnagging. Ensure vegetation recovers quickly once works have ceased, and control any resultant weed growth ➢ see section 4.1.7
Site safety during resnagging	➢ Hazardous site conditions	Low	➢ Elect site manager responsible for site safety
	➢ Unsafe heavy machinery operation	Low	➢ Ensure heavy machinery operators are appropriately licensed and all tickets/certifications are up to date. ➢ Develop snag Transportation and Handling Plan with contractor
	➢ Disregard for OH&S requirements	Low	➢ Clearly outline OH&S requirements to contractors and ensure they are adhered to and safety equipment is used (hard hats, vests, etc)
	➢ Unsafe/unreliable machinery and equipment	Low	➢ Ensure all machinery and equipment is in good working order (has been recently serviced, etc)
	➢ Waterway safety at risk during resnagging	Low	➢ Work with NSW Maritime to develop a waterway safety plan ➢ Positioning of clear warning signs and/or safety personnel in boats when barge is in use or when cables are across the river channel
Public support for Project	➢ Unsupportive landholders adjacent to resnagging sites	Medium	➢ Engage landholders prior to implementation, establish level of support, discuss concerns and consider alternate options where appropriate

	➢ Adverse public reaction	Low	appropriate. ➢ Effective implementation of the communication and liaison plan. Encourage support through media, publications (advisory material) and workshops, etc.

Appendix 2 - Resnagging Design Plan

The Resnagging Design Plan is presented in the maps that follow. These maps detail the proposed locations of specific resnagging sites within the three priority areas.

Key to Maps:

1. Resnagging site reference map

Priority Area 1

2. Reach 23
3. Reach 24
4. Reach 25

Priority Area 2

5. Reach 32
6. Reach 33

Priority Area 3

7. Reach 14
8. Reach 15