Goulburn Broken Catchment Management Authority

Lower Broken Creek Waterway Management Strategy

Final Report Appendices – Volume II

July 2005

Appendix A

Review of the 1998 Broken Creek Management Strategy

Final Report

Goulburn Broken Catchment Management Authority

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Executive Summary

The Broken Creek provides important environmental, social and economic values for local residents as well as visitors and tourist who come to enjoy the specific values retained by the environment. The Lower Broken Creek is rated as “high significance” in terms of flora due to the presence of endangered and depleted Ecological Vegetation Classes along most of the length of the creek in a landscape that is largely cleared and intensively farmed. The Broken Creek is also highly prized as one of the best remaining habitats for the Murray Cod and other native fishes, and the four reaches on the Broken Creek are defined as High Priority Waterways within the Goulburn Broken Regional River Health Strategy as a result of their notable high environmental values. The Broken Creek is also an important supply of water for domestic, stock, urban and irrigation purposes, and as a conduit for irrigation and dryland drainage, as well as providing a range of other social and economic values for the community.

Activities in the catchment and alterations to the waterway have resulted in significant degradation of the Broken Creek environment. Activities such as large scale irrigation within the catchment, irrigation and dryland drainage, weir and levee construction, agriculture and urban development have resulted in a range of impacts on the Broken Creek system (SKM, 1996), including significant changes to stream hydrology, flooding, degraded water quality, loss of riparian vegetation and weed infestations to name a few.

A management strategy for the Broken Creek was released in 1998 to provide a framework for addressing the issues affecting the management of the creek and its environs. This plan included an assessment of the effects of land use practice and other management strategies on the physical and biological condition of the Broken Creek, its water quality, and flooding and drainage issues. To gauge the level of implementation and success of the 1998 Broken Creek Strategy and to bring it up to date, the Goulburn Broken Catchment Management Authority engaged GHD and URS to review the 1998 strategy and, utilising the results of the review, develop an updated strategy for the management of the Lower Broken Creek.

This report (Volume 1) presents the findings of the review of the 1998 Broken Creek Strategy. A subsequent document (Volume 2) presents the updated strategy for the Lower Broken Creek.

Key steps in the review included:

- The degree to which the action items identified within the 1998 strategy had been implemented within the timeframe established;
- The degree to which the strategy has been successful in meeting its original objectives and performance criteria; and
- An assessment of the ongoing relevance of the 1998 Strategy for addressing current and emerging issues in the Broken Creek.

The review indicates that many of the actions in the 1998 Strategy have been implemented, as measured by the following actions:

- Removal of approximately 90-95% of willows downstream of Katamatite;
- Improved riparian zone management through 82 km of fencing and 155 off-stream watering points;

- Removal of in-stream barriers through weir replacement and the installation of 12 vertical slot fishways downstream of Katamatite;
- Gazetting of Broken-Boosey State Park, and creation of the Nathalia and Numurkah Natural Features Reserve;
- Best practice drain design and construction;
- Best practice drainage management for Kinnairds wetland;
- Best practice drain management, including improved monitoring, Drainage Diversion Plans (DDPs) and Drainage Management Plans (DAMPs);
- Improved farm management through landholder investment, irrigation extension and the development of guidelines and incentive schemes;
- Development of best practice guidelines, such as:
  - Lower Broken Creek Operational Guidelines;
  - Best Practice Principles of Drainage in Dryland Catchments;
  - Dairy Shed Effluent & Nutrient Mgmt on Dairy Farm Guidelines;
  - NE Planning Guidelines for Water Quality;
  - Best Practice Drain Management, including improved monitoring, development of Drainage Diversion Plans (DDPs) and Drainage Management Plans (DAMPs);
  - Best Practice Drain Design and Construction;
- Improved management framework:
  - Key role of the CMA since strategy developed;
  - Good coordination with other agencies via SIRTech and RHWQC; and
- Enhanced monitoring of drains discharging to the Broken Creek.

However, there are some key actions identified that have not been implemented. These include:

- Water quality and flow monitoring - the recommendation in the 1998 strategy that *'water quality (and flow) should be monitored in at least three other locations'* in addition to the permanent gauging stations at Katamatite and Rices Weir has not been implemented. Improved data will assist in better defining the condition of the Broken Creek, and assist with developing targeted management actions and in measuring the success of those actions for improving water quality;
- Limitations for the improvement to in-stream habitat due to the limited availability of large woody debris; and
- Constraints with variation in weir pool levels for management of siltation.

Most importantly, 1998 Strategy has not yet been successful in meeting all its original objectives, in particular the prevention of further degradation and an improvement the environmental condition of the Broken Creek Catchment, although it is recognised that the plans 10 year timeframe has not yet elapsed. This is highlighted by a number of key ongoing issues:

- A fish-kill in Rices Weir pool in November 2002 resulted in the death of 179 Murray Cod (*Maccullochella peeli*) and six Carp (*Cyprinus carpio)*. Lack of flows associated with prolonged fishway closures and build up of the floating fern azolla (*Azolla filiculoides* and *A. pinnata*) has been identified as the likely cause;

- Weed infestations such as azolla and arrowhead are significant issues requiring targeted and ongoing management;
- There is ongoing poor water quality, particularly turbidity and nutrients. There is evidence of some improvements, however the lack of sufficient monitoring data and the ability to separate out the effect of the drought on reduced nutrient loads is difficult; and
- Weir upgrades have almost completely eliminated weir leakage, which in the past have provided a proxy environmental flow for the Broken Creek. This is likely to have led to reduced flows along Lower Broken Creek, which has been exacerbated in recent years by drought. This loss of flow may potentially impact on important native fish communities in the Lower Broken Creek. It is therefore important to determine and providing flow requirements to achieve improved protection of in-stream ecological values.

In many instances it has been difficult to assess the success of the 1998 Strategy, due to lack of clear targets and measurement criteria. The 1998 Strategy did identify nine Performance Criteria to measure the success and review the progress of the Management Strategy, however these were "starting points for debate" and while there was significant agency input to the development of the strategy, it appears that these performance criteria were not endorsed. More importantly, in some instances the baseline value against which these criteria were to be measured was not identified, and there was insufficient monitoring data collected to measure improvement.

In addition to these issues:

- There have been significant institutional, policy and strategic changes since the 1998 Strategy was finalised, such that the context of the 1998 Strategy is no longer relevant; and
- Approaches to the development, and structure of waterway management plans have evolved, and an opportunity exists to provide a more user-friendly document.

As a result of these outstanding and emerging issues, further work is required to ensure the Lower Broken Creek continues to provide a water supply and drainage function, while protecting and enhancing its ecological values. In preparing a revised Strategy for the Broken Creek, therefore, the following are considered important:

- Provide a structure and content that is consistent with the current regional policies and strategies, particularly the Regional River Health Strategy and the Regional Catchment Strategy;
- Develop a clear and concise vision for the Broken Creek and clear objectives for the Broken Creek Strategy against which the success of the Strategy can be assessed in the future;
- Present the Management Programs and Actions in a clear and concise format, that can stand alone and be easily referred to by those responsible for implementing the strategy;
- Develop meaningful and measurable performance criteria, including both Management Action Targets and Resource Condition Targets, against which the success of the Strategy can be measured;
- Outline a monitoring program that will allow the collection and analysis of appropriate data to determine baseline conditions and measure whether the performance criteria have been met;
- Provide a clear overview of the process that was followed to develop the revised strategy, including stakeholder consultation for the development of key components such as the vision, objectives and management actions;

- Clearly present any assumptions made, information gaps, and limitations of the revised strategy; and
- Outline the process for review and updating of the revised strategy in the future.

A revised management strategy for the Broken Creek has been developed as Stage 2 of this project, and presented as a separate report (Volume 2).

1. Introduction

The Broken Creek provides important environmental, social and economic values for local residents as well as visitors and tourist who come to enjoy the specific values retained by the environment. The Lower Broken Creek is rated as “high significance” in terms of flora due to the presence of endangered and depleted Ecological Vegetation Classes along most of the length of the creek, in a landscape that is largely cleared and intensively farmed. The Broken Creek is also highly prized as one of the best remaining habitats for the Murray Cod and other native fishes, and the four reaches on the Broken Creek are defined as High Priority Waterways within the Goulburn Broken Regional River Health Strategy as a result of their notable high environmental values. The Broken Creek is also an important supply of water for domestic, stock, urban and irrigation purposes, and as a conduit for irrigation and dryland drainage, as well as providing a range of other social and economic values for the community.

Activities in the catchment and alterations to the waterway have resulted in significant degradation of the Broken Creek environment. Activities such as large scale irrigation within the catchment, irrigation and dryland drainage, weir and levee construction, agriculture and urban development have resulted in a range of impacts on the Broken Creek system (SKM, 1996), including significant changes to stream hydrology, flooding, degraded water quality, loss of riparian vegetation and weed infestations to name a few.

A management strategy for the Broken Creek was released in 1998 to provide a framework for addressing the issues affecting the management of the creek and its environs. This plan included an assessment of the effects of land use practice and other management strategies on the physical and biological condition of the Broken Creek, its water quality, and flooding and drainage issues. The original strategy was part of a broader project initiated in 1995 that assessed the floodplain impacts of proposed drainage works as part of the surface drainage strategy of the Shepparton Irrigation Region. The 1998 Broken Creek Strategy was developed for the Lower Goulburn Waterway (LGW) by Sinclair Knight Merz in association with Neil Craigie & Associates, Sandra Brizga & Associates and Streamline Research Pty Ltd. In 1997 LGW became a coordinating committee of the then newly formed Goulburn Broken Catchment Management Authority.

To gauge the level of implementation and success of the 1998 Broken Creek Strategy and to bring it up to date, the Goulburn Broken Catchment Management Authority engaged GHD and URS to review the 1998 strategy and utilising the results of the review develop an updated strategy for the Lower Broken Creek.

This report (Volume 1) presents the findings of the review of the 1998 Broken Creek Strategy. A subsequent document (Volume 2) presents the updated strategy for the Lower Broken Creek.

2. Study Approach

An independent review, using an audit-type framework, was used to provide a structured and comprehensive approach to the review process. The aim of using an audit-type approach was to foster consistency with an approach being developed by EPA for the audit of natural resources. Audits are an integral part of a monitoring and evaluation process in Victoria's overarching water protection policy, the State Environment Protection Policy (SEPP), Waters of Victoria (WoV). The SEPP WoV makes provision for land managers to use independent audits of natural resources to assess the progress and effectiveness of the implementation of programs and actions.

The study took the form of an independent review of the Broken Creek Management Strategy against certain defined criteria, with a peer review undertaken by Dr David Telford, an auditor appointed pursuant to the Environment Protection Act. By adopting an approach consistent with the environmental condition audit guidelines being developed by EPA Victoria (EPA), GBCMA should be well placed to implement management practices that are consistent with the future expectations of EPA and DSE.

Key steps in the review included:

- **Review of Implementation of Action Items:** The degree to which the action items identified within the 1998 strategy had been implemented within the timeframe established;
- **Achievement of Objectives and Performance Criteria:** The degree to which the strategy has been successful in meeting its original objectives and performance criteria; and
- **Assessment of Ongoing Relevance:** An assessment of the ongoing relevance of the 1998 Strategy for addressing current and emerging issues in the Broken Creek, including assessing the relevance of the 1998 Strategy to current policies and strategies and its ability to achieve measurable environmental improvement.

The following methods were used in the review process:

- **Literature and data review:** Review of management plans, strategies and scientific reports provided by the steering committee, as well as available data to assist in determining the current condition of the Broken Creek.
- **Review checklist:** A checklist of the issues identified within the 1998 waterway management strategy as requiring action was developed and used to guide the assessment of implementation of the 1998 Strategy actions. The completed checklist, in which the results of the review are incorporated, is presented in Appendix A.
- **Targeted discussions:** Discussions with Project Technical Steering Committee members and other relevant personnel were conducted to assess the level of implementation of the actions in the 1998 Broken Creek Strategy and to determine current or outstanding issues.
- **Field visits:** A field visit was undertaken over two days to review the current catchment and waterway condition and issues and confirm the implementation of measures identified in the 1998 strategy.
- **Stakeholder feedback:** Feedback from the Community Reference Group on the success of the 1998 Strategy and the review findings.

3. The Broken Creek Catchment

The Broken Creek catchment occupies approximately 3 300 km^2 of the Murray Valley Plains in northeastern Victoria. Figure 1 shows the Lower Broken Creek catchment within the main study area.

Main towns along the creek include Nathalia and Numurkah. Within the catchment, Katamatite and Tungamah are located on the Boosey Creek and Wunghnu is located on the Nine Mile Creek.

The general slope of the land and fall of the drainage is to the west-northwest, outfalling in the Murray adjacent the Barmah-Millewa Forest. Most of the land in the catchment is used for grazing, with dairying being the predominant industry. The western parts of the catchment are irrigated with water supplied from external sources, including the Goulburn Weir via the East Goulburn Main Channel within the Shepparton Irrigation Region (SIR) to the south of Broken Creek, and Yarrawonga Weir (Lake Mulwala) within the Murray Valley irrigation district to the north of the Broken Creek. There are also limited transfers of water from weirs on the Broken River at Caseys Weir and Nine Mile Creek at Katandra Weir.

Well-developed drainage systems and arterial drains are a feature of the Murray Valley and Shepparton irrigation districts (approximately 34% of the catchment), and many of these drain outfall to the Broken Creek and Nine Mile Creek. Shepparton Drains 11 and 12 are the largest in the SIR and outfall to the Nine Mile Creek downstream of Wunghnu. Murray Valley Drain 13 and 18 are the largest drains outfalling to the Broken Creek, downstream of Nathalia and Waaia respectively. In addition, there has been further development in the SIR since the original strategy was completed, with the development of the Muckutah Scheme which outfalls to the Broken Creek upstream of Numurkah through Kinnairds Swamp. Water supplied from Caseys Weir and Gowangardie Weir does not have well developed drainage systems, and rely primarily on natural watercourses for drainage.

There are also substantial constructed drainage systems in dryland areas, including the Drain Road outfall into Boosey Creek upstream of Katamatite and Kreck Road / Sandy Creek near Tungamah. There are also roadside drains, smaller drains, and laser graded drainage lines in the dryland areas of the upper catchment.

Variations in runoff occur and are related to seasonal rainfall variations, with higher rainfall in winter and lower rainfall in summer months. However, the natural hydrological regime of the catchment's waterways has been considerably altered through irrigation and drainage practices.

Water quality within the catchment is degraded by elevated concentrations of nutrients, suspended solids and high turbidity. Land clearing has been extensive and as a result, habitat has diminished and runoff and erosion has increased. Clearing and other inputs from farming activities, including use of fertilisers, have contributed to the decline in water quality within the catchment. The physical condition of waterways varies from poor to satisfactory and willow infestations occur in sections of the creek cause loss of aquatic and fauna habitat. In addition as a result of the above native fish species have suffered a decline in numbers.

The 1998 Broken Creek management strategy aims for an integrated approach to catchment management designed to protect and / or restore the environmental values of the catchment; to improve water quality; to improve on-farm management; and supply adequate irrigation water to support the farming within the region.

Legend

- Towns
- G-MW Drains
- Streams
- Rivers
- Roads
- SIR
- Weirs

Rices Weir
Kennedys Weir
Schiers Weir
Hardings Weir
Lukes Weir
Magnussons Weir
Chinamans Weir
Town Weir
Melville Street Weir
Station Street Weir
Ratandra Weir

Barmah
Picola
Barwo
Nathalia
Baulkamaugh North
Vaaia
Numurkah
Katunga
Strathmerton
Koonoomoo
Bearii
Barooga
Yarroweyah
Cobram
Cobram East
Yarroweyah South
Sandmount
Muckatah
Naringaningalook
Ratamatite
Dunbulbalane
Drumanure
Wunghnu
Invergorden North
Youanmite
Marungi
Yabba North
Ratandra West
Tallygaroopna
Katandra
Marionvale
Yabba South
Zeerust
Bunbartha
Undera North
Undera
Saint Germains
Wyuna East
Wyuna
Barep
Pederick
Tongala
Tongala East
Kotupna
Yambuna
Kanyapella
Kaarimba
Mundoona

Broken Creek
Broken Creek
Nine Mile Creek

0 5 10 15
Kilometres

N
W E
S

DATA SOURCE:

Prepared.	SLP		17/08/04	Workspace	Fig 1 - Lower Broken Creek.WOR
Checked.	AWR		17/08/04	Location	G:\31\15069\GIS\Workspaces
Approved.	AWR		17/08/04	Map Grid	MGA94 Zone 55

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Project: Review of the Broken Creek Management Strategy

TITLE: **Figure1: The Lower Broken Creek**

Project No.	Date.	Scale			
3115069	17/08/04	Scale: 1:195000	A3	Sh 1 of 1	Rev. O

4. Overview of the 1998 Strategy

4.1 Structure and Format

The study for the development of a management strategy for Broken Creek was initiated by the Lower Goulburn Waterway Management Authority commencing in 1995.

The objectives of the 1998 Broken Creek Management Strategy, identified in Section 10.1 of the 1998 strategy were:

- To integrate the components of catchment management, waterway management and floodplain management;
- To develop a program of works and activities to guide management activities over the coming years;
- To set performance criteria to allow assessment of management works in future years;
- To prevent further degradation of the condition of Broken Creek and its environment;
- Conserve the values of the natural resources for the enjoyment of all Australians and future generations;
- Achieve productive and sustainable use of resources for those living and working in the catchment, and
- Prevent further degradation in the short term, and to improve the environmental condition of the Broken Creek Catchment.

The 1998 Strategy was developed for the entire catchment of Broken Creek, as it was recognised that activity anywhere in the catchment potentially has an effect on Broken Creek and its associated waterways and tributaries.

The content of the 1998 strategy is summarised below:

- **Chapter 1** provided an introduction to the study and a description of the catchment;
- **Chapters 2 to 6** provided detailed background information on current condition and issues for management within the Broken Creek Catchment under the Chapter headings Agriculture, Irrigation and Drainage; Waterways; The Upper Creek System; The Middle Creek System; and The Lower Creek System;
- **Chapters 7 to 9** presented the management measures and strategies under the headings Catchment Management; Waterway Management; and Floodplain Management, which are the key focus areas of the strategy. Much of the information presented in Chapters 2 to 6 was repeated within these chapters under the subheading Key Management Issues; and
- **Chapter 10** titled Integrated Catchment Management. This chapter provided objectives for the strategy. An Action Program was provided that summarised the key activities recommended in Chapters 7 to 9 and recommended funding priorities over four levels, and identified Performance Criteria.

4.2 Key Issues and Actions from the 1998 Strategy

Key management issues identified for the Broken Creek in the 1998 Strategy were divided into those associated with:

- Catchment management;
- Waterway management; and
- Floodplain management.

Key issues identified in the 1998 Strategy in each of these areas are described below.

4.2.1 Catchment Management

Irrigation drainage

Irrigation drainage issues identified in the 1998 Strategy included: flood response; water quality; sedimentation; wetlands; and water management as discussed below.

Flood response

Traditional drain design emphasised hydraulic efficiency to transfer runoff water quickly away from the properties being served. Drains that are hydraulically efficient lead to higher flood peaks that occur earlier resulting in an increase in frequency of downstream flooding, particularly of lower magnitude floods.

Improved drainage and land management has generally reduced catchment storage and increased runoff. Storage is naturally distributed throughout unimproved areas due to surface irregularities such as minor depressions.

Water quality

Irrigation drainage was designed to mitigate soil salinity problems in the region. The drains were intended to export excess runoff and reduce accessions to shallow groundwater. In doing so, the drains exported salt to receiving streams, the effects of which have been minimised by the direct input of good-quality irrigation supply water to the creeks. As a result, the water quality of the creeks, although degraded, was identified as being of a moderate standard.

A similar situation applies to nutrients, phosphorous and nitrogen. Drains provide a conduit for the transport of fertilisers, pesticides and other chemicals used in farming. Identified potential consequences of high nutrient inputs include degraded water quality, proliferation of pest plants, and potentially algal blooms – although no serious blue green algal blooms have been identified in the Broken Creek system. Management of nutrients was identified as being necessary to control such algal blooms. Effluent from intensive animal husbandry such as dairying, piggeries and beef cattle feedlots was also identified as requiring a high standard of management.

Continued maintenance of a balance between poorer quality drainage water and higher quality water supply was also identified as being important by the 1998 Strategy.

Sedimentation

Sedimentation was identified as an important issue in the Broken Creek system. Sediment transport increases with high velocity flows increasing stream turbidity and causing erosion of more susceptible, exposed banks.

Nutrients such as phosphorus are readily adsorbed onto sediments, resulting in increased nutrients loads to waterways. Degradation of soil structure resulting from soil salinity, stock access and cropping are all potential contributors to soil erosion. The direct relationship between sediment deposition in streams and proliferation of pest plants such as willows and weeds, has led to a spiralling effect of pest plant infestations, which have blocked waterways and aggravated flooding problems.

The relationship between increased silt and sediment in streambeds and reduced species diversity was also identified. For example, many native fish species, including the Murray Cod, prefer firm streambeds for feeding and breeding; higher rates of sediment transport tends to favour introduced species such as the European Carp.

Wetlands

Many wetlands have been drained or converted to alternative land uses, limiting their availability to act as natural sinks for nutrients and sediments, and to maintain local biodiversity. Where wetlands remain, they have often been used as outfalls for irrigation drainage, or to store water for stock watering or irrigation storage. The 1998 strategy identified that the use of wetlands for water storage has altered their hydrological regime, disrupted their established natural equilibrium resulting in wetland degradation. Drainage outfall to wetlands has also decreased water quality through increased sediment loads and introduced exotic weeds which often out-compete native vegetation.

Water management

Water supplied in excess of demand, or which runs off because of inefficient on-farm practices, combined with irrigation drainage, had led to increased flows in drains and creeks, distorting the natural water cycle and degradation in creek ecosystems.

Management of runoff and subsequent bank erosion and sediment deposition was identified in the 1998 Strategy as being important to aid in improving water quality, as was the application and management of irrigation water and flows.

4.2.2 Dryland drainage

Many of the issues associated with irrigation drainage were also identified as relevant to dryland drainage. Lack of effective management, such as effective catchment storage including the cumulative effect of connecting drains, was identified as a specific issue related to dryland drainage.

Because of poor regulation and management, little attention had been paid to the designing outfalls to steams and wetlands in a manner that preserves the physical conditions of waterways or the watering regimes of wetlands.

4.2.3 Salinity and Waterlogging

Soil salinity and waterlogging are a response of the landscape to vegetation clearing. In addition, the application of irrigation water on poorly drained land was identified in the 1998 strategy as potentially contributing to rising groundwater levels and hence salinity problems in the catchment. Loss of soil structure and higher salt content has led to reduced land productivity and a further reduction in vegetation cover.

The main impacts on the creek system associated with salinity and waterlogging were identified as increased levels of salinity, and increased volumes of runoff from areas of shallow groundwater.

4.2.4 Urban Wastewater Management

At the time of the 1998 strategy, many of the rural towns within the catchment did not have well developed wastewater disposal systems, particularly in relation to stormwater. Poor stormwater management and lack of outfall regulation were identified as important issues.

4.2.5 Remnant Vegetation

Remnant strips or pockets of native vegetation were identified as being important for the health of the catchment and its waterways, particularly as habitat for native animals, maintenance of groundwater levels, soil conservation and erosion prevention, shade and shelter and recreational and nature study opportunities. Remnant vegetation protection was seen as a high priority.

4.2.6 Coordination and Linking

The coordination of activities and enhancement of communication and sharing funding between all groups involved with catchment health was seen as an extremely important issue by the 1998 strategy.

4.3 Waterway Management

4.3.1 Waterway Erosion

Waterway erosion was generally not seen as a major issue in the Broken Creek system by the 1998 Strategy, as stream energies are low and the transport of sediment is limited. However, there were a number of locations such as Sandy Creek and the lower reaches of Nine Mile Creek and Nathalia where erosion was seen as an issue.

4.3.2 Sediment Deposition and Transport

The 1998 Strategy considered natural conditions within the Broken Creek system made the system prone to sediment deposition. This was reinforced by the effect of weirs, which acted as efficient sediment traps, and increased inputs of sediment from modified land use and drainage.

Increased sediment deposition and its relationship with water flow rate resulted in decreased habitat diversity and increased water turbidity.

4.3.3 Riparian Zone Vegetation

The 1998 Strategy identified that riparian zone vegetation had been depleted in a large number of locations, including long reaches of the Broken Creek upstream of Katamatite. Uncontrolled access of stock to waterways and past tree removal was identified as being major influences.

Riparian zone vegetation was identified as being important to vegetation health, providing a movement corridor for birds and other animals and providing natural stabilisation of creek beds.

4.3.4 In-stream Conditions

Large woody debris (LWD) was identified in the 1998 Strategy as playing a vital role in maintaining physical and biological balance, stability and habitat enhancement within a creek system. A reduction LWD had resulted in degraded in-stream habitat. Weed infestations, such as willows, had also occurred within the creeks and waterways.

4.3.5 Streamflow Management

Supplementation of flows in Broken Creek and Nine Mile Creek, and the regulation of flows by weirs, was seen as having an important influence on the condition of waterways in the 1998 Strategy. The unseasonable flows and the effects of weirs were identified as having contributed to the decline in habitat and waterway conditions.

4.3.6 In-stream Barriers

The 1998 Strategy identified in-stream barriers such as weirs to have inhibited fish passage and sediment transport. The weirs were identified as having blocked native fish migration and providing favourable conditions for introduced fish species, such as carp.

4.3.7 Excavated Pools

Excavated pools were identified in the 1998 Strategy as having caused degraded water quality downstream and decreased habitat values.

4.4 Floodplain Management

4.4.1 Strategic Planning

Planning and agreements within floodplain communities was identified in the 1998 Strategy as being necessary to control proliferation of independent landholders constructing levees, channels and other obstructions in the floodplain, which effect down stream uses.

4.4.2 Floodplain Wetlands

Restoring intermittent water supply to important ecosystem units including billabongs and cut-off meanders during high creek stages was seen to be important in the 1998 Strategy. These wetlands were recognised as being important as feeding and breeding habitats for native species, such as the Murray Cod.

4.4.3 Regulation and Control

Municipalities had been reluctant to appeal against contentious developments using planning approvals process because of ambiguous regulations. The 1998 strategy identified that planning approvals and enforcement of regulations dealing with floodplain obstructions needed to be enforced more thoroughly and consistently. Inadequate resources for policing regulations had also been a problem.

4.4.4 Catchment Transfers

The 1998 Strategy identified that, due to low relief in the landscape, high-level transfers of water between other catchments and Broken Creek could occur under natural conditions. High transfers between catchments could cause aggravated flooding in receiving catchments (both to and from Broken Creek).

4.4.5 Numurkah

During larger floods, inundation of some residential, commercial and industrial areas within Numurkah had occurred.

Flood protection and precision of hydraulic modelling of flood flows through Numurkah was identified as being impaired by the lack of knowledge of the distribution of flood flows in the Middle Broken Creek system.

4.4.6 Nathalia

The 1998 Strategy identified that the large levee capacity in Nathalia had provided protection from large floods.

4.4.7 Box Creek

Floodplain management had been neglected at Box Creek. For example, obstructions at overflow locations pass water towards Box Creek.

4.5 Action Program

The 1998 Strategy outlined the future directions or action programs for catchment management; waterway management and floodplain management (Sections 7, 8 and 9). The action program was based on a 10-year time frame and proposed works or actions were assigned a priority based on need, timing and funding availability. These actions included:

- Review of approaches, resources, management, guidelines, design standards and existing structures;
- Formation of a technical review group;
- Implementation of objectives for improvement of drainage, storage, outfall capacity and protection and transfers to minimise or reduce environmental impact;
- Improved management of wetlands;
- Improvement in monitoring and recording of outfalls and water quality;
- Improvement of on-farm management of nutrients, erosion and water;
- Improvement regulation of released from Casey Weir;
- Stabilisation of banks and creek beds, especially for Sandy Creek;

- Improved management of weirs including: management of sediment transport; variations in pool levels to create seasonal variation; fish passage etc;
- Management of weeds and introduced species;
- Improved protection of riparian zones; and
- Development of strategic plans for Lower and Middle Broken Creek and Numurkah.

4.6 Priority Items

The 1998 strategy recommended funding priorities over four levels:

- Priority 1 items were assets or values of State or national concern requiring prompt action without delay;
- Priority 2 items were assets or values of regional or State concern requiring early action;
- Priority 3 items were assets or values of local or regional concern requiring action within the timeframe of the program (10 years); and
- Priority 4 items were assets or values of only local significance where action can be deferred until funding or opportunities permit.

The time frame of the program was set at 10 years, and the estimated cost was $160 000 for the priority one actions, excluding the cost of the weir replacement program. Planning for Priority 2 actions was to be completed within 12 months, and the item completed within five years with a budget of $1.6 million. Planning for Priority 3 items was to be completed within 2.5 years, and completed within 10 years, with a budget of $1.4 million. This gave a total of $3.2 million for priorities 1 to 3 items, with an additional $400 000 million for Priority 4 items if funding or opportunities permitted.

4.7 Performance Criteria

The 1998 Strategy considered the setting of performance criteria in order to measure success and review progress of the Management Strategy. Preliminary performance criteria were presented as a 'starting point for debate', The 1998 Strategy did identify nine Performance Criteria to measure the success and review the progress of the Management Strategy, however these were "starting points for debate" and while there was significant agency input to the development of the strategy, it appears that these performance criteria were not endorsed by the relevant agencies responsible for implementing and/or monitoring the strategy. The performance criteria are listed below:

- Turbidity should be reduced by 25% within 10 years and by 40% within 20 years;
- Salinity (EC) should not increase from current levels in the next 10 years, and should decline by 10% within 20 years;
- Nutrient concentrations should not increase in the next 10 years, and nutrient loads should decline by 20% within 10 years;
- Greater seasonal variation of flow should be achieved within five years;
- Effective control of stock access to waterways and riparian zones (fencing, off-stream or controlled on-stream watering points) should be achieved for at least 50% of the length of the steams within 10 years;

- Guidelines for good management practice in rural drainage will be produced within three years;
- The Index of River Health should be applied for benchmarking within 18 months, and the index should show a measurable improvement within five years of the benchmark date; and
- An increase in native fish numbers should be demonstrated by fish surveys within seven years. A decline in carp numbers should be evident within 10 years.

A perceptible decrease in green tree falls should be achieved within 10 years.

5. Implementation of Action Items

The completed review checklist, in which the key management issues alongside the management measures and strategies presented in the 1998 strategy are summarised, is presented in Appendix A. The degree to which each of these management measures and strategies has been implemented within the recommended timeframe is described below.

5.1 Coordination of Management

Several management structures to coordinate activity between agencies, and between government bodies and the community have been established or modified since the 1998 strategy was released. Some of the key committees are outlined below.

5.1.1 Shepparton Irrigation Region Implementation Committee

The SIR IC is an implementation committee of the GBCMA that has the responsibility to implement the Regional Catchment Strategy in the SIR. The SIR IC is a group of eight skills based community representatives including representatives from DPI and G-MW.

The SIR IC is supported by the Technical Review Panel (SIRTEC) made up of agency staff to provide high level coordination role for agencies across programs, and a number of working groups – including Surface, Farm and Environment, and Waterways, that involve community and agency staff in detailed implementation.

At an operational level, there are a number of technical groups, including the Community Surface Drainage Coordination Committee for Community Drains (CSDCC), a state wide group which sets standards for surface water management schemes on behalf of DSE; GM-W's D800 Committee which manages construction and primary drains, and Surface Water Management Working Groups for community input.

5.1.2 River Health and Water Quality

Coordination of river health and water quality issues in the Broken Creek is undertaken by the River Health & Water Quality Committee (RHWQC), which replaces the previous River Environment and Water Quality Committee (REWQC). This committee has members who represent the community and agencies such as GBCMA. This has led to development the Goulburn Broken Water Quality Management Strategy 1996-2016 (GBCMA, 2002b), and is undertaking drain audits to identify point source input to the drainage system.

5.1.3 Community Reference Group

The 1998 Strategy recommended that a Community Reference Group be formed. The Broken Creek Water Quality and Environment Reference Group was formed and ran for a number of years as a sub-committee of the now RHWQC. It is understood that his committee was disbanded at the end of 2000, due to lack of interest and replication with the role of the SIR waterway working groups.

5.1.4 Land Management

The need for a technical reference group for land management identified by the 1998 strategy has largely been addressed though the formation of the GBCMA. Land management issues are covered by the "Partnership Team" established under the GBCMA. This team includes all Managers within the CMA, Implementation Committee coordinators, DPI, DSE and G-MW and ensures that there are links between all relevant programs.

5.2 Development of Strategies and Best Practice Guidelines

A range of strategies and best practice guidelines have been developed to cover key management areas such as dryland and irrigation regions of the catchment, and to protect specific environmental assets such as wetlands. Key strategies and best practice guidelines that have been developed or implemented in the region since the 1998 Broken Creek Strategy was developed are provided in Table 1 below. It is difficult to determine if these best practice guidelines are being implemented in the catchment, and the ongoing dissemination and communication of best practice information is important for ongoing improvement of management practices.

Table 1 Strategy/Management Plan/Guidelines Relevant to Broken Creek

Management Issue	Strategy / Management Plan/Guideline
Catchment Management	◗ Goulburn Broken Regional Catchment Strategy
Dryland Drainage	◗ Best Practice Management Principles and Standards for Dryland Drainage
Irrigation and Irrigation Drainage	No overarching guideline, but a range of guidelines, including: ◗ Nutrient Best Practice Guidelines for Horticulture ◗ Nutrient Best Practice Guidelines for Irrigated Pasture ◗ Best Practice Guidelines for Construction of Surface Water Management Schemes ◗ Automatic Irrigation Incentive Scheme: Guidelines for the Shepparton Irrigation Region Catchment Strategy ◗ Drainage Reuse Incentive Scheme: Guidelines for the Shepparton Irrigation Region Catchment Strategy. ◗ Whole Farm Plan Incentive Scheme: Guidelines for the Shepparton Irrigation Region Catchment Strategy ◗ Irrigation Drainage Memorandum of Understanding ◗ Lower Broken Creek Operational Guidelines ◗ Muckatah Depression Drain Stage 1, Draft Drain Management Plan ◗ Murray Valley Drain 13 Performance Assessment ◗ SIR Catchment Strategy ◗ SIR Surface Strategy Review ◗ SIR Sub Surface Strategy Review ◗ Farm Strategy Review ◗ Community Surface Drainage Guidelines
Wetlands Management	◗ Environmental Assessment Procedure for Integrated Catchment Management ◗ Environmental Assessment Procedure for Integrated Surface Water Management ◗ Kinnaird's Swamp Environmental Management Plan

Management Issue	Strategy / Management Plan/Guideline
Water Quality Management	◗ Guidelines for the Protection of Water Quality (NE Victoria Planning Referrals Committee, 2000) ◗ Goulburn Broken Water Quality Strategy 2002 ◗ Current Recommended Practices for the Goulburn Broken Catchment 2004
Effluent from Intensive Animal Industries	◗ Concentrated Dairy Effluent Guidelines ◗ AgNote 0435 and 0430 for Dairy Shed Effluent ◗ Dairy Cattle Feedpad Guidelines for the Goulburn Broken Catchment ◗ Managing Nutrients on Irrigated Dairy Farms
Stormwater	◗ Moira Shire Stormwater Management Plan

5.3 Improved On-Farm Management

There appears to have been a significant improvement in farm management since the development of the 1998 strategy. SIRIC has a farm program aimed at improving irrigation efficiency, which includes three incentive schemes:

- Farm planning incentive scheme;
- Automatic irrigation incentive scheme; and
- Irrigation re-use incentive scheme.

The farm program also has an extension program aimed at improving farm management.

Annual reports (from 1997-98 to 2002-03) indicate that these incentive schemes have been implemented progressively with more farms becoming involved each year. The GBCMA (2002/03) indicated that: 59.6% of irrigated areas within the region now have whole-farm plans (WFPs); and each year a further 6% of properties install drainage re-use systems. Over that period a total of 171 drainage re-use systems; and 66 automatic irrigation systems were installed with assistance from the incentive scheme. Incentives for the construction of reuse systems and installation of automatic irrigation were introduced in 2001/2002. It is understood that over 80% of irrigators now have re-use systems (Ken Sampson - GBCMA, pers. comm.).

Works including farm reuse and improved irrigation layout have been undertaken at a rate of 6% a year since 1998. Guidelines for the SIRCS, WFP incentive scheme, drainage reuse scheme and automatic irrigation incentive scheme were prepared in 2003, and are upgraded regularly to incorporate any changes.

In addition, there are incentives to encourage the planting of indigenous vegetation on farms within the Shepparton Irrigation Region, under the Environmental and Tree Growing Incentives scheme managed by the DPI (Alex Sislov, DPI, pers. comm.).

5.4 Catchment Storage

Retardation basins and constructed wetlands are now being incorporated into the design of new drainage schemes such as Kinnairds Wetland along the Muckatah system to compensate for the lack of catchment storage. However there has been limited work undertaken on existing drainage systems.

A high flow diversion process exists which is aimed at capturing surplus flows in existing drains (See 5.2.8).

5.5 Transfers

Limitations on cross-catchment transfers were addressed within the Implementation Plan of the Surface Water Management Strategy Review for the Shepparton Irrigation Region. An underlying philosophy of the Surface Water Management Strategy is that all drains are to be constructed within their natural catchments and the total catchment is to be considered. While the underlying principle that drains are constructed within their natural catchments where possible is currently supported and promoted as the first option, it is recognised that in some instances, such as for Drain 11 and Drain 13, this is not practical or possible.

5.6 Water Supply Distribution

Supply is now more closely managed by G-MW to meet demand than it was at the time of the 1998 plan. The Lower Broken Creek Operational guidelines indicate that, during the irrigation season, the weir pools will be operated around the target operating level for each weir. To assist in this, four day advanced ordering and scheduling of diversions are proposed to be introduced for customers (G-MW, 2003).

Releases from Casey's Weir are now better regulated to avoid oversupply to the Broken Creek. Broken Creek Bulk Entitlements and the Caseys Weir-Major Creek proposal for piping of current open channel are likely to reduce the need for future releases from Caseys Weir. The Bulk Entitlement for the Casey's Weir and Major Creek Rural Water Authority outlines that the total diversions over a five-year period must not exceed 26 625 ML (a five year cap of 5 325 ML/annum) and a maximum of 6 150 ML in any one year.

5.7 Retrofits

Drainage resource assessments have been completed for the 20 main drain catchments, and 2.2 km of existing primary drains have been remodelled. Extensive retrofits have not taken place.

5.8 Diversion from Irrigation Outfalls

Incentive schemes have been implemented to achieve increased diversions from irrigation outfalls and drains to private farm storage for reuse. GM-W manages a program for low flow and high flow diversions. For the high flow diversion program DPI is involved in securing funding grants, and G-MW is responsible for assessing and allocating the resource. There has been a recent acceleration of the diversion metering program (Kevin Preece, pers. Comm.)

5.9 Weir modification and operations

Weirs were identified as a critical barrier to fish passage in the 1998 strategy, and modifications to allow fish passage were recommended.

This issue has largely been addressed through a weir replacement program. Site visits and a review of GBCMA annual reports indicates that fishways have been progressively built throughout the region with twelve vertical slot fishways having been installed at all weirs downstream of and including Katandra Weir. The ten weirs from Melville Street Weir downstream have either been replaced with a new structure or had alterations made to the existing structure. A number of rock-graded structures have also been constructed along the Nine Mile Creek (G-MW, 2003).

Weir replacement has also addressed the issue of sediment transport and siltation problems in weir pools as identified in the 1998 Strategy. Installation of drop leaf gates has allowed water to flow freely over weirs with the potential for sediment to move down the system.

To monitor this movement, silt surveys of channel cross sections have been undertaken. These surveys show little to no change in the silt profile in the weir pools. There was concern that the new weirs would cause a mass migration of silt down the system, with a consequent adverse impact on water quality. As there has not been a major flood since the drop leaf gates have been installed, it is still uncertain if this may occur.

The 1998 strategy also recommended that water levels within weir pools be varied to allow consolidation of fine sediment and colonisation of emergent aquatic plants. This issue has been addressed through the Lower Broken Creek Operational Guidelines, which state that during the non-irrigation period (winter) gates will be set to automatic level control to lower weir pool level to improve the stability of the riparian zone by allowing consolidation of sediments and establishment of emergent native aquatic vegetation (G-MW, 2003). It is understood that this requirement of the Operational Guidelines has not been implemented to date, however is expected in the near future (K. Preece, pers. comm.).

Weir pool levels have been manipulated to assist the clearance of *Azolla* in 2003. Implementation of this measure in the future may be constrained by a landholders need for domestic and stock water and the risk to existing aquatic vegetation from frost.

Weir upgrades have almost completely eliminated weir leakage, which in the past has provided a proxy environmental flow for the Broken Creek. SKM (1996b) predicted that weir upgrades could lead to reduced flows along Broken Creek during the irrigation season because of reduced drain outfalls to Broken Creek or reduced outfalls from the EGMC. Butcher (2004) noted that other programs designed to improve water delivery efficiency and to improve regional water quality have reduced creek flows, especially during the late winter/early spring period. The tendency for reduced flows in response to water saving actions has been exacerbated in recent years by drought. These losses in flow may potentially have an adverse impact on important native fish communities in the Lower Broken Creek.

5.10 Riparian Zone and Frontage Management

Stock access to and impact on riparian vegetation, banks and waterways was identified as a significant issue for the Lower Broken Creek in the 1998 Strategy. This issue has been largely addressed through the installation of 81.2 km of fencing and 155 offstream watering points from $351 000 of incentive program funding. Approximately 55 000 plants have been planted.

It is recognised that incentives alone will not solve the issue of grazing along waterways. Some liaison between GBCMA and DSE (Lands Victoria) has been undertaken to improve frontage management, including the voluntary management arrangements established under the fencing grant schemes referred to above. Although most frontages are on Crown Land, for which DSE has prime responsibility, the CMA should to be more involved in the Crown Frontages review that is happening along the Lower Broken Creek particularly by reviewing grazing licences, putting protection conditions on new licences and providing this advice to Crown Land Management. Some stream frontages, such as the Broken – Boosey State Park (see below) are managed by Parks Victoria.

The 1998 Strategy recommendation that a cooperative plan for a system of riparian and wetland reserves along habitat corridors provided by the Broken Creek has been partially achieved through the gazetting of the Broken - Boosey State Park covering an area of valuable riparian vegetation. The Kinnaird's Swamp Environmental Management Plan and the constructed wetland component of Kinnaird's Swamp have also partially addressed this issue. In addition, the Nathalia and Numurkah Natural Features Reserves have been created. These are areas permanently reserved under the Crown Land (Reserves) Act 1978 and managed by Parks Victoria. Generally Natural Feature Reserves (NFRs) are used to protect natural features and values and to preserve indigenous flora and fauna. Grazing is generally not permitted within NFRs.

5.11 Willow and Aquatic Weed Management

Control of willow infestation in the Lower Broken Creek has been largely addressed, with the removal of approximately 90 to 95% of willows downstream of Katamatite. However, community consultation has highlighted some areas where treated willows have not been adequately removed, or where infestations still remain (eg. below Schiers Weir). These issues need to be investigated and addressed within the revised strategy.

Azolla infestation has been a significant issue in recent years and *Azolla* build-up at Rice's Weir due to low flow is believed to have contributed to the 2002 fish-kill. Since this time, GM-W has implemented a new method of controlling *Azolla* by deliberately passing water over the weir gates to break up the mats of *Azolla* and reducing the risk of high biological oxygen demand and low dissolved oxygen levels in the waterway.

Cumbungi (*Typha* sp.) is an issue around Numurkah and within the Muckutah system, where it holds water up and provides enhanced conditions for arrowhead infestation upstream. Control of cumbungi using herbicide is being implemented.

Arrowhead is now also a significant issue, with infestation being enhanced by low water levels associated with the drought. G-MW are currently managing the problem using herbicide, however this method is effective only during the summer months. Non-chemical approaches (eg steam weed control) have been trialled, but have been found to have limited effectiveness on a large scale. Other methods for controlling arrowhead need to be explored.

5.12 Waterway Stabilisation

Erosion is not considered a major issue in the Lower Broken Creek, however, the 1998 strategy did recommend bed stabilisation works for Sandy Creek and grade reducing structures for the lower reaches of Nine Mile Creek. Both these works have been completed. Tethering of logs on the banks at Chinaman's Weir in Nathalia was also recommended, however it is understood that this work is no longer considered appropriate and was not implemented.

5.13 Enhancement of In-stream Habitat

The 1998 strategy recommended that the in-stream habitat should be enhanced through the placing of large woody debris (LWD) within the stream. It is understood that this has been difficult to achieve due to the difficulty in obtaining appropriate debris. On public land, debris has a value for terrestrial habitat and on private land it is often used by landholders for firewood. GBCMA has purchased some decking timber from two bridges, which are to be demolished, for placing in the waterway. It is understood that this will continue when suitable opportunities to obtain suitable materials arise.

5.14 Carp Control

Carp control has not been specifically addressed as a result of the Strategy. Some work has been done in Barmah to trap carp and the GBCMA has been involved in the National Carp Taskforce indirectly. This issue is difficult for GBCMA, as the authority is responsible for managing fish habitat, but not fish, which is the responsibility of DPI Fisheries.

5.15 Environmental Flow

The need for an environmental flow strategy for the Broken Creek was highlighted within the 1998 Strategy and continues to be an important issue for the environmental health of the Lower Broken Creek, while allowing for the ongoing role of the system as a conduit for irrigation water. Following the fish-kill, the need for an increased environmental flow in the Broken Creek has gained greater urgency. Extra Murray River flows have been provided, however, this needs to be formalised to provide a mechanism for securing and delivering water for the waterway. This may be addressed within the Environmental Reserve System set out in the recently released White Paper. The loss of weir leakage as a form of environmental flow through the weir replacement program (see 5.2.9) and the recent drought has highlighted the importance of this issue.

The need to provide a minimum flow in order to keep fishways functional during August to December has been addressed within the Lower Broken Creek operational guidelines. This sets out that during the irrigation season, fishways will remain open wherever there is greater than the fishway operating flow available, which is likely to be for most of the irrigation season. During the non-irrigation period, lower pool levels may mean that the fishways to not operate properly, as fishways will be closed when the weir level is below the target operating level. This is less critical as winter is not a period of high fish movements.

5.16 Floodplain Management

The specific requirements of the 1998 strategy that specific strategic floodplain management plans for each of the Lower Broken Creek, Middle Broken Creek and Numurkah have not been implemented. Instead, flooding has been addressed through the Goulburn Broken Regional Floodplain Management Strategy, with planning controls for works in the floodplain, alterations to existing levees and prevention of new levees being incorporated within the planning scheme and Victorian planning provisions.

It is difficult to monitor if landholders have been making alterations to levees without obtaining the necessary planning permit. To address this issue, the need for a full inventory of levees has been identified.

Flood operations of weirs are outlined in Lower Broken Creek operational guidelines.

A Flood Study is planned for Numurkah but has not been implemented. Funding of this project is provided within the Moira Shire Council and GBCMA 2004/5 budget.

5.17 Monitoring Channel Outfalls and Drains

There has been some improvement in operational flow monitoring and management systems for channel outfalls, drains and waterways including for the key drains highlighted in the 1998 strategy (Shepparton Drains 11 and 12, and Murray Valley Drains 13 and 18). Monitoring is in place for the new Muckatah system, with monitoring points upstream and downstream of Kinnairds Wetland to monitor nutrient stripping. Fortnightly monitoring of nutrients and continuous monitoring of turbidity, EC and flow is undertaken on Shepparton Drains 11 & 12 and MV drains 13 & 18 by Thiess on behalf of G-MW, under cost sharing arrangements between G-MW and GBCMA. Monitoring information is fed back to SIRIC through the RHWQC.

5.18 Point Source Monitoring

There is monitoring at a number of points in the system made up of a combination of the GM-W network and Waterwatch monitoring; however there are some resource limitations. These limitations have been highlighted most recently by the fish-kill at Rice's Weir in 2002, where insufficient monitoring data was available to determine the cause with any certainty. It is recognised that the high cost of detailed monitoring is a common constraint for waterway managers.

5.19 Flood monitoring

Flood Monitoring Action outlines intention to monitor and collect data to facilitate effective flood monitoring (GMCMA, 2002a, p77.). No data have been collected yet, as there have been no major floods since the 1998 strategy was produced.

6. Achievement of Objectives and Performance Criteria

The review of the 1998 Broken Creek Management Strategy has identified that significant effort has been made to implement the key action items set out in the original strategy; however it is also critical to establish if and where the strategy has been successful in meeting its original objectives and the nine identified performance criteria or other relevant criteria.

6.1 Objectives

The objectives of the 1998 Broken Creek Management Strategy, identified in Section 10.1 of the 1998 strategy were to:

1. Integrate the components of catchment management, waterway management and floodplain management.
2. Develop a program of works and activities to guide management activities over the coming years.
3. Set performance criteria to allow assessment of management works in future years.
4. Conserve the values of the natural resources for the enjoyment of all Australians and future generations.
5. Achieve productive and sustainable use of resources for those living and working in the catchment.
6. Prevent further degradation in the short term, and to improve the environmental condition of the Broken Creek Catchment.

As described in the previous sections, objectives 1 and 2 have been addressed through the development of the program of works and activities described under the key areas of catchment management, waterway management and floodplain management.

Objective 3 (performance criteria) has been partially been met. Performance criteria were set, although it appears that these performance criteria were 'starting points for debate' and not endorsed by the relevant agencies. The individual performance criteria are discussed in more detail below.

From our review of available information, it appears that objectives 4 to 6, relating to protection and enhancement of the Broken Creek environment within a sustainable catchment, have not been achieved.

This is highlighted by a number of key ongoing issues:

- A fish-kill in Rices Weir pool in November 2002 resulted in the death of 179 Murray Cod (*Maccullochella peeli*) and 6 Carp (*Cyprinus carpio)*. Lack of flows associated with prolonged fishway closures and build up of the floating fern Azolla (*Azolla filiculoides* and *A. pinnata*) have been identified as the likely cause;
- Weed infestations such as azolla and arrowhead are significant issues requiring targeted and ongoing management;
- There is ongoing poor water quality, particularly turbidity and nutrients. There is evidence of some improvements, however the lack of sufficient monitoring data and the ability to separate out the effect of the drought on reduced nutrient loads is difficult; and

- Weir upgrades have almost completely eliminated weir leakage, which in the past have provided a proxy environmental flow for the Broken Creek. This is likely to have led to reduced flows along Lower Broken Creek, which has been exacerbated in recent years by drought. This loss of flow may potentially impact on important native fish communities in the Lower Broken Creek. It is therefore important to determine and providing flow requirements to achieve improved protection of in-stream ecological values.

It is recognised that the plan's 10 year timeframe has not yet elapsed, and that these are ambitious objective are unlikely to be realised in the short term. Instead, it is important that more meaningful and measurable short term goals and targets should be set that can be the basis for determining if the long term objective has been achieved.

6.2 Performance Criteria

Table 2 presents each of the preliminary performance criteria from the 1998 Strategy, and where sufficient information is available, makes comment on the degree to which these criteria have been achieved. Further discussion around key issues is then presented in the following sections.

Table 2 Level of Achievement Against Each of the 1998 Strategy Performance Criteria

Performance Criteria	Comment
Turbidity should be reduced by 25% within 10 years and by 40% within 20 years.	Insufficient information was provided to be able to assess whether this criteria has been met. Preliminary assessment of turbidity data from Rices Weir indicates a slight downward trend, but turbidity levels are still well in excess of SEPP objectives.
Salinity (EC) should not increase from current levels in the next 10 years, and should decline by 10% within 10 years.	Preliminary assessment of EC data from Rices Weir indicates a downward trend, and EC within SEPP objectives.
Nutrient concentration should not increase in the next 10 years, and nutrient loads should decline by 20% within 10 years. ◗ Total Nitrogen concentration ◗ Total Phosphorus concentration ◗ Total Nitrogen load ◗ Total Phosphorus load	**TN concentration**: No statistically significant trend for data on Drain 11, 12 and Broken Ck at Rices Weir. **TP concentration**: No significant trend for Shepparton Drain 11, significant downward trend for Shepparton Drain 12, but a very significant upward trend for Broken Creek at Rices Weir. For Murray Valley Drain 13 there was a very significant upward time trend associated with TP concentration. **TN and TP load:** A very significant downward trend for both Shepparton Drains 11 and 12. No trend result was available for the Broken Creek at Rices Weir, based on the SKM GAM analysis.
Greater seasonal variation of flow should be achieved within five years.	Operational mechanism for managing weir pool levels and flow established. Implementation has been constrained by the drought limiting water availability. Greater flow variation in the Broken Creek, therefore, remains an ongoing issue.

Performance Criteria	Comment
Effective control of stock access to waterways and riparian zones (fencing, off-stream or controlled on-stream watering points) should be achieved for at least 50% of the length of the steams within 10 years.	Almost 50% fencing has been achieved in five years with approx. 82 km of 180 km of stream having been fenced in this time. However, some landholders are reluctant to remove grazing from riparian zones and will not respond to incentives. Alternative approaches need to considered to allow ongoing protection of riparian zones.
Guidelines for good management practice in rural drainage will be produced within three years.	A range of good management practice guidelines has been developed. See Table 1
The Index of River Health should be applied for benchmarking within 18 months, and the Index should show a measurable improvement within five years of the benchmark date.	Index of Stream Condition (ISC) undertaken five years ago. Recent field surveys have just been undertaken for the second ISC assessment. Changed methodology may limit the ability to assess improvement.
An increase in native fish numbers should be demonstrated by fish surveys within seven years. A decline in carp numbers should be evident within 10 years.	Some fish monitoring was undertaken prior to the installation of the fishways, but insufficient to allow assessment of performance criteria.
A perceptible decrease in green tree falls should be achieved within 10 years.	No baseline data has been collected, and there has been no ongoing monitoring, so this criteria cannot be assessed. Based on community comment, green tree falls continue to be an issue in parts of the Lower Broken Creek

6.2.1 Water Quality

Historical monitoring on the Broken Creek focussed on the influence of the Broken Creek system on the Murray River, particularly salt and nutrient loads from the catchment. As such, monitoring tended to focus on the end of the system, at Rices Weir, rather than monitoring direct impacts on the Broken Creek itself. The 1998 Strategy recommended that water quality and flow should be monitored in at least three additional locations (in addition to Rices Weir and Katamatite), and recommended sites at or near Numurkah and Walshe's Bridge on the Broken Creek, and Wunghnu on Nine Mile Creek. These sites have not been established. However, there has been an expansion of the water quality monitoring within a number of drains discharging to the Broken Creek, these being Shepparton Drains 11 and 12, and Murray Valley Drain 13, in addition to long monitoring undertaken on the Broken Creek at Rices Weir. Due to the lack of available data to assess the water quality and health of the Broken Creek, the revised strategy should include recommendations for additional water quality monitoring sites on the Broken Creek.

Each year the data from the nutrient monitoring program is summarised and an assessment made of the impact of irrigation drainage on nutrient loads exported from the Goulburn and Broken catchments to the Murray River. SKM (2004) provides the latest analysis of trends in flow, nutrient concentrations and nutrient loads in Irrigation Drains in the Shepparton Irrigation District, which includes the Broken Creek at Rices Weir and Shepparton Drains 11 and 12. Data collated as part of the analysis includes rainfall data, irrigation delivery data, load data and concentration data, and their trend was analysed using the Generalised Additive Model (GAM). Variation in nutrient concentration with time was tested independent of the variability of flow, whilst the trend in flow was tested after removing the effects of rainfall variability. Both of these parameters were also tested independent of seasonality and, if found to be a significant indicator, irrigation deliveries. The trend analyses for the river monitoring sites, including Broken Creek were carried out for TP and TN concentrations only. If a statistically significant trend was identified at a site for any of the parameters analysed, a trend analysis of load was also undertaken. This parameter was tested independent of rainfall, irrigation deliveries and seasonality (SKM, 2004).

Key findings of this report are:

- **Flow** - There is a significant downward trend with time for Shepparton Drain 11 and a very significant trend with time for Shepparton Drain 12. No result was available for Broken Creek at Rices Weir, although most sites in the SIR show a very significant downward trend over time. The downward trend for flow trend is consistent with the drought that has been experienced in the region over recent years;
- **Total Nitrogen (TN) concentration -** There is no significant trend for Shepparton Drains 11 and 12, and Broken Creek at Rices Weir. For Broken Creek, the trend has changed from a significant upward time trend from the trend analysis completed two years earlier. This indicates that the downstream sites are receiving less TN than previously. Irrigation was also found to have a very significant impact on TN concentration at Shepparton Drain 11, Shepparton Drain 12. For Murray Valley Drain 13 rainfall was found to have no effect on TN concentration and there was also no time trend associated with this parameter;
- **Total Phosphorus (TP) concentration -** There was no significant trend for Shepparton Drain 11, significant downward trend for Shepparton Drain 12, and a very significant upward trend for Broken Creek at Rices Weir. For Murray Valley Drain 13 there was a very significant upward time trend associated with TP concentration; and
- **TN and TP load –** A very significant downward trend for both Shepparton Drains 11 and 12. Broken Creek at Rices Weir was not analysed for load. Murray Valley Drain 13 did not collect flow data during the study period so only TN and TP concentrations were analysed. Flow rather than concentration is the current driver affecting nutrient loads, and the influence of flow on load data is believed to be considerable.

This information indicates that TN concentration currently complies with the performance criteria of no increase in the next 10 years, although TP does not comply, as a significant upward trend was determined. For TN and TP load on Shepparton Drains 11 and 12, the very significant downward trend indicates that TP load is heading in the right direction, although this is more influenced by flow than concentration, and the recent drought is likely to be a significant contributor to this downward trend.

The load performance target was set as a 20% reduction over 10 years, and only six years have elapsed since the 1998 strategy was released. Nevertheless, a preliminary assessment has been undertaken of the data from Drains 11, 12 and Broken Creek at Rices Weir based on raw data provided by G-MW. This analysis indicates that the 20% reduction has been achieved (Appendix B).

The Goulburn Broken Water Quality Strategy target of a 50% reduction from 1993 loads over 10 years was also assessed. This target has also been achieved (Appendix B). However, this assessment needs to be read with some caution, because:

- The influence of flow on load data is believed to be considerable;
- No baseline year on which to calculate the performance criteria reduction was set; and
- The load trend is based on data from two monitored drains in the catchment, but no load trend was calculated for the Broken Creek at Rices Weir.

SKM (2004) indicated that while management practices such as changes in irrigation practices and land use, implementation of farm re-use schemes, dam diversion, and drain construction and maintenance are likely to influence water quality trends in the SIR, more detailed studies are required to better understand the causes behind the identified trends.

Water quality data for electrical conductivity and turbidity have also been collected on the Broken Creek at Rices Weir, but it appears that this data has not been assessed to determine if the performance criteria for turbidity and salinity are being met. As part of the review of the 1998 Strategy, some preliminary assessment of this data has been undertaken (Appendix B). This reviews revealed that turbidity levels appear to be constant or to have a slight downward trend, however, neither the statistical significance, nor influence of the drought has been assessed. Turbidity levels would need to decrease significantly for further for ecological benefits to be realised. In addition, high turbidity levels may be limiting algal growth where nutrient concentrations are elevated, and so efforts to control turbidity need to be undertaken in conjunction with the management of nutrients. Electrical conductivity appears to be decreasing, although again the statistical significance of this trend, or influence of the drought, have not been assessed. However, it is expected that EC should increase under drought condition, so this preliminary result is promising. Electrical conductivity levels are below SEPP objectives of 500 µS/cm.

It is important that an update to the Broken Creek Strategy identifies meaningful water quality performance criteria or targets, and that these are clearly linked to monitoring and assessment efforts. This may need the current water quality and monitoring program to be re-assessed.

6.2.2 Flow

The flow regime of the Lower Broken Creek has been totally reversed at all levels [low flows (90th percentile), median flows (50th percentile) and high flows (10th percentile)] when compared to flow upstream, which is regarded as similar to pre-regulation flow. Large volumes of irrigation water totally dominate the flow regime within the system altering the flow regime to a level which elsewhere is known to have a significant ecological effect. Given that flows are intensely managed it is imperative that the current flow regime and the ecological responses to different flows are understood. This understanding is required to better manage flows in order not only to maintain current ecological values but also to enhance these values.

A related issue is the recent fish-kill, which may have removed much of the brood stock for the long-lived species such as Murray Cod and Golden Perch. Breeding and recruitment will be required for the long-term viability of these species. This is likely to require a flow high enough for overbank flows which inundate nearby wetlands and which are known to increase cod and Golden Perch survival.

Finally, a flow level of at least 40 ML/day is required to allow the fish ladders to operate efficiently. These fish ladders were recently installed throughout the system to replace old weirs that limited fish passage. These flows are currently being provided as a passing flow arranged with River Murray Water (Murray-Darling Basin Commission) regime. Unfortunately, these flows can only be provided when flows are below channel capacity (Kevin Preece, pers. comm.).

Flow (or lack of overbank flows) may also be impacting on the health of Black Box.

6.2.3 Stock Access to Riparian Areas

This issue has already been discussed in detail in Section 5.10.

Grazing does not appear to be having a major influence on erosion of bed or banks of the Broken Creek, however it is impacting on remnant vegetation. Along its length, the Lower Broken Creek has riparian vegetation ranging from fair to excellent condition. This condition of the vegetation is likely to have been further enhanced by the implementation of extensive fencing and off stream watering points along the waterway over recent years. The challenge is to find other mechanisms to allow for fencing of the remaining areas.

6.2.4 Guidelines

This has already been discussed in detail in Section 5.2.2. However, one of the key information gaps that was unable to be assessed as part of this review has been the level of uptake and application of these guidelines by landholders, and the potential benefits to the health of the Broken Creek from the implementation of better management practices on farms. This could be a monitoring objective developed in the revised strategy.

6.2.5 Index of Stream Condition

The Index of Stream Condition (ISC) was undertaken five years ago and provides a benchmark. Recent field surveys have just been undertaken for the second ISC assessment and results are currently being assessed. However, it is understood that due to changes in the ISC methodology since the original benchmarking was undertaken, it may not be possible to assess some changes against the latest ISC data. It is therefore currently unclear if a measurable improvement can be assessed.

6.2.6 Increased Numbers of Native Fish

Some fish monitoring was undertaken prior to the installation of the fishways, but no comprehensive follow-up monitoring has been undertaken to assess the overall impact of the Strategy on fish numbers. Fish numbers alone may not be a suitable parameter, as species diversity could decline without a change to total fish numbers.

6.2.7 Green Tree Falls

While not documented, verbal information provided during the review process indicate that this may have been addressed through the weir replacement program, which has reduced bank saturation. However, anecdotal evidence from landowners may disagree with this (K. Preece pers. comm.). The ongoing importance of this issue needs to be considered in the development of the revised strategy.

6.3 Limitation of 1998 Strategy Performance Criteria

In many instances it has been difficult to assess the success of the 1998 Strategy due to lack of clear targets and measurement criteria. The nine Performance Criteria to measure the success and review the progress of the Management Strategy have been difficult to assess, as in many instances the baseline value against which these criteria were to be measured was not identified, and there was no or insufficient monitoring data collected to measure improvement. In addition, the Performance Criteria identified do not appear to be adequate to be able to assess one of the key objectives of the strategy in preventing further degradation and improving the environmental condition of the Broken Creek Catchment. It is therefore critically important that any review of the Strategy develops meaningful and measurable performance criteria, including both Management Action Targets and Resource Condition Targets, against which the success of the Strategy can be measured, and that appropriate monitoring programs are put in place.

6.4 Outstanding and Emerging Issues

In addition to the issues assessed above as part of the review of the 1998 Strategy performance criteria, there are several other outstanding or emerging issues identified from the field visit that need to be considered in as part of the review of the Broken Creek Waterway Management Strategy. These are discussed below.

6.4.1 In-stream Habitat

A reduction large woody debris was identified has having resulted in degraded in-stream habitat in the 1998 Strategy, and opportunities to improve in-stream habitat through the re-insertion of in-stream habitat has been difficult to achieve due to the difficulty in obtaining appropriate debris. Opportunities to purchase suitable material, such as the bridge decking timber recently acquired by GBCMA should be identified where possible.

The insertion of large woody debris may present a threat to other values in the Broken Creek, by inhibiting water flow, allowing sediment accumulation and weed growth, and potentially causing a public safety issue. The benefits and risks of the insertion of large woody debris should be assessed at each location prior to any works being undertaken. This issue should be identified in the revised strategy.

6.4.2 Weeds and Silt

While arrowhead has been recognised locally as a problem for some years, its significance as a threat to waterway health requiring a concerted management response has only been recently recognised. Arrowhead has probably not yet reached the potential limit of its distribution on the creeks, and as / if creeks silt up, from land erosion or bank retreat, or reduced flow, the extent of the Arrowhead is likely to increase. The amount of silt on the substrate and the carp populations probably also reduce/prevent submerged aquatic vegetation from establishing.

6.4.3 Outlets to Wetlands

The wetlands of the Broken Creek are highly valued, as other wetlands in the region have been alienated from rivers and creeks due to the construction of levees. This has also occurred in a few locations on the Broken Creek, which could be re-engineered to allow high flows to inundate these sites. The engineering works required to do this might be relatively simple but discussions with landholders will be necessary to allow this to happen and landholders would require assurance these works would result in an increased flood risk.

7. Relevance to Current Institutional and Policy Framework

There are have been a number of institutional and policy changes since the 1998 Strategy was developed which have influenced the delivery of the strategy action items, and provide an important context for the development of a revised strategy for the Lower Broken Creek. In the past the Department of Natural Resources and Environment (now the Department of Sustainability and Environment, and the Department of Primary Industries), Goulburn Murray Water (G-MW) and local government bodies have played key roles in initiatives and management of the catchment. Lower Goulburn waterways and the Goulburn Broken CMA at the time of the Broken Creek Management Strategy (1998) were new participants in management of the catchment with the aim of providing a leadership role in integrated catchment management. GBCMA now coordinate many administrative functions and organise communications mechanisms including a technical review group, community consultative committees and a Broken Creek working group. The Department of Sustainability and Environment (DSE), and the Department of Primary Industries (DPI), G-MW, Parks Victoria and local government bodies still play an important role in management of the catchment. The changes to the institutional and policy framework at a National, State and Regional level are discussed below.

7.1 National Framework

When the 1998 strategy was finalised, Natural Heritage Trust provided the majority of the national funding for implementation of the strategy actions. More recently, the National Action Plan for Water Quality and Salinity (NAP) has replaced the National Heritage Trust as the key national funding source for activities in the Goulburn Broken Catchment. In the 2002/2003 GBCMA Annual report, National Contributions to the CMA in 2003 were $849 000 from NHT and $19 112 000 from NAP, compared with 2002 contributions of $9 207 000 from NHT and $19 861 000 from NAP.

7.1.1 Natural Heritage Trust

The Natural Heritage Trust was set up in 1997 to help to restore and conserve Australia's environment and natural resources. Funding was provided directly from the Commonwealth to regional organisations, such as the CMA as well as individual community based organisations for often small-scale projects such as local revegetation projects. Due to the direct funding mechanism from the Commonwealth to local organisations, one of the criticisms of the original NHT program was the lack of regional coordination, and funding not necessarily being provided to the projects of regional priority.

Lessons learnt from the first phase of the Trust and the establishment of the National Action Plan for Salinity and Water Quality (see below) have been taken into account in the finalisation of a framework for the extension of NHT funding from 2002, and there has been a fundamental shift in the Trust towards more strategic investment. The model for regional investment under the extension of the Trust is based on that used for the NAP, including bilateral and regional partnership agreements, investment against accredited regional plans, and the provision of foundation and priority funding.

The Trust will have three overarching objectives:

- Biodiversity Conservation - the conservation of Australia's biodiversity through the protection and restoration of terrestrial, freshwater, estuarine and marine ecosystems and habitat for native plants and animals;
- Sustainable Use of Natural Resources - the sustainable use and management of Australia's land, water and marine resources to maintain and improve the productivity and profitability of resource based industries; and
- Community Capacity Building and Institutional Change - support for individuals, landholders, industry and communities with skills, knowledge, information and institutional frameworks to promote biodiversity conservation and sustainable resource use and management.

These overarching objectives have been the basis for defining the four programs and the development of the ten areas of activity.

The Trust will have four programs. These programs establish the resource condition outcomes that will be sought through Trust investment.

1. The **Landcare Program** will invest in activities that will contribute to reversing land degradation and promoting sustainable agriculture.
2. The **Bushcare Program** will invest in activities that will contribute to conserving and restoring habitat for our unique native flora and fauna that underpins the health of our landscapes.
3. The **Rivercare Program** will invest in activities that will contribute to improved water quality and environmental condition in our river systems and wetlands.
4. The **Coastcare Program** will invest in activities that will contribute to protecting our coastal catchments, ecosystems and the marine environment.

Investment under the Trust will be available for salinity and water quality measures across Australia, including in NAP regions. At least $350 million of the Trust funds will be invested directly on measures to improve water quality.

7.1.2 National Action Plan for Water Quality and Salinity

The National Action Plan for Water Quality and Salinity (NAP) is targeted at 21 priority catchments, which include the Goulburn Broken Catchment.

The goal of the Action Plan is to motivate and enable regional communities to use coordinated and targeted action to prevent, stabilise and start to reverse trends in dryland salinity affecting the sustainability of production, the conservation of biological diversity and the viability of infrastructure; and to improve water quality and secure reliable allocations for human uses, industry and the environment.

The National Action Plan involves the six elements listed below, all of which are necessary to achieve lasting improvements over dryland salinity and deteriorating water quality.

1. Targets and standards for salinity, water quality and associated water flows, and stream and terrestrial biodiversity agreed either bilaterally or multilaterally, as appropriate.
2. Integrated catchment/regional management plans developed by the community and accredited jointly by Governments, in the 20 agreed catchments/regions that are highly affected by salinity, particularly dryland salinity, and deteriorating water quality.

3. Capacity building for communities and landholders to assist them to develop and implement integrated catchment/region plans, together with the provision of technical and scientific support and engineering innovations.
4. An improved governance framework to secure the Commonwealth-State/Territory investments and community action in the long term: including property rights; pricing; and regulatory reforms for water and land use.
5. Clearly articulated roles for the Commonwealth, State/Territory, local government and community to provide an effective, integrated and coherent framework to deliver and monitor implementation of the Action Plan.
6. A public communication program to support widespread understanding of all aspects of the Action Plan so as to promote behavioural change and community support.

The Action Plan involves new expenditure by Commonwealth, State and Territory governments to address salinity, particularly dryland salinity, and water quality of $1.4 billion over seven years. The agreed principles for funding the Action Plan are listed below:

- The Commonwealth's financial contribution of $700 million for regional implementation of the Action Plan will be matched by new State/Territory financial contributions;
- COAG agreed that new State/Territory financial contributions include funding attached to measures announced since jurisdictions' budgets, provided that money is redirected to joint funding under the Action Plan;
- Commonwealth contributions will be available to a State/Territory once agreement is reached with that jurisdiction on the implementation of the whole package of measures; and
- Participating communities are also expected to make appropriate contributions in addition to the above.

NAP funds are spent through the regions via regional bodies such as the GBCMA.

Bilateral Agreements specify in more detail the agreements between the Commonwealth and individual States/Territories on how the Action Plan will be implemented. See www.napswq.gov.au/ for more information.

7.2 State Framework

There have been a number of institutional and policy changes at a State level influencing natural resource management for the Broken Creek system. These are discussed briefly below.

7.2.1 Department of Sustainability and Environment / Department of Primary Industries

In December 2002, the Victorian government formed two departments to supersede the role of what had previously been known as the Department of Natural Resources and Environment (NRE). The departments formed were called the Department of Sustainability and Environment (DSE) and the Department of Primary Industries (DPI), with some other functions previously performed by the NRE being handed over to other departments, such as Energy information handed to the Department of Infrastructure.

The roles of the newly formed departments were divided as follows:

- DSE to incorporate; Coasts & Marine, Conservation & Environment, Fire Management, Forestry, Heritage, Land & Water, Parks & Reserves, Planning, Plants & Animals, Property, Titles & Maps and Recreation & Tourism; and
- DPI to incorporate; Agriculture & Food, Fishing & Aquaculture, Minerals & Petroleum, Science & Research and Trade & Investment.

Repercussions of the newly formed departments for the Catchment Management were that the responsibilities of floodplain management at the ground level were now passed down from the State to DSE.

7.2.2 State Environment Protection Policy (Waters of Victoria)

The State environment protection policy (Waters of Victoria) was updated in June 2003 to reflect current scientific approaches and Victoria's catchment management arrangements, replacing the first policy from 1988. The 1988 SEPP focused mainly on the key problems facing our waters in the 1980s, particularly point source discharges. The new policy recognised that, since 1988, a partnership approach for protecting the environment has been developed where government, businesses and community members are working together, and that catchment management authorities and the regional coastal boards are central to these coordinating these partnerships.

The revised SEPP provides an updated framework that reflects the changes that have occurred since 1988 and provides a statutory framework for the next 10 years to protect Victoria's water environments. The SEPP sets a statutory framework for the protection of the uses and values of Victoria's fresh and marine water environments. As required by the Environment Protection Act 1970, the SEPP includes:

- The uses and values of the water environment that the community and government want to protect – these are known as beneficial uses;
- The objectives and indicators which describe the environmental quality required to protect beneficial uses; and
- Guidance to catchment management authorities, coastal boards, water authorities, communities, businesses and local government and state government agencies to protect and rehabilitate water environments to a level where environmental objectives are met and beneficial uses are protected (the attainment program).

Objectives and indicators of environmental quality have been updated from the original SEPP. The SEPP includes objectives (i.e. the goal posts) and targets (i.e. interim milestones) to both provide the ultimate objective and to encourage and drive continuous improvement, towards that objective. Objectives for nutrients have been incorporated within the new SEPP. There are also several new assessment approaches such as ecological risk assessment protocols and a methodology for developing local waterway trigger values, which need to be taken into account for the development of the revised Strategy.

7.2.3 Victorian River Health Strategy

The Victorian River Health Strategy (VRHS) outlines the government's long-term direction for the management of Victoria's rivers. It provides a vision for the management of rivers in Victoria, policy direction on issues affecting river health and a blueprint for integrating efforts on rivers and ensuring that effective river health benefits and achieved for the resources invested. A key philosophical change in this policy is the approach of "protecting the best", rather than spreading limited resources across all environmental issues affecting river health.

The VRHS provides a framework for regional communities to make decisions on river protection and restoration and to find the balance between using our rivers and maintaining their ecological condition. This document therefore provides an overall policy framework that needs to be considered within when identifying management directions for the Broken Creek.

7.2.4 The White Paper – Our Water Our Future

In June 2004, the Minister for Water John Thwaites released the White Paper, Securing Our Water Future, an action program including 110 new initiatives to secure Victoria's water for the next 50 years. The White Paper follows on from the release of a Green Paper in August 2003, which was followed by a period of public meetings, stakeholder consultation, and public submissions prior to the finalisation of the White Paper.

The White Paper is a key policy document aimed at guiding water management in Victoria into the future, and needs to be considered in the development of the revised Lower Broken Creek Strategy.

The White Paper identifies a number of initiatives in the Goulburn Broken Catchment, including:

- 165 000 ML environmental water for Murray and Victorian tributaries;
- Improved environmental flows in Goulburn and Broken Rivers;
- River Murray icon site gains water – Barmah Forest;
- Lake Mokoan returned to wetlands;
- Making 'sales' water into secure, tradeable entitlements;
- Irrigation channel upgrade and new technology for Tatura;
- Projects to improve on-farm water efficiencies and reuse systems;
- Pipeline for efficiency of Tungamah supply, saving 4 000 ML;
- Water recycling projects;
- $30 million for dam safety and $50 million for irrigation system improvements; and
- Eildon Dam wall improvements.

7.3 Regional Framework

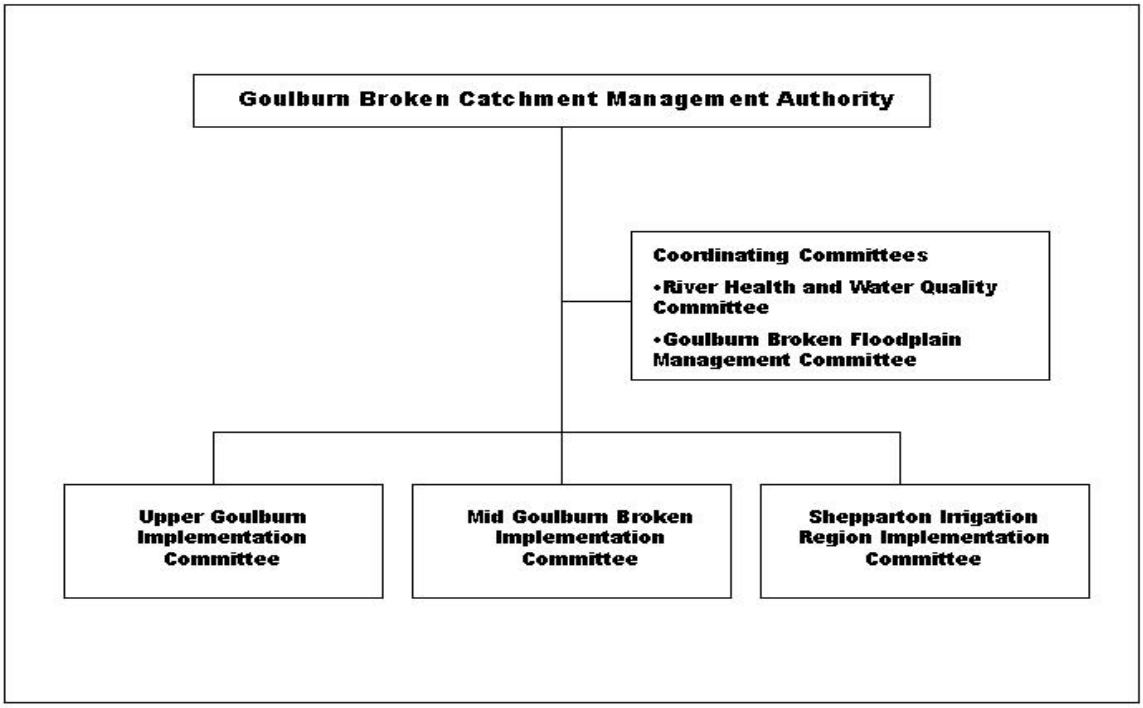
7.3.1 Goulburn Broken Catchment Management Authority

The Goulburn Broken Catchment Management Authority was formed in 1997, resulting in an amalgamation of various groups responsible for looking after natural resources in the area, such as Lower Goulburn Waterways, the other water boards and the Catchment and Land Protection Board, with the aim of creating a whole of catchment approach to natural resource management.

The primary goal of the CMA is to ensure the protection and restoration of land and water resources, the sustainable development of natural resources-based industries and the conservation of our natural and cultural heritage, via legislation and support passed down from the State, via the DSE, previously NRE.

The Authority, using the provisions of s180 of the Water Act 1989 has established three geographically based Implementation Committees, structured as shown in Figure 2.

Figure 2 Goulburn Broken Catchment Management Authority Implementation Committees



River Health and Water Quality Committee

The River Health and Water Quality Coordinating Committee oversees river health and water quality research, monitoring and implementation activities in the catchment. The committee is made up of community and agency representatives and is responsible for ensuring works and activities reflect regional priorities set with the input of the community and current knowledge.

The Committee has strong links to Goulburn Broken Catchment Management Authority's geographically based community implementation committees and waterway working groups. These Implementation Committees provide direction towards the implementation of on-ground actions and report to the Goulburn Broken Catchment Management Authority Board. Further information is provided in Section 5.2.1.

Goulburn Broken Regional Catchment Strategy

The Goulburn Broken Regional Catchment Strategy provides the context in which the Goulburn Broken catchment community will work with the Commonwealth and State agencies, rural and urban water authorities, landholders, the broader community and local government to achieve the CMA's vision. It sets the context for the Catchment's sub-strategies and action plans. Timescales for targets and actions reflect the timescales of different biophysical processes.

The Goulburn Broken RCS 2003 features an updated vision and a reassessment of the catchment's natural assets and current and emerging threats such as salinity and declining water quality. The RCS prioritises the actions and works that must occur to address these threats so that effort and funding can be directed where they are most needed. A key element of the framework is the whole of catchment approach that promotes investment that offers benefits to the natural environment, the social fabric and the economy of the region. Strong leadership and sound partnerships with government, other agencies and the community have led to Goulburn Broken Catchment being at the forefront of natural resource management in Australia. GBCMA has won national and international acclaim for the efforts of its community and agencies in dealing with issues such as salinity and waterway management. The Strategy aims to build on that success.

Draft Regional River Health Policy

The Goulburn Broken Regional River Health Strategy was prepared by the River Health and Water Quality Committee of the Goulburn Broken Catchment Management Authority. The Goulburn Broken Regional River Health Strategy builds on existing river-related action plans, implementation plans and strategic documents and is supported by a series of sub-strategies and discussion papers. The Regional River Health Strategy provides a framework for integration of actions that will enable rivers of high quality to be protected and others to be improved in quality for current and future generations. The Strategy relies on four key objectives:

- Protecting the rivers that are of highest community value from any decline in condition;
- Maintaining the condition of ecologically healthy rivers;
- Achieving an 'overall improvement' in the environmental condition of the remainder of rivers; and
- Preventing damage from future management activities.

The strategy identifies a number of high priority waterways within the Goulburn Broken catchment. These include rivers that are "of greatest value to the community", and rivers that are currently "ecologically healthy". It also identifies waterways within the catchment that can potentially be improved to ecologically healthy condition.

The strategy identifies opportunities for restoration or improving the environmental condition of other rivers throughout the catchment, including the establishment of a new population of Trout cod in Hughes Creek. Key threats to high value assets in the Goulburn Broken Catchment waterways were identified using a risk analysis. Comments on the draft Strategy are presently being taken by GBCMA.

Broken Boosey State Park and Nathalia and Numurkah Natural Features Reserves

Broken-Boosey State Park, a linear corridor bordering the Broken, Nine Mile and Boosey Creeks spanning 1030 hectares, was proclaimed with the passing of the Box-Ironbark Bill on 30 October 2002. The State Park is managed by Park Victoria, and increases their roles and responsibilities within the Lower Broken Creek system. This is a major shift in riparian zone management in the Goulburn Broken catchment.

8. Conclusions and Recommendations

It is now more than six years after the 1998 Broken Creek Strategy was finalised, and the strategy is now of limited relevance for the ongoing management of issues within the Lower Broken Creek for the following reasons:

- Many of the priority actions from the 1998 Strategy have been implemented, and any outstanding issues, such as remaining control of stock access to the riparian zone, need new approaches;
- There are several emerging environmental threats to the identified values of the Broken Creek, such as new weed infestations, that need to be addressed;
- There has been significant institutional, policy and strategic changes since the 1998 Strategy was finalised, such that the context of the 1998 Strategy is no longer relevant; and
- Our approach to the development, and structure of waterway management structures has evolved, and there is the opportunity to provide a more user-friendly document.

In addition to these, the 1998 Strategy recognised that a review of performance criteria and management objectives should be undertaken in five years (i.e. 2003) and that the Strategy should be refined, developed and improved on an ongoing basis. This review therefore meets the intent of the original Strategy.

8.1 Key Ongoing and Emerging Issues

Many of the management measures to address the key management issues identified in the 1998 Strategy have been implemented. However, there are several issues where ongoing effort is required, and several emerging issues. These include:

- **Riparian zone and stock access:** Managing riparian vegetation along the creek is important to allow the creek to provide habitat and function as an important wildlife corridor. While many riparian frontages have been fenced as a result of actions under the 1998 Strategy, there are further areas still requiring protection that will need new incentives or approaches;
- **Degraded instream habitat:** The lack of available timber has limited the ability to install large woody debris in waterways as identified in the 1998 strategy, and the issue of lack of adequate instream habitat remains current. Future opportunities to address this issue will need to be considered;
- **Water quality:** While an initial review of available data shows improving water quality, this is based on limited data within the Broken Creek and it is difficult to exclude the influence of the drought on this improvement. Expansion of the monitoring program recommended in the 1998 strategy was not implemented, but should be considered in the revised strategy;
- **Environmental Flow Regime:** The need to determine an environmental flow for the Broken Creek is considered critical to protect and enhance the environmental health of the Lower Broken Creek, while allowing for the ongoing role of the system as a conduit for irrigation water. Following the fish-kill, the need for an environmental flow in the Broken Creek has gained greater urgency, which needs to be formalised to provide a mechanism for securing and delivering water for the waterway;

- **Weed infestations:** The invasion of weeds – terrestrial, riparian and aquatic, remains a serious threat to riparian vegetation. The most significant aquatic weed species at the present is Arrowhead, which has spread rapidly in the last few years until it now presents a very difficult control problem. Other species of concern include proliferations of the native species Azolla and Cumbungi in specific locations, as well as other exotic species such as *Lippia*, blackberries, olives, date palms, briars and peppercorns. Weed infestations and spread need to be considered and addressed in the revised strategy; and
- **Wetland Enhancement:** Wetland health is one of the major aims of the Goulburn Broken Regional River Health Strategy, and 2 500 ha the Broken Creek floodplain is regarded as a “nationally important” wetland. There are likely to be a number of sites, which if "opened up" would allow floodwaters or high flow to enter the floodplain wetlands and improve their

These issues should be assessed in more detail and incorporated within the revised Broken Creek Management Strategy presented in Volume 2.

8.2 Strategy Structure and Format

The Reviewers found the 1998 Strategy difficult to read, as the existing document was not clearly laid out and was at times repetitious. This is partly because the 1998 Strategy is both a state of the environment report for the Broken Creek as well as a strategy document. For example, the initial six chapters provide background information on the Broken Creek and its catchment, and then this information is then again repeated in Chapters 7 to 9, which begins to put the issues into a management context, with actions identified. However, the actions themselves are not clearly listed in a tabular format, but incorporated within lengthy sections of text. It is not until Chapter 10 that the objectives for the 1998 Strategy are identified, and once again the overall objective is not clear from the surrounding text. Preliminary performance criteria are presented, but it is not clear the process undertaken to develop these criteria, and hence their status. They appear to have been put forward by the authors, and may not be based on any stakeholder or agency consultation. No monitoring program is provided that specifies the parameters that will need to be monitored, monitoring locations or the frequency of monitoring required to determine if these performance criteria have been met.

In preparing a revised Strategy for the Broken Creek, therefore, the following are considered important:

- **Policy Context:** Provide a structure and content that is consistent with the current regional policies and strategies, particularly the Regional River Health Strategy and the Regional Catchment Strategy;
- **Vision and Objectives:** Develop a clear and concise vision for the Broken Creek and clear objectives for the Broken Creek Strategy against which the success of the Strategy can be assessed in the future;
- **Clear Management Program format:** Present the Management Programs and Actions in a clear and concise format, that can stand alone and be easily referred to by those responsible for implementing the strategy;
- **Measurable Performance Criteria:** Develop meaningful and measurable performance criteria against which the success of the Strategy can be measured;
- **Develop and Implement Appropriate Monitoring:** Outline a monitoring program that will allow the collection and analysis of appropriate data to determine whether the performance criteria have been met;

- **Transparent Process:** Provide a clear overview of the process that was followed to develop the revised strategy, including stakeholder consultation for the development of key components such as the vision, objections and management actions;
- **Limitations:** Clearly present any assumptions made, information gaps, and limitations of the revised strategy; and
- **Review Process**: Outline the process for review and updating of the revised strategy in the future.

These issues will be addressed in Volume 2, which will form the revised waterway strategy for the Broken Creek.

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SKM, 1996b, *A Management Strategy for Broken Creek, Study Report, Stage 1, Volume 1*, Lower Goulburn Waterway Management Authority, Sinclair Knight Merz, Armadale, Vic.

SMEC, 2002; *Best Practice Principles and Standards for Drainage in Dryland Catchments: Background Report*, Snowy Mountains Engineering Corporation, 2002.

Webb et al, 2004; *Review of Water Quality Monitoring Programs in the Goulburn-Broken Catchment*, J. Angus Webb, Michael R. Grace, Carmel A. Pollino, Samantha J. Imberger. Water Studies Centre, Monash University, Melbourne, 2004.

Appendix A

Audit Checklist

Key Asset/ Issue (1998 Strategy)	Additional information	1998 Strategy – Management Issues and Strategies		Review Checklist	
		Existing Initiatives (1998)	Future Directions (1998)	Action Implemented? Yes/No/Partially Complete/Ongoing	Further information
1. CATCHMENT MANAGEMENT					
Irrigation Drainage ***Flood Response*** Elimination of natural storage of runoff, resulting in: ◗ Greater volume outfalls to receiving waters & flooding ◗ Flows of higher frequency ◗ Flows with higher peaks Agricultural drains increase the frequency and duration of low/intermediate flood events on the creek. ***Water Quality*** Removal of irrigation surface water, outfall from channel overflows & groundwater control pumps ◗ Salinity 500 – 2500 EC in waterway ◗ Increase nutrient (phosphorus and nitrogen) loads Export of fertilisers, pesticides and other chemicals from farm drains Management of effluent from intensive animal husbandry Maintenance of balance between poorer quality drainage water and higher quality water supply ***Sedimentation*** ◗ Sediment transport increases with high velocity flows, increasing stream turbidity	Future drainage expansion was identified in 1998 Strategy for Muckatah catchment & Brownings Rd Diversion Drain**.** Design incorporates measures to regulate outfall rates and manage nutrients and sediment. Review of GW pumping under SIRLWSMP (SKM) recommended: ◗ Disposal from public & private pumps can proceed after 7 days or greater of Broken Ck flow >300ML/day ◗ Public pump discharge should commence within 7 days of approval & continue for 60 days ◗ Private pump discharge should commence within 21 days & continue for a min of 30 days ◗ Public pumping only during irrigation season, rostered to achieve a uniform distribution & target salinity <500 EC units In Middle Catchment, Shepparton Drains 11 & 12 have excessive drain capacity, resulting in: ◗ Increased flooding frequency ◗ Decreased water quality ◗ Increased Siltation No history of serious blue-green algae blooms. Potential future concern as increased water management on farm & weir replacement will result in reduced	◗ Policy development on control of works in natural drainage lines (DNRE, GMW)1 ◗ Review of drainage design policy and guidelines (GMW) ◗ Draft drainage policy, Shire of Moira ◗ ◗ Salinity Management Strategy (SIRLWSMP): ◗ Initiative under Nutrient Mgt strategy aimed at improvements of on-farm water mgt, re-use systems, Control of dairy shed effluent ◗ Promotion of drainage diversions by pumping from drains, eliminating outfall flows during irrigation season ◗ Implementation of groundwater control pumps (both public and private) ◗ Implementation of surface drainage in currently underdrained parts of Irrigation Areas ◗ ◗ Wetland management Plans (DNRE) ◗	***Surface Drainage Management*** 1.1. <u>CMA Coordination</u>: CMA to coordinate and monitor GMW and local government activities in regard to: 1.1.1. Reviewing the consistency of approach to drainage throughout catchment; 1.1.2. Reviewing the equity of allocation of resources on drainage activities; 1.1.3. Reviewing the likely downstream impacts on waterways and streams	1.1 Yes	***Surface Drainage Management*** 1.1. <u>CMA Coordination:</u> 1.1.1. There is a consistent approach within the dryland areas and within the irrigation areas, but not across both. Strategies have been developed for both dryland and irrigation areas. 1.1.2. This is managed under a formal process. Budgets are developed annually and reviewed throughout the year as programs are implemented. They are based on priorities set out in the Regional Catchment Strategy, which is reviewed every 5 years, with the most recent review occurring in 2001/2002 (Ken Sampson, GBCMA, pers. comm). 1.1.3. Drainage Operation Monitoring Program (DOMP) monitors irrigation returns to natural waterways and is used to assess whether nutrient outputs meet MDBC end of valley targets. According to the SKM (2002) report in Webb et al. (2004), the program does not have complete coverage of all so called 'hot spots' across the GB region. It has limited spatial range, but nonetheless meets it's objectives. Sampling is conducted fortnightly, and the temporal sampling strategy of the program should also be assessed to determine whether sampling is meeting the objectives of water quality strategies, particularly during the irrigation season. Information from Water EcoScience and the SKM (2002) report suggest sample parameters are inconsistent between sites, limiting spatial comparisons. Salinity is measured at the majority of drain sites, but DO (a key indicator of anoxic conditions as a result of an algal bloom) is not. It also recommends that other ecologically relevant parameters (e.g. chlorophyll a as a direct measure of algal biomass) be considered (Webb et al, 2004). A monitoring program of outfalls to the Broken Creek and ultimately the River Murray has been developed for the

[1] Natural Drainage Systems. Control of Works and Activities. Draft Policy Paper 1997

[2] Natural Drainage Systems. Control of Works and Activities. Draft Policy Paper 1997

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◗ Exposed banks more susceptible to erosion ◗ Increased transport of nutrients attached to sediment ◗ Stock access and cropping exposed soils to erosion ◗ Relationship between sediment deposition, transport and the proliferation of pest plants ◗ Relationship between increased silt / sediment in stream beds and reduced species diversity ***Wetlands*** ◗ Increased water storage in wetlands leads to altered hydrological regimes and wetland degradation ◗ Poor quality drainage outfalls results in poor water quality ,increased sediment loads and weeds invasion ***Water management*** ◗ Distortion of the natural watering cycle from inefficient on-farm practices and irrigation drainage; ◗ Management of runoff and subsequent bank erosion and sediment deposition; Application and management of irrigation water and flows; **Dryland Drainage** Issues as for irrigation drainage, including: ◗ Changed hydrological balance ◗ Increased runoff volume & peak flows ◗ Increased loads of sediment, nutrients and dissolved solids (salts)	import of high quality irrigation water resulting in increased risk of algal blooms. Particularly an issue in the upper catchment: ◗ Landforming 10% upper catchment ◗ Private drainage 25% upper catchment Poorly managed drainage schemes include: ◗ Drain Rd Drain Kreeck Rd drain (Sandy Creek)	Policy development on control of works in natural drainage lines (DNRE, GMW)2 ◗ Review of drainage design policy and guidelines (GMW) ◗ Draft drainage policy, Shire of Moira	1.2 <u>Technical Review Group</u>: Formation of a Technical Review Group for Regional Drainage and formulate guidelines 1.3 <u>Storage</u> – Compensate for the effect of loss of catchment storage and retardation of natural drainage by incorporating storage within drainage system. For example, linear wetlands along drainage paths	1.2 Yes 1.3 Partially complete	Muckatah Drainage network as outlined in 2SKM (2002), G-MW (2002) investigates the behaviour of four irrigation drains (Shep Drain 11 & 12; MV Drains 13 & 18) in relation to export of phosphorus loads, and how the magnitude of flow events has an impact. [3]GBCMA (2002), Section 10.3.2 indicates that monitoring programs allow practitioners to develop their knowledge and to improve design, construction, and management techniques. SIRIC 2000 (p35) indicates a monitoring program is in place at 17 sites. The Memorandum of Understanding for Irrigation Drainage provides a policy for drain monitoring, including establishing Resource Condition KPIs linked to management targets. 1.2. <u>Technical Review Group</u>: A different approach has been taken for the dryland & irrigation regions of the catchment. For the dryland areas, there has been a review of dryland drainage in the catchment, with the Best Management Principles and Standards for Drainage in Dryland Catchments Background Report being prepared by Snowy Mountains Engineering Corporation (SMEC) for the GBCMA in December 2002 (SMEC, 2002). For the irrigation region the Technical Review Panel (SIRTec) of the SIRIC, made up of Agency staff, provides a high level coordination role for Agencies across programs. At an operational level, there are a number of working groups - Surface, Farm & Environment, and Waterways, that involve community and agency staff in detailed implementation. There are also a number of technical fora, including the Community Surface Drainage Coordination Committee for Community Drains (CSDCC), a state wide group which sets standards for surface water management schemes on behalf of DSE, GM-W's D800 Committee which manages construction and primary drains, and the Surface Water Management Working Groups for community input. (Ken Sampson, GBCMA, pers. comm). 1.3. <u>Storage</u>: Drainage designs are to be based on 50mm 24-hour summer rainfall with a 2-year Average Recurrence Interval (ARI) and a five-day runoff removal period (SMEC, 2002). A number of retardation basins have been built into the design of the Surface Water Management Scheme, eg. Kinnaird's Wetland on the Muchatah System (SKM, 2002, Section 4.4) which meet this standard for catchment storage. Works are also to be incorporated into new drains, and existing drains retrofitted where possible.

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◗ Spread of weed species along drainage lines ◗ Erosion of the drain waterways Other issues include: ◗ Landforming ◗ Uncontrolled drainage Roadside drainage **Salinity and Waterlogging** Response of the landscape to: ◗ Clearing of native vegetation for agriculture ◗ Application of irrigation water on poorly drained land Main impacts are: ◗ Rising groundwater tables ◗ Loss of soil structure ◗ Loss of productivity, vegetation cover & salt encrustation Increased salinity in creeks & drains (from rural drainage & groundwater pumping) **Urban Wastewater Management** Lack of stormwater management leads to runoff of oils, litter and sediments Increased runoff volumes from impervious surfaces	Review of GW pumping under SIRLWSMP (SKM) recommended: ◗ Disposal from public & private pumps can proceed after 7 days or greater of Broken Ck flow >300ML/day ◗ Public pump discharge should commence within 7 days of approval & continue for 60 days ◗ Private pump discharge should commence within 21 days & continue for a min of 30 days Public pumping only during irrigation season, rostered to achieve a uniform distribution & target salinity <500 EC units Upper Creek System: Generally moderate condition. Poor water quality noted at: ◗ Broken Ck downstream of Devenish ◗ Boosey Ck downstream of Sandy Ck ◗ Katamatite & Tungamah (unsewered towns / stormwater) Middle Creek System: Little data. enerally moderate condition. Issues: ◗ Numurkah & Wunghu (urban stormwater) Lower Creek System. Issues: Nathalia (urban stormwater)	Review of urban stormwater management (Shire of Moira) ◗ The River Environment and Water Quality Committee (REWQC), an initiative of the former catchment and Land Protection Board ◗ Creation of wetlands for nutrient stripping ◗ The Goulburn and Broken Water Quality Strategy, an initiative of the former catchment and Land Protection Board	1.4 Outfall capacity – Drainage should include measures to retain storage within the sub-catchment to be drained. Outfalls to receiving streams should be designed with the similar capacity as the existing or former capacity of the undrained catchment 1.5 Transfers – Transfers of water away from natural drainage lines or across sub-catchment boundaries should be avoided 1.6 Drainage Standards – drainage should be limited to the removal of runoff in excess of natural or dryland rates of runoff. 1.7 Guidelines – TRG for Regional Drainage should develop drainage design guidelines for good management practice throughout the region. 1.8 Drainage referral – Other agencies should be required to consult the CMA in case of any variation to the design standards 1.9 Property Boundaries – With private land, unrestricted outfalls across the property boundary should not be permitted in both areas of irrigation and dryland drainage. 1.10 Recording – All drainage outfalls from private property to drains constructed or managed by agencies should be licensed	1.4 Partially complete 1.5 Yes 1.6 Yes 1.7 Yes 1.8 Yes 1.9 Yes 1.10 Yes	1.4. Outfall Capacity: Controlled farm outfall to drains means that storage is maintained on each individual property and released in a controlled manner. Increase in reuse storage also results in an increase in catchment storage. SMEC (2002), Section 8.3 outlines that drainage designs are to be based on 50mm 24-hour summer rainfall with a 2-year Average Recurrence Interval (ARI) and a five-day runoff removal period are considered to be appropriate for community drainage schemes. This is also outlined in GBCMA (2002), p37. 1.5. .Transfers – An underlying philosophy for all new works for the Surface Water Management Strategy is that all drains are constructed within their natural catchments and the total catchment is considered ([3]GBCMA, 2002). It is recognised that in some instances this is not possible, but it should be promoted as the first option. 1.6. Drainage Standards: SMEC, 2002 outlines dryland drainage design standard and principles, as detailed in the Community Surface Drainage Schemes Document (SKM, 1997) including: Standards, Drain Design Details, Catchments, Location, Entry and Exit Locations, Salinity issues and Protection of the Environment 1.7. Guidelines: Refer to 1.6 1.8. Drainage Referrals: Community drainage controls are incorporated in the Planning Scheme. Major drainage infrastructure must be designed in accordance with the drainage standards, unless agreed with the CMA (Ken Sampson, GBCMA, pers. comm.).. 1.9. Property Boundaries: See 1.4. 1.10. Recording: This information is recorded for both community and primary drains. Farm drains are small in capacity and direct excess irrigation and rainfall runoff to drainage reuse systems. The excess

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Remnant Vegetation Excessive removal of native vegetation has resulted in: ◗ Increased soil salinity ◗ Soil erosion and land degradation ◗ Loss of biodiversity ◗ Loss of shade & shelter Most important remnants line waterways or wetlands		Provision of incentives for tree planting and regeneration (DNRE)	licensed 1.11 Roadside drainage – This type of drainage should be designed and implemented to minimise downstream impacts 1.12 Outfall Protection: As well as reducing capacity, outfalls should be designed to reduce velocities of flow entering the riparian zone of waterways, & minimise erosion risk. Guidelines should be developed. TRG should develop guidelines. 1.13 Constructed wetlands: All large drains should incorporate online & offline wetlands or storage to trap nutrients, sediment and weeds. TRG should develop guidelines. 1.14 Water Quality Management: CMA must be an active participant in the REWQC, and work with GMW & municipalities to ensure that management plans are developed to reduce nutrient loads from existing drains outfalling to the Broken Ck & tributaries, esp Shep Drains 11 & 12, and MV drains 13 & 18. All new works under SDS should be designed for nutrient stripping & drainage reuse. ***1.15*** Retrofits – existing drains should be upgraded to better conform with contemporary drainage design standards and community expectations, in particular Shepparton drains 11 and 12, Drain Road Drain and Kreeck Road Drain	 1.11 Yes 1.12 Yes 1.13 Partially complete 1.14 Yes 1.15 Partially complete	runoff is then passed to regional drainage systems such as CSDs or Primary Drains (SMEC, 2002) 1.11. Roadside Drainage: This is broadly addressed within the Background Report for Best Practice Principles and Standards for Drainage in Dryland Catchments, that constructed drainage should be limited to particular locations with existing drainage or soil salinity problems, which cannot be improved by management practices, and must be subject to proper planning controls (SMEC, 2002). 1.12. Outfall Protection: Three or four sites have been done by incentive programs (50% of design & construct costs covered) for individual properties. This is difficult as the stream is perched in many locations, so water cannot flow into the waterway. There is limited landholder uptake, and is best undertaken when a whole farm plan is being developed. There are limited tangible benefits for the landholder as the benefits usually occur downstream (Dustin Lavery, GBCMA, pers. comm). 1.13. Constructed Wetlands: This is limited to KinnairdsWetland near Numurkah on the Muckutah system. Incorporates best practice for rural water management (Muckatah Drain Management Plan, 2002). All new drains will incorporate similar design, and retrofit opportunities have been explored (report). 1.14. Water Quality Management: River Environment and Water Quality Committee (REWQC), now the River Health & Water Quality Committee (RHWQC), has been established which has representative from the community and agencies, including the CMA. This has led to the development the Goulburn Broken Water Quality Management Strategy 1996-2016 ([2]GBCMA, 2002) and is undertaking drain audits to identify point source input to the drainage system. ***1.15.*** Retrofits: This has been assessed, and consideration given to using offline storage or online vegetation to detain but not restrict flow. The GBCMA (02/03), p11 indicates that Drainage Resources Assessments have been completed for the 20 existing main drain catchments. It also outlines 2.2km of existing primary drains have been remodelled.

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			Land Management		***Land Management***
			1.16 Technical Review Group for Land Management: To provide a formal procedure for regular reporting between relevant agencies.	1.16 Yes	1.16. TRG for Land Management: This has not been formally established, but may be covered by other initiatives / groups, such as PISC & Dryland Support Team, and has been met in principle. The formation of the CMA may largely cover this, with the "Partnership Team", which includes all Managers within the CMA, Implementation Committee coordinators, DPI, DSE and GMW. Ensures that there are links between all relevant programs. The CMA, Community and Partner Structures, these include the GB CMA Board, Implementation Committees (community based and the GB River Health and Water Quality Committee as outlined in [1]GBCMA (2004), Section 14.1.
			1.17 Wetlands Management: Liaise with DNRE & relevant drainage authorities to ensure future drainage schemes do not detrimentally change wetting & drying cycles in wetland systems	1.17 Yes	1.17. Wetlands Management: This occurs via environmental assessments for new surface drainage management scheme proposals
			1.18 Management of Water Quality Inputs: Through TRG Land Management & REWQC, work with other agencies / community to improve knowledge of magnitude and timing of pollution sources to Broken Creek, and devise management practices to mitigate.	1.18 Yes	1.18. Management of Water Quality Inputs: This has occurred through implementation of the WQ strategy, drain audits, drain monitoring stations & Waterwatch (GMW & landholders). Information provided in GBCMA Annual reports .
			1.19 Development Referral: Relevant planning authorities should refer all development applications to the CMA if development may impact on water quality.	1.19 Yes	1.19. Development Referral: There is no formal requirement to refer to GBCMA. Instead the NE Vic Planning Guidelines for Water Quality prepared by the CMA has been provided to all local planners.
			1.20 Effluent for Intensive Animal Industries: Through TRG LM & REWQC, CMA should work with planning authorities to ensure that (i) no effluent from intensive animal husbandry is discharged directly to drains / waterways, (ii) all effluent is managed in accordance with best practice, (iii) a nutrient balance	1.20 Partially complete	1.20. Effluent for Intensive Animal Industries: This has been largely addressed via the development of AgNote 0435 and 0430 for Dairy Shed Effluent. Principally enforced by EPA & GMW. GBCMA (NDS) outlines that modern effluent systems are designed to collect all waste water generated by and during the milking and washdown process. The EPA requires all dairy shed waste to be held and managed on farm. (p10) Concentrated Dairy Effluent Guidelines were produced in 2000, which outline risks, management options

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			approach is adopted by all sectors.		were produced in 2000, which outline risks, management options, acceptable operating criteria, management and control options (GMW, 2000). Based on information provided, there has been a marked decrease in effluent discharge to waterways, which generally occurs as a result of major rainfall events.
			1.21 Other Point Source Management: CMA should work with EPA to manage point source inputs from industry to drains & waterways.	1.21 Yes	1.21. Other Point Source Management: The issue of point source inputs from industry to drains is addressed by Local Govt through the development of the Moira Shire Stormwater Management Plan, covering 16 towns in the Shire. For Broken Ck, industry is generally limited to Nathalia & Numurkah, which is covered by the Plan.
			Irrigation Water Management		***Irrigation Water Management***
			1.22 Water Supply Distribution – Releases and diversions for irrigation supply should match demands as close as possible	1.22 Yes	1.22. Water Supply Distribution: Due to drought, there has been the need for increased efficiencies. As a result, supply has been carefully set to meet demand. The Lower Broken Creek Operational guidelines indicate that during the irrigation season the weir pools will be operated around the target operating level for each weir, to assist in this 4 day advanced ordering and scheduling of diversions will be introduced for customers (GMW, 2003).
			1.23 Improve on-farm management – through water recycling / harvesting, improved irrigation technology	1.23 Yes	1.23. Improve on-farm management: Shepparton Irrigation Region Implementation Committee (SIRIC) has an on farm program, which includes 3 incentive schemes: On farm planning, automatic irrigation & irrigation re-use. Annual reports (from 97-98 to 02-03) indicate that these incentive schemes have been implemented progressively with more farms becoming involved each year. The GBCMA (02/03) indicated that: 59.6% of irrigated areas within the region now have Whole farm plans (WFPs); each year a further 6% of properties install drainage re-use systems, now totalling 171 systems; and a total of 66 automatic irrigation systems have now been installed. Incentives for the construction of reuse systems and the installation of automatic irrigation were introduced in 2001/2002, it is noted, however, that works including farm reuse and improved irrigation layout have been undertaken at a rate of 6% a year since 1998. Guidelines for the SIRCS, WFP incentive scheme, Drainage reuse scheme and automatic irrigation incentive scheme were prepared in 2003.
			1.24 Channel Outfalls: Investigate incentives or other means to achieve increased diversions from irrigation outfalls & drains to private on-farm storage for	1.24 Yes	1.24. Channel Outfalls: GMW manages licensing of low and high flow diversions, including the diversion point and storage dam. DPI manages an incentive program for high flow diversions. GM-W has also developed a strategy for diversions for all drains (Dustin Lavery &

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			re-use		Ken Sampson, GBCMA, pers. comm.).
			1.25 Casey Weir System Management: Releases from Casey Weir should be better regulated to avoid over-supply leading to small persistent flows in Broken Ck, Major Ck & Boosey Ck downstream of diverters during dry weather. A similar issue of lesser priority applies to Gowangardie Weir.	1.25 Yes	1.25. Casey Weir System Management: Broken Creek Bulk Entitlements & Caseys Weir-Major Creek proposal for piping of current open channel will reduce future releases from Caseys Weir. The Bulk Entitlement for the Casey's Weir and Major Creek Rural Water Authority (CW&MCRWA) outlines that the total diversions over a 5-year period must not exceed 26625 ML (a 5 year cap of 5325 ML/annum) and a maximum of 6150 ML in any one year.
			Monitoring		***Monitoring***
			1.26 Monitoring Channel Outfalls & Drains: CMA & LGW should use the proposed TRG for Regional Drainage to liaise with GMW & ensure its operational flow monitoring & management systems are improved for channel outfalls, drains & waterways. Priority should be given to Shepp Drains 11 & 12, MV drains 13 & 18 & proposed Muckatah Main Drain. A monitoring program should be formulated.	1.26 Yes	1.26. Monitoring Channel Outfalls & Drains: See 1.1.3. Monitoring is in place for the new Muckatah system, with monitoring points upstream and downstream of Kinnairds Wetland to monitor nutrient stripping. Fortnightly monitoring of nutrients and continuous monitoring of turbidity, EC and flow is undertaken on Shepparton Drains 11 & 12 and MV drains 13 & 18 by Thiess on behalf of GMW, under cost sharing arrangements between GMW and GBCMA. Monitoring information is fed back to SIRIC through the RHWQC (Sam Green, GMW, pers. comm.)
			1.27 Point Source Monitoring: CMA to work with EPA to manage point source inputs from industry to drains & waterways	1.27 Yes	1.27. Point Source Monitoring: Combination of GMW network (Greg Smith / Shane Papworth) & Waterwatch (Dustin Lavery). Some resource limitations. Water quality programs in the GB Catchment include, Drainage Operation Monitoring Program, Major Storages Operations Program, Individual Reservoir Sites, Victorian Water Quality Monitoring Network, GB Dryland Salinity Monitoring Program, Shepparton irrigations region land and water SMP, MDBC Water
2. WATERWAY MANAGEMENT					
Waterway Erosion Bed & banks erosion is not a major issue in the Broken Creek system, with sediment deposition being a bigger issue. However, there are some locations where erosion is an issue, being:			2.1. Waterway Stabilisation: 2.1.1. Bed stabilisation will be required for at least 50% of the reach of Sandy Ck downstream of Benalla-Yarrawonga Road to retrieve impact of past excavation. Riparian vegetation should be re-established.	2.1. Yes	2.1. Waterway Stabilisation 2.1.1. Work on Sandy Creek completed approx 4 years ago. Sandy Creek Erosion Control Design Report was published in Feb 1999, it indicates that G-MW was commissions by the GBCMA to undertake investigation, design and construction services for remedial stabilisation works. Based on consultants report, approx $121,000 was spent,

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◗ Sandy Creek downstream of Benalla-Yarrawonga Rd (Kreeck Rd drain) ◗ lower reaches of Nine Mile Creek			2.1.2. Grade reducing structures are also recommended for stabilisation of the bed of lower reaches of Nine Mile Creek. Selective reshaping of the creek banks to reduce slope and introduce variation is also recommended. 2.1.3. If Chinaman's Weir is to be retained, tethering of logs on the outside banks of bends within the pool through Nathalia is also recommended 2.2. Water Quality Strategy: The River Environment & Water Quality Committee (REWQC) must be encouraged to develop a specific water quality strategy for the Broken Creek.		compared to a budget of $67K. 2.1.2. Grade reducing structures: This was completed in 2003 (D. Lavery, pers. comm.). 2.1.3. Chinaman's Weir: It is understood that this item has not been implemented. The rationale for why this work was recommended is not clear, however it may have been resolved through work on weirs within the Lower Broken Creek system 2.2. Water Quality Strategy: It is understood that a specific water quality strategy for the Broken Creek was not developed.
Sediment Deposition and Transport Streams are disposed to sediment deposition due to very low gradients and oversized channels. This is reinforced by the effects of weirs trapping sediments and increased inputs from modified land use and drainage. Weirs maintain permanent deep pools of water and inhibit consolidation of fine sediments. This reduces biodiversity, degrades aquatic habitat and favours opportunistic species (carp, typha, willows) Carp increase turbidity by recycling sediment. Willows slow velocities and trap sediment, and can increase water levels.		Works in upper catchment to control upland erosion (DNRE)	2.3. Sediment Transport Management: Operate weir gates to manage transport of sediment and alleviate siltation problems 2.4. Variation in Weir Pool Levels: Weir pool levels should be varied to allow consolidation of fine sediment & colonisation of emergent aquatic plants. 2.5. Carp Control: CMA should give priority to research to investigate impacts and control carp, and support National Carp	2.3. Yes 2.4. Partially complete 2.5. Partially complete	2.3. Sediment Transport Management: Installation of drop leaf gates has allowed water to flow freely over weirs, with the potential for sediment to move down the system. To monitor this movement a preliminary survey of channel cross sections has been undertaken. 2.4. Variation in Weir Pool Levels: The Lower Broken Creek Operational Guidelines states that during the non-irrigation period (winter), gates will be set to automatic level control to lower weir pool level to improve the stability of the riparian zone by allowing consolidation of sediments and establishment of emergent native aquatic vegetation (GMW, 2003). It is understood that this requirement of the Operational Guidelines has not been implemented to date, however is expected in the near future (K. Preece, pers. comm.). Weir pool levels have been manipulated to assist the clearance of *Azolla* in 2003. Implementation of this measure may be constrained by landholders need for domestic and stock water (Dustin Lavery, GBCMA, pers. comm.) and the risk to existing aquatic vegetation from frost (Sam Green, G-MW, pers. comm.). 2.5. Carp Control: Some work has been done in Barmah to trap carp. CMA has been involved in the National Carp Taskforce indirectly. Some constraints as CMA is responsible for fish habitat, but not fish

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			Task Force.		(DPI Fisheries responsibility).
Riparian Zone Vegetation Depletion of riparian zone vegetation, including long reaches of Broken Ck upstream of Katamatite. Due to: ◗ Past tree removal ◗ Uncontrolled stock grazing and stock access to waterways, ◗ Also results in weed invasion, bank erosion and water quality decline. Importance of riparian zone vegetation to catchment health	Worst affected areas of native vegetation due to stock access are: ◗ Broken Ck upstream & downstream of Numurkah & upstream of Buerckner Rd ◗ Along Sandy Ck ◗ Along Major Ck ◗ Along Nine Mile Ck & Broken Ck downstream of Shepp Drain 12 outfall, adjacent to excavated sections Also damage to riparian vegetation due to indiscriminate spoil placement (eg Lower Nine Mile/Broken Ck downstream of Drain 12 & upstream of Sloleys Bridge near Drain 20 outfall) Important riparian vegetation located at: ◗ Boosey Ck downstream of Tungamah ◗ Around Katamatite & downstream to Dip Bridge area ◗ Discontinuous sectors along Nine Mile Ck between Dunbulbalane & Wunghnu, esp. b/w Cargeeg Rd & Kellys Rd ◗ Around bifurcation of Broken Ck & Nine Mile Ck, near Katandra Weir, including section along both creeks ◗ Broken Ck downstream of Kokoda Rd ◗ Short sections of Broken Ck downstream of Numurkah near Lyons Rd & Central Mundoona Rd ◗ Patch of Nine Mile Ck downstream of Wunghu at end of Central Mundoona Rd	Works to protect stands of remnant vegetation, involving fencing and other initiatives at 24 sites (DNRE) National Heritage Trust (NHT) funding for a program on public lands, including fencing of remnant vegetation (DNRE)	2.6. Riparian Zone Management: CMA should encourage landholders and licensees to install fences and off-creek watering systems to control stock access. Priority should be given to areas of highest habitat value. 2.7. Frontage Management: LGW should liase with DNRE to control use of waterway frontages. 2.8. Reserves: – REWQC, LGW, DNRE and Parks Vic. should develop a cooperative plan for a system of riparian and wetland reserves along habitat corridors provided by Broken Ck catchment.	2.6. Yes 2.7. Partially Complete 2.8. Partially complete	2.6. Riparian Zone Management:. 81.2 Km of fencing and 155 offstream watering points have been provided, from $351,000 of incentive program funding. Approx 55,000 plants have been planted. Based on an average cost of $3/plant (range $1.50 to $5.00), this equates to spending of approx $165,000. This gives a total expenditure of approx $500K (Dustin Lavery, GBCMA, pers. comm.). [4]GBCMA (2002) outlines the length of fencing and revegetation undertaken and proposed. There are incentives for landholders to fence off waterways & install offstream watering points. Approx 75% of the frontages that can be fenced have been, and the remaining areas will be more difficult to achieve and may require a generational shift in land ownership and increased funding (D Lavery, GBCMA, pers comm). 2.7. Frontage Management: No MOUs exist, but most frontages are on Crown Land. Lands Vic (DSE) have been notified. There has also been a review of licences for Crown Water Frontages across the catchment, which includes Broken Creek. This looked at condition, measures for improvement, etc, but is now out of date. Management responsibility still rests with DSE and not the CMA, which restricts action. Frontages are controlled by Lands Vic, via generic agricultural grazing licences. Voluntary management agreements are also established with fencing grants programs. Parks Victoria land is not fenced or grazed and is generally in better condition. No formal agreements exist. See also Section 2.6 for fencing. 2.8. Reserves: This has been achieved through gazetting the Broken Boosey State Park in the last 12 months. This is managed through Park Vic, who is developing a management plan. Wetlands have not been included. A draft Wetland Strategy has been developed for the catchment. 99% of wetlands are on private land. The implementation of the Surface Water Management systems provides indirect protection to native vegetation remnants and wetlands by reducing accessions to GW and lowering regional watertable ([3]GBCMA, 2002, p17).

Key Asset/ Issue (1998 Strategy)	Additional information	1998 Strategy – Management Issues and Strategies		Review Checklist	
		Existing Initiatives (1998)	Future Directions (1998)	Action Implemented? Yes/No/Partially Complete/Ongoing	Further information
	◗ Adjoining Barmah Forest near Rice's Weir ◗ Patches & short segments on Lower Broken Ck: north bank near Boals Rd, James Bridge, Fairmans Bridge, Bourkes Bridge, just downstream of Barwo, downstream of Carlands Bridge & downstream of Walshes Bridge ◗ Short segments on south bank of Lower Broken Ck near Thompsons Rd, upstream of Carlands Bridge and near Prentices Rd.				
Instream Conditions Artificial reduction in large woody debris and resultant habitat degradation; Excavation and straightening resulting in loss of instream habitat. Willows have infested sediment bars in several locations.	Reduced LWD notable on excavated section between Kempsters Rd on Broken Ck and Wunghnu on Nine Mile Ck. Weed invasion notable at: ◗ Broken Ck downstream of Numurkah / Walshes Bridge ◗ Boosey Ck between Tungamah & confluence with Broken Ck Excavations / straightening have been undertaken: ◗ From entry of Shepparton Drain 12 on Nine Mile Ck, 32 km downstream of Carlands Bridge on Broken Ck. ◗ Downstream of GVH bridge, Numurkah ◗ Upstream of Go Cart Track, Numurkah ◗ Many parts of Majors Ck ◗ Boosey Ck upstream of Tungamah ◗ Sandy Ck up to Benalla-Yarrawonga Rd ◗ Nine Mile Ck upstream of Cargeeg Rd ◗ Upper end of Broken Ck to facilitate Caseys Weir transfer ◗ Most of Pine Lodge Ck 20km from		2.9. <u>Enhancement of In-stream Habitat</u>: Re-insertion of large woody debris (LWD) is recommended eg. Lower reaches of Nine Mile Ck. Where excessive silt accumulation exists, nearshore part of stream should be stabilised with indigenous vegetation. Removal or realignment of LWD should not be undertaken except where structures are threatened. 2.10. <u>Willow and Weed Management</u>: Actions to eradicate willows and aquatic weeds (eg arrowhead, etc) should be coordinated by LGW. Coordination with other groups to promote such action. 2.11. <u>Management of Macrophyte Infestation</u>: excessive growth of reeds and aquatic vegetation should be controlled (eg typha). The preferred means of management is through the provision of	2.9. No 2.10. Yes 2.11. Ongoing	2.9. <u>Enhancement of In-stream Habitat</u>: This has been difficult to achieve due to the difficulty in obtaining appropriate debris. On Public Land, debris has a value for terrestrial habitat and on private land it is usually used by landholders for firewood. GBCMA has purchased some decking timber from 2 bridges, which are to be demolished, for insertion in the waterway. This will continue when suitable opportunities arise to obtain suitable materials. 2.10. <u>Willow and Weed Management</u>: Willow management was subcontracted to GMW on an annual basis, with expenditure of $25K-$35K/annum, and occasional larger works (e.g. $100K around Numurkah/Nathalia). Approx 90-95% of willows downstream of Katamatite have been removed, and is no longer a major issue in the lower Broken Ck, although community consultation has highlighted some areas where treated willows have not been adequately removed, or where infestations still remain (eg below Schiers Weir) In addition a new method of controlling azolla has been implemented - involving deliberately passing water over gates to get the floating mats to break up, thus reducing the risk of catastrophic BOD (GMW, 2003, p6). Arrowhead is an ongoing / emerging issue, which is discussed further below. 2.11. <u>Management of Macrophyte Infestation:</u> Typha / cumbungi is an issue around Numurkah, and within the Mukutah system where it holds water up and provides enhanced conditions for arrowhead infestation upstream. Herbicide control of typha is being implemented. Arrowhead is now also an issue, with infestation

Key Asset/ Issue (1998 Strategy)	Additional information	1998 Strategy – Management Issues and Strategies		Review Checklist	
		Existing Initiatives (1998)	Future Directions (1998)	Action Implemented? Yes/No/Partially Complete/Ongoing	Further information
	outfall ◗ Most of Corgupna Ck 10km up to Katamatite Rd		a dry spell during the year.		being enhanced by low water levels associated with the drought. GMW are currently managing with herbicide, but this is only effective during the summer months. Non-chemical approaches (eg steam weed control) have been trialed, but have limited effectiveness on a large scale (Greg Finlay, GMW, pers. comm.)
Streamflow Management Broken and Nine Mile Creeks were once ephemeral streams that ceased to flow for extended periods in summer & autumn, but due to flow regulation & weirs are now perennial streams. This has contributed to a decline in habitat values and waterway conditions. Injection of good quality water has maintained moderate water quality despite poor quality drainage water entering the waterways.	Water input at: ◗ Caseys Weir for upper catchment ◗ Katandra Weir Resulting in: ◗ Alterations of natural hydrology from seasonal to perennial ◗ Elimination of chained waterhole environment ◗ Facilitating spread of introduced pest species (eg willows & carp) Notable in Broken Ck upstream of Numurkah (Middle Ck system) These changes are fully entrenched & reversion to a fully natural system unrealistic.		2.12. <u>Environmental Flow Strategy:</u> 2.12.1. Through appropriate forums (eg REWQC) LGW should gain acceptance for an environmental flow strategy. 2.12.2. To provide a minimum flow in order to keep fishways functional during August to December. Should maximise habitat benefits for wetlands, floodplain, instream and riparian environment.	2.12. Partially complete	2.12. <u>Environmental Flow Strategy:</u> 2.12.1. Following the fish-kill, the need for an environmental flow in the Broken Creek has become a higher priority. Extra Murray River flows have been provided however this needs to be formalised to provide a mechanism for securing and delivering water for the waterway. This may be addressed within the Environmental Reserve System set out in the recently released White Paper. 2.12.2. A study of the Broken Creek fishways demonstrated that there are similarities in the fish communities of the Broken Creek where fishways have been installed and that these communities are dissimilar to fish assemblages at sites with no fishways. This survey was conducted in December 1999 and March 2000 (NRE, 2000, p10) Fish movement is also addressed in the Lower Broken Creek Operational Guidelines which sets out that during the irrigation season, fishways will remain open wherever there is greater than the fishway operating flow available, which is likely to be for most of the irrigation season. During the non-irrigation period, lower pool levels may mean that the fishways to not operate properly, as fishways will be closed when the weir level is below the target operating level. This is less critical as winter is not a period of high fish movements (GMW, 2003).
Instream Barriers Obstruction of fish passage Localised sedimentation within waterway, due to reduced flow velocity & sustained depth. Especially upstream of Numurkah Reduction in habitat value due to sediment deposition. Maintenance of constant water levels in pools shown to: ◗ Concentrate bank erosion & carp	41 structures within the catchment which represent a barrier to fish passage. Most significant are: ◗ 8 diversion weirs on Lower Broken Ck ◗ Numurkah town weirs (Station St & Melville St) ◗ Katandra Weir ◗ Tungamah Weir ◗ Katamatite Weir	Replacement of weirs (GMW). Project on riparian frontage and instream management (fish ladders at Schiers and Hardings Weirs, NHT).	2.13. <u>Modification of Instream Barriers</u>: All weirs and obstructions in the waterways should be modified to allow fish passage	2.13. Yes	2.13. <u>Modification of Instream Barriers</u> The GBCMA Redundant weir review looked at all barriers to fish passage to identify if any are no longer required and can be removed. The review summary indicated that there were 400+ barriers to native fish migration and at that time fish could access about 330km of stream. The review found that modification of the nominated 27 barriers would give fish a further 230km of stream. For example, fords, weirs, culverts, etc. Determined that most of the 30 barriers on the Upper Broken and Boosey Creeks above Katamatite have a function, but with future piping of Major Creek, many could be removed. The GBCMA has addressed fish passage at 24 barrier sites across the catchment under the fishways program to date (GBCMA: 2000). A review GBCMA Annual reports indicates that fishways are been

Key Asset/ Issue (1998 Strategy)	Additional information	1998 Strategy – Management Issues and Strategies		Review Checklist	
		Existing Initiatives (1998)	Future Directions (1998)	Action Implemented? Yes/No/Partially Complete/Ongoing	Further information
damage (Chinaman's weir pool, Nathalia) ◗ Eliminate natural wetting & drying cycles & sediment consolidation ◗ De-stabilisation of banks thru saturation & confined root depth leading to tree falls ◗ Favourable environment for pest fish ◗ Hinder growth of emergent macrophytes, destabilising banks	◗ Wunghu Town Weir Fixed crest structures in the lower creek system in poor condition & impossible to control weir levels Need for fishways and flow control gates in replacement weirs. Important remnant fish habitat identified at: ◗ One small wetland on Nine Mile Ck ◗ One location on Wild Dog Ck Lower Broken Creek system recognised as important hatchery for native migrating fish such as Murray Cod, however instream weirs have historically restricted passage. Fish ladder has been installed at Rices Weir Fish stocks are depleted.				progressively built throughout the region. 12 vertical slot fishways have been installed at all weirs downstream of and including Katandra Weir. The ten weirs from Melville Street Weir downstream have either been replaced with a new structure or had alterations made to the existing structure. A number of rock graded structures have also been constructed along the Nine Mile Creek. (G-MW, 2003)
Excavated Pools Excavated pools causing degraded downstream water quality and loss of habitat values			2.14. Monitoring: Water quality and flows should be monitored in at least 3 locations, with recommended sites at or near Numurkah and Walshs Bridge on Broken Creek, and Wunghnu on Nine Mile Creek. Water levels should be recorded continuously to establish discharge ratings, and water quality parameters including pH, turbidity, EC, DO, and temperature should be recorded at least weekly.	2.14. No	2.14. Monitoring: Additional monitoring sites as recommended have not been established, and this issue needs to be considered in the revised strategy. Some additional monitoring has been undertaken as part of GMWs network (Greg Smith / Shane Papworth) & Waterwatch (Dustin Lavery). Resource limitations have limited the implementation of further monitoring. Water quality programs in the GB Catchment include, Drainage Operation Monitoring Program, Major Storages Operations Program, Individual Reservoir Sites, Victorian Water Quality Monitoring Network, GB Dryland Salinity Monitoring Program, Shepparton irrigations region land and water SMP, MDBC Water Quality Monitoring, Waterwatch and EPA. There is little coordination between programs, Waterwatch in a state of flux. There are some apparent problems with the Water Monitoring program and access to information ([2]GBCMA, 2004, p12).
3. FLOODPLAIN MANAGEMENT					
Strategic Planning Developments which obstruct the floodplain (levees, irrigation earthworks) can result in increases in flood flows and velocities downstream and increases in flood levels upstream. The cumulative impact of many	Middle Catchment Capacity of bridges on minor roads over Nine Mile Ck does not reflect fact that Nine Mile Ck is the main conveyor of flows through the Middle Catchment. Levees prevent some transfer during high floods from Nine Mile Ck to Broken Ck		3.1. Strategic Floodplain management Plan for Lower Broken Creek: the main requirement for development in consultation to gain community acceptance of proposed strategic measures	3.1. Partially complete	3.1. Strategic Floodplain management Plan for Lower Broken Creek: Flooding issues have been addressed through the GB Regional Floodplain Management Strategy ([1]GBCMA, 2002), with planning controls for works in the floodplain, alterations to existing levees and prevention of new levees being incorporated within the Planning Scheme and Victorian Planning Provisions (Guy Tierney, pers comm..) Specific management plans have not been developed, although studies have been started but not completed in Nathalia.

Key Asset/ Issue (1998 Strategy)	Additional information	1998 Strategy – Management Issues and Strategies		Review Checklist	
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individual landholder actions can be significant, highlighting the need for strategic planning of floodplain activities and consensus from the majority of the floodplain community. **Floodplain Wetlands** Some floodplain obstructions deprive important ecosystems of intermittent water supplies. **Regulation and Control** Powers of agencies to enforce regulation of floodplain obstruction is poorly dealt with under the Water Act (1989), which relies of concept of reasonable flow. Municipalities are often reluctant to use their planning powers to appeal contentious developments. Inadequate resources. **Catchment Transfers** High level transfers between other catchments (eg Broken River, Goulburn River) & Broken Creek could occur under natural conditions and are exacerbated due to catchment developments. These have the potential to cause enormous impacts on this smaller catchment. **Numurkah** There is a modest level of flood protection, but larger floods still inundate some residential, commercial &	Melville St & Station St crossings are perceived as restrictions to flood passage & have been advocated for upgrading. <u>Lower Catchment</u> Downstream of Walshes Bridge, flood passage would be confined at lower levels under natural conditions due to natural levees formed from ancient river system Construction of numerous levees along lower Broken Ck has confined the extent of inundation during moderate floods Levees & other constructions have separated many cut off meanders & billabongs from natural intermittent water supply.		3.2. <u>Strategic Floodplain management Plan for Middle Broken Creek:</u> (ie for the part of the creek system b/n the Dip bridge and Walshs Bridge) – It is first necessary to gain more quantitative information to adequately define this physical system, therefore: 3.2.1. Monitor flows in main channels of Nine Mile Ck and Broken Ck 3.2.2. Recording of flood heights when future floods occur 3.2.3. Acquisition of aerial photographs during floods (LGW 3.2.4. Field survey to collect topographic data 3.3. <u>Strategic Floodplain management Plan for Numurkah</u>: As Middle Broken Creek Strategy must await data collection, preliminary Strategic Plan for Numurkah should be developed. Main requirement is consultation to gain community acceptance of proposed strategic measures 3.4. <u>Outlets for Wetland Watering</u>: Low capacity outlets should be provided in some of the obstructions in Lower Broken Ck to restore intermittent watering of ecological units with remnant habitat value (billabongs & cutoff meanders) 3.5. Monitoring: There are needs for stream	3.2. No 3.3. No 3.4. No	Flood operations of weirs are outlined in G-MW (2003), p11. Melville Street culvert upgrade at Nathalia has received funding and been implemented. A need for a full inventory of levees has been identified (Guy Tierney, pers. comm.) to allow monitoring of landholder amendments to levees in breach of the planning requirements, and to differentiate levee maintenance from changes to levee height. 3.2. <u>Strategic Floodplain management Plan for Middle Broken Creek</u> See 3.1 3.3. <u>Strategic Floodplain management Plan for Numurkah</u>: See 3.1. A Flood Study is planned for Numurkah, but has not been implemented. Funding is provided within the Moira Shire Council and GBCMA 2004/5 budget. 3.4. <u>Outlets for Wetland Watering:</u> This has not been done as it is difficult to obtain landholder uptake.

Key Asset/ Issue (1998 Strategy)	Additional information	1998 Strategy – Management Issues and Strategies		Review Checklist	
		Existing Initiatives (1998)	Future Directions (1998)	Action Implemented? Yes/No/Partially Complete/Ongoing	Further information
industrial areas. Further work is required to confidently formulate a floodplain management strategy for Numurkah. **Nathalia** Reasonable level of flood protection through construction of levees, and high level floods bypass the town. Further unregulated construction of levees downstream since 1993 now places the town levees at risk of flooding **Box Creek** During moderate to large floods, Box Creek conveys floodwaters between Broken Ck & Nine Mile Ck, & relieves flooding severity in & downstream of Numurkah & along Nine Mile Ck. This role has been constrained through floodplain obstructions.			gauges to measure flow levels and acquisition of data for discharge ratio; observation of flood levels during & after floods; and acquisition of aerial photography as a flood record.	3.5. Ongoing	3.5. Monitoring: Flood Monitoring Action outlines intention to monitor and collect data to facilitate effective flood monitoring ([1]GMCMA, 2002, p77.). No data has been collected yet as there have been no major floods since the 1998 strategy was produced.

Appendix B

Water Quality Assessment

Appendix B

Figure 1 Estimated Total Phosphorus Loads from all Irrigation Drains in the Goulburn Broken Catchment

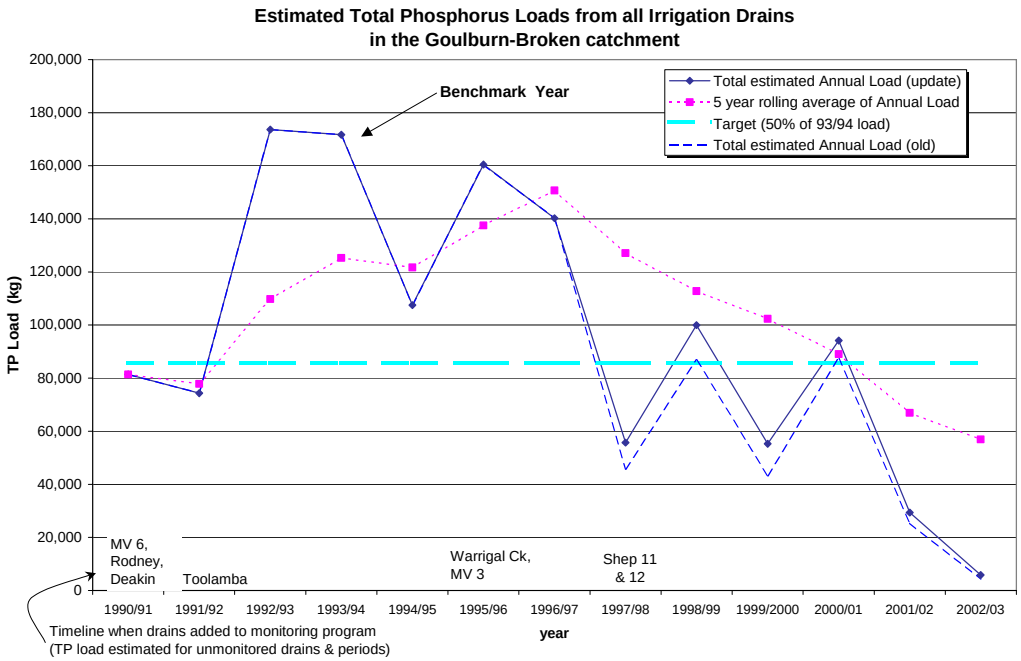


Figure 2 Broken Creek at Rices Weir – Total Phosphorus Annual Load

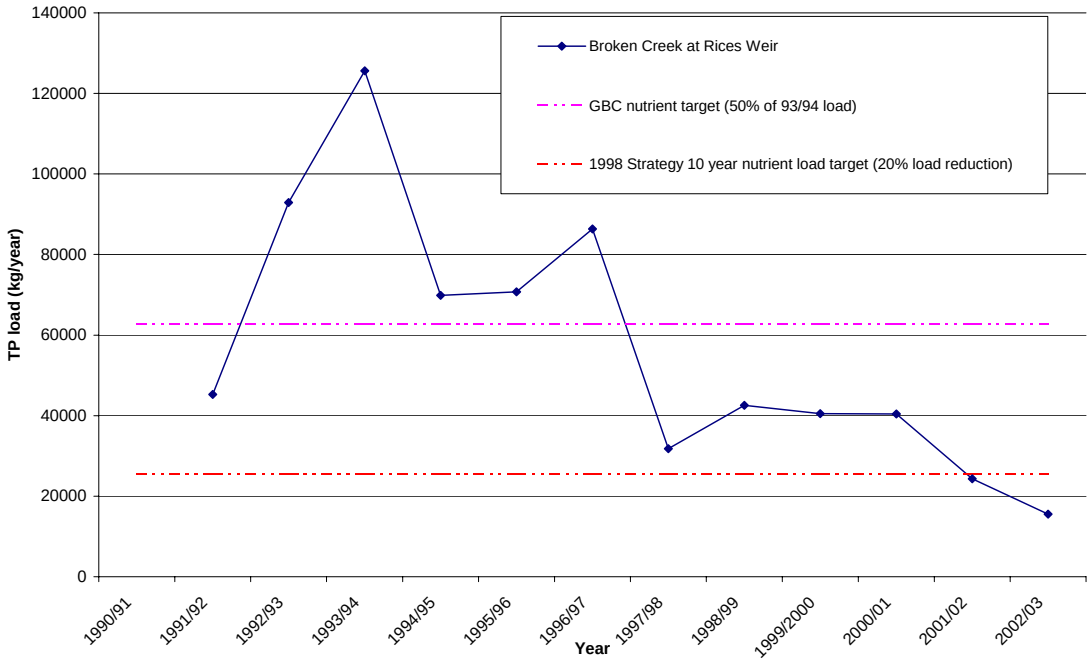


Figure 3 Drain 11 – Total Phosphorus Annual Load

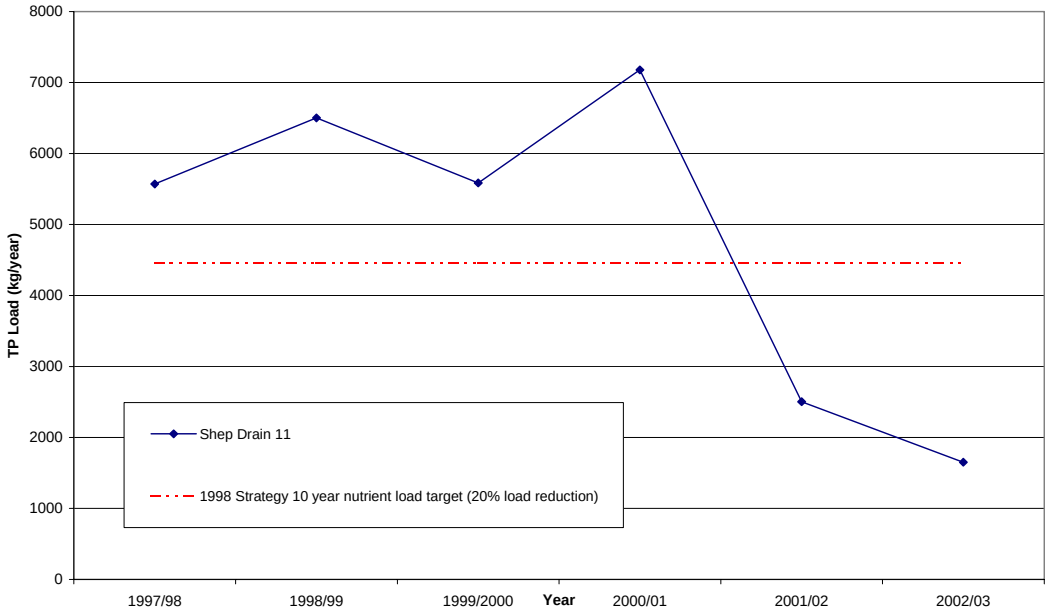
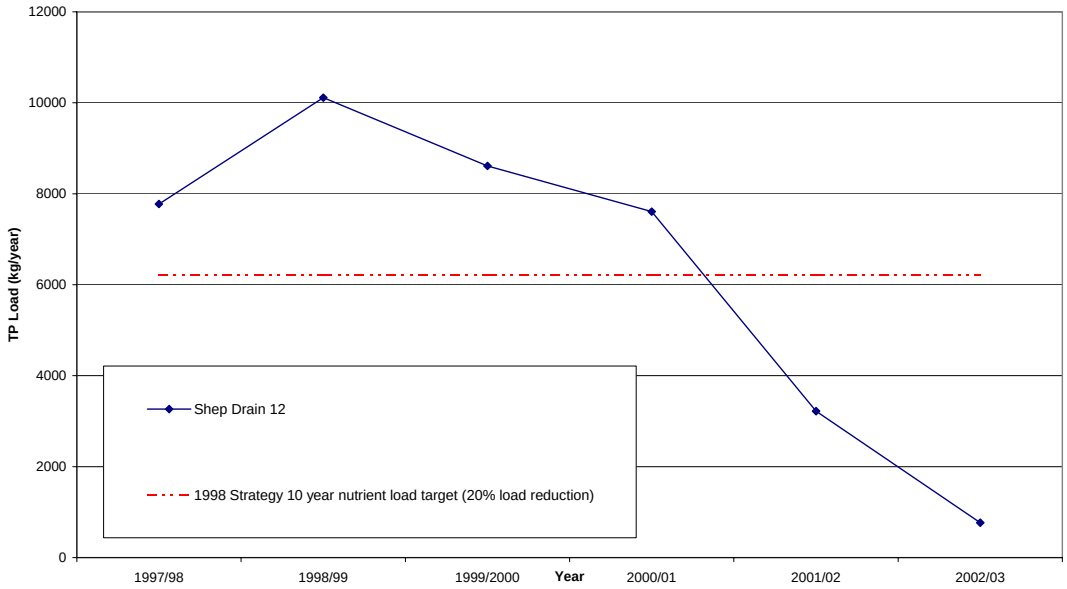


Figure 4 Drain 12 – Total Phosphorus Annual Load



Reference: Sinclair Knight Merz - TATDOC-309910-v3-NUTRIENTS FROM DRAINS (C806) - PRELIMINARY ANALYSIS OF TP & TN LOADS AND FLOWS SINCE 1990.XLS)

Figure 5 Turbidity in the Broken Creek at Rices Weir

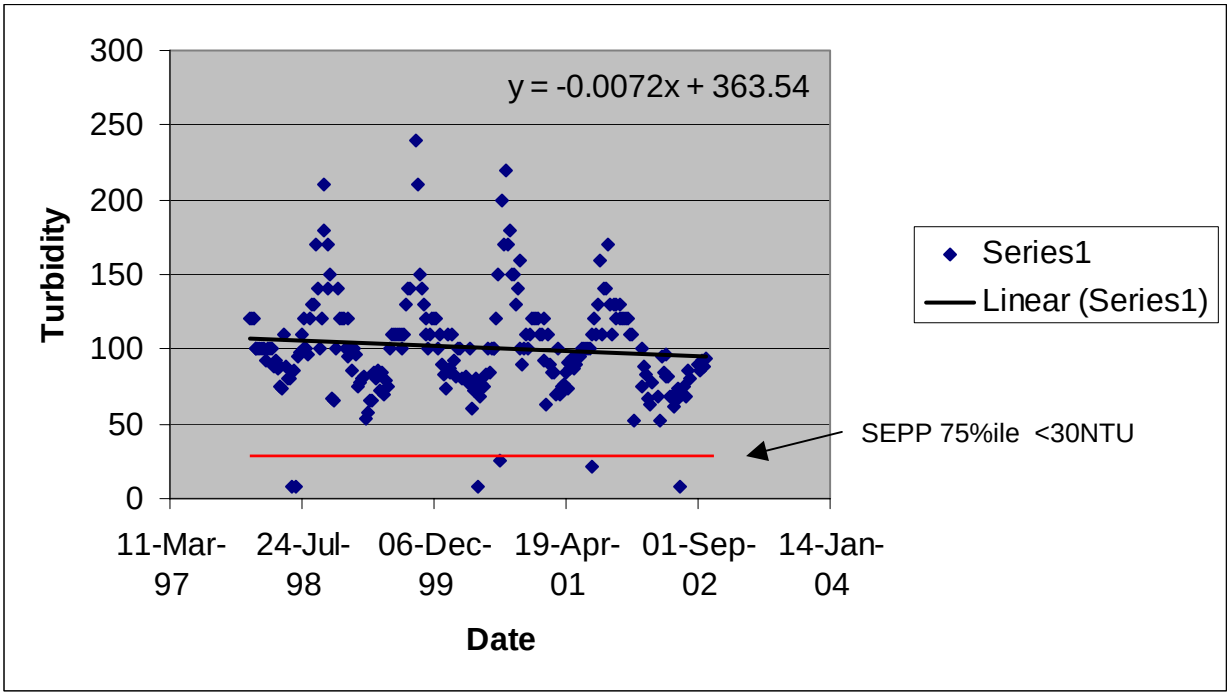
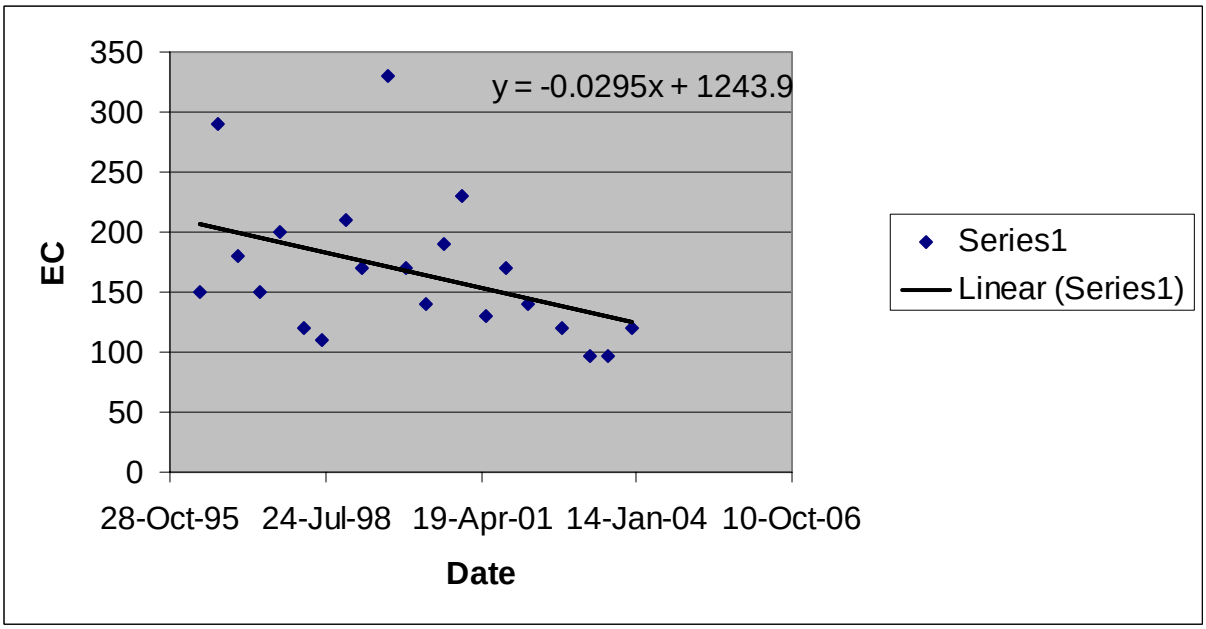


Figure 6 Electrical Conductivity in the Broken Creek at Rices Weir



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0	A Roy	D Petch, K Fung	* D. Petch	D Petch	* D Petch	12/07/05

*Denotes signature on original

Appendix B

Broken Creek Management Strategy - Setting Priorities for Investment using a Benefit Cost Analysis

Final Report

FINAL REPORT

Broken Creek Management Strategy - Setting Priorities for Investment using a Benefit Cost Analysis

Prepared for

Goulburn Broken Catchment Management Authority

July 2005

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URS
Sustainable Development

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Limitation

URS Australia Pty Ltd (URS) has prepared this report for the use of the Goulburn Broken Catchment Management Authority in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Project Brief.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between August 2004 and July 2005 and is based on information supplied by the Goulburn Broken Catchment Management Authority at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Contents

2.1 The study area

The Broken Creek Management Strategy covers the length of the Broken Creek downstream of the confluence with the Boosey Creek. Within these sections of the middle and lower Broken Creek, there are five river reaches that have been assessed for asset values, threats and management priorities within the Goulburn Broken Catchment Management Authorities (GBCMA's) RiVERS model.

2.2 Purpose

The purpose of this report is to use benefit cost analysis to assess the benefits and costs of management actions that are recommended for the Broken Creek based on a risk assessment using the RiVERS database and field visits to the study area. The specific objectives of this report are:

1. To determine priority management actions within the Broken Creek;
2. To use this information to decide on which management actions and programs are to be included within the Revised Broken Creek Management Strategy; and
3. To assess the overall benefits and costs of those actions included within the Strategy.

2.3 Linking RiVERS outputs and Benefit Cost Analysis

The investment prioritisation framework used within the project takes the management responses identified by RiVERS, and then uses benefit-cost analysis to assess the benefits and costs of those management alternatives in monetary terms.

Benefit-cost analysis is the most widely used methodology for the economic evaluation of public and private projects. Benefit-cost analysis is best viewed as a framework within which all benefits and all costs of a contemplated project or policy can be systematically appraised.

In BCA, the potential outcomes (benefits) of a project and the sacrifices (costs) which it entails are compared in monetary terms. Benefits and costs, therefore, are directly comparable with one another and subtracting costs from benefits allows a measure of the net social benefit. Net benefit is described as 'social net benefit' because the benefits are measured in terms of the gains and losses to the economy as a whole irrespective of to whom they accrue.

3.1 Introduction

A three staged process has been used for this assessment of the benefits and costs of the Broken Creek Management Strategy.

- ***Identify Priority Actions*** – Firstly, we used benefit cost analysis (BCA) to assess the costs and benefits of management actions that were identified as part of a risk assessment using RiVERS.
- ***Determine Strategy Actions/Programs*** – Secondly, these costs and benefits were one of the inputs used by the project steering committee to determine priority management actions to be included within the Revised Broken Creek Management Strategy.
- ***BCA for Strategy*** – Finally, the overall costs and benefits of the Strategy were assessed for those management actions and programs included within the revised Strategy.

3.2 Identify Priority Actions

The approach that has been used to identify priority actions has been based on a method developed by URS (2003) to assess the benefits and costs of management to achieve improved river health. The approach uses benefit cost analysis and benefit transfer to assess the benefits of changes in the health of waterways in Victoria.

For more please refer to this report "An Economic Methodology to Analyse Investments in River Health – Preservation versus Restoration" by URS (2003).

The individual benefits and costs of management actions are presented in Section 6 of this report.

3.3 Determine Strategy Actions/Programs

The findings of Section 6 were one of the inputs provided to the project steering committee to identify those management actions and programs to be included in the revised Broken Creek Management Strategy.

3.4 BCA for Strategy

The costs and benefits of the Broken Creek Strategy are assessed in Section 7.

4.1 Introduction

Estimates of the benefits of the proposed waterway management actions rely on predicting the future health of the waterway in two situations, namely:

- with the implementation of the proposed management activities; and
- without the implementation of the proposed management activities.

The benefits of the program of management activities are the differences between the values of these two scenarios, either in terms of damages avoided or values enhanced (refer to Figure 4-1).

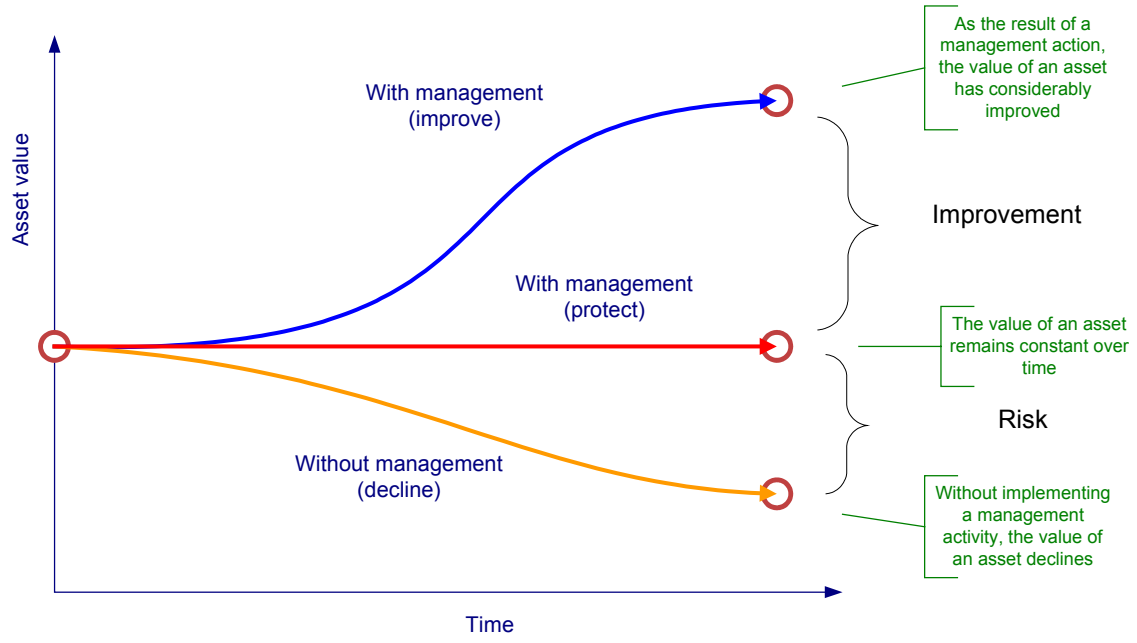

Figure 4-1: Conceptual framework for identifying risks to asset values and opportunities to improve asset values

Although some of the benefits may be very long-term, a planning horizon of 30 years has been adopted for the evaluation of benefits.

4.2 Values suitable for benefit transfer

Actions to improve the condition of a degraded river or protect the quality of a high value river result in many unpriced benefits that are not traded in markets. These may include benefits such as improvements in fishing opportunities, aesthetics, and water quality.

There are currently no published studies specifically relating to the value of improving the health of the Broken Creek. To calculate this value using either stated preference techniques or the travel cost method would be costly both in terms of time and financial outlays. Therefore, to value improvements in river health in the Broken Creek, we can either use benefit transfer[1] where the criteria for using this approach are met, or alternatively, we can form an 'impression' of what these values would be by looking at past studies that have valued similar environmental benefits.

Recently, values for attributes of river health have been determined for a range of rivers in NSW (Bennett and Morrison, 2001). The values determined in this study are particularly useful because they were estimated in a way that is tailored to benefit transfer. Based on a review of previous studies, and professional judgment, it was decided to use the Bennett and Morrison study to assess the value of changes in the health of the Broken Creek. The Murrumbidgee River (southern inland river) was chosen by the consultants as an appropriate match for the Broken Creek.

The value estimates for environmental attributes of rivers recommended for transfer to the Broken Creek are shown in Table 4-1 (this is Tables 14 on p.26 of Bennett and Morrison, 2001).

Table 4-1: Attribute value estimates for southern inland rivers

Attribute	Value estimate ($ per within catchment household)	Value estimate ($ per outside catchment household)
Native Vegetation[a]	1.45	2.17
Native Fish[b]	2.58	3.81
Fauna[c]	1.59	1.80
Water Quality:Boatable to Fishable[d]	53.43	30.50
Water Quality:Fishable to Swimmable[e]	20.35	60.68

[a] Vegetation Unit = Value ($) per 1% increase in river length with healthy vegetation and wetlands

[b] Fish Unit = Value ($) per unit increase in the number of native fish species present

[c] Fauna Unit = Value ($) per unit increase in the number of waterbird and other fauna species present

[d] Water Quality Unit = Value ($) of increasing water quality from boatable to fishable across the whole river

[e] Water Quality Unit = Value ($) of increasing water quality from fishable to swimmable across the whole river

* denotes BT model estimates were used due to insignificant coefficients in model at the 5 per cent level

The units used to measure the attributes are different for each attribute. That is, the native fish attribute is per additional species and the vegetation attribute is per additional one per cent of the river's length having healthy riverside vegetation and wetlands. These units of measurement can be simply aggregated for the population in question.

[1] Benefit transfer is an accepted, albeit somewhat controversial, process that makes the evaluation feasible in a reasonable timeframe (see Sturgess 2001).

Of importance to this study is Bennett and Morrison's finding that the value placed on the improvement in a river's environmental condition is likely to be different for a person living within the river's catchment compared to a person living at some distance from the river.

4.2.1 Example of the aggregation process

As an example of the aggregation process, consider a river management option in a southern inland catchment of NSW that would:

- increase native vegetation along 5 per cent of the length of the river,
- result in the reintroduction of 2 native fish species, and
- improve water quality across 15 per cent of the length of the river from boatable to fishable.

In calculating benefits, it is recommended that only 38 per cent of the population is used, because this was the proportion of respondents to the original survey (Bennett and Morrison, 2001).

The catchment population was estimated at 4,000 households, leading to the following within catchment aggregate value estimate.

Within catchment value = 4000 x 0.38 x [(5 x 1.45) + (2 x 2.58) + (0.15 x 53.43]
= $31,045

Given the NSW population is around 1.8 million households, the outside catchment aggregate value estimate is:

Outside catchment value = 1.8m x 0.38 x [(5 x 2.17) + (2 x 3.81) + (0.15 x 30.50)]
= $15.8 million

4.2.2 Appropriate values – WTP versus WTA

The values discussed in Table 4-1 are measures of willingness to pay (WTP), that is how much people would be prepared to spend to restore or maintain an Australian River. Within this assessment, we are concerned with both the maintenance and restoration of the Broken Creek. The appropriate measure for 'maintenance' is willingness to accept (WTA), whilst the appropriate measure for restoration is WTP. Estimates of WTP typically underestimate WTA many times over. Based on the method proposed in URS (2003), the project team has estimated multipliers for the study area between 1.3 and 3.7 (for more information see Appendix A). In other words, where an appropriate environmental value is determined for WTP, the associated value for WTA would be up to 3.7 times that value.

4.3 Other values used in the evaluation

4.3.1 Values for recreation and tourism

A benefit cost analysis is concerned with net economic values. Organisers of major events often use estimates of tourist expenditure, but they are **not** relevant to benefit cost analysis. Benefit cost analysis is concerned with economic value, which represents net gains to the economy. There have been many estimates of the economic value of tourism and recreation in Australia and elsewhere, most often derived by seeking the amount that visitors would be willing to pay for particular recreation experiences (see for example, Herath and Jackson 1994; Read Sturgess and Associates 1994; Read Sturgess and Associates 1999; Sappideen 1993; Sinden 1990). The unit economic values shown in Table 4-2 were derived from a number of these studies to value recreation and tourism when assessing the benefits and costs of nutrient management (DNRE 2000). We have used these same values as part of this study.

Table 4-2: Economic values associated with recreation and tourism

Recreational activity	Economic value per visit ($)	
	Low	High
Walkers	0.50	1.00
Local residents for day trips	2.00	4.00
Day visitors from outside region	4.00	8.00
Overnight visitors	10.00	15.00

4.3.2 Values for wetlands

The wetlands of a Catchment can be extremely valuable environmental assets. The value of a wetland involves a mix of use and non-use values, which are difficult to separate. A wetland, for example, may produce use values such as bird watching, picnicking, eel harvesting, duck shooting and as a photographic subject. Most economic studies that have attempted to value wetlands have indicated that recreational values are typically small compared to other components of the total economic value.

There have been few attempts to value wetlands in Australia. A study of the wetlands of the Barmah Forest on the Murray River determined a value for the preservation of the wetlands of about $3,000 per hectare (Stone 1992). For the purposes of valuing wetlands, more conservative values ($2,000 and $1000 per ha) have been used in other studies of wetlands which are not classified under the RAMSAR Convention (McGregor, Harrison and Tisdell 1994)[2].

[2] This is a conservative approach since some non-RAMSAR wetlands may be of equal value to those with RAMSAR listing.

Based largely on the work of Stone (1992) for the Barmah Forest, we have applied the following estimates of non-use values to gain a rough indicative valuation of the capital embodied in wetlands on a flood plain or in a catchment.

- International and National (I+N) $3,000 per ha
- State (S) $2,000 per ha
- Local (L) $1,000 per ha

The importance of indirect use values (flood retention, life support and pollution assimilation etc) needs highlighting because of the high values and the complexity of the systems involved. For example, Jensen (1993) notes that recent estimates in the United States put the value of wetlands for flood retention buffers at A$19,285 per hectare and up to A$286,000 per hectare for nitrogen retention. Jensen also cites a demonstration by the US Army Corps of Engineers that intact wetlands stored 70 percent of a 1 in 2-year flood, providing a cheaper and more effective method of flood mitigation than levees. Other studies in the US have shown high values - up to US$14,600 per hectare (1971 values) for the life support values of forested wetlands. A more recent study (Costanza et al. 1997) has suggested values up to US$14,785 per hectare per year for the total ecosystem services provided by wetlands. These studies indicate that indirect use values may often be five times, or even an order of magnitude greater, than the recreational and non-use values.

Given that what we have termed indirect use values may account for about 80 percent of the total economic value of a wetland, if this were true for the Barmah Forest, the total economic value would be about $15,000 per hectare.

4.3.3 Water Quality

While not valued in this analysis, research in Canada has shown that cattle given unrestricted access to natural water holes gained 20 per cent less weight than those drinking from a piped water source (Willm 2002). The research did not conclude a reason for the difference in weight gain, but suggesting that stock tend to drink less water if it is polluted, which in turn reduces their production.

Key issues for management were identified based on field visits and risk assessments using RiVERS. The key issues identified included those that affected the entire Broken Creek study area to those that only affected hotspot areas. As part of our assessment of the costs and benefits of river health, we have described a number of case studies to assess site-specific (hot spot) river health issues.

Case studies have been used to assess the benefits and costs of:

- riparian fencing and revegetation;
- willow and aquatic weed management (including large woody debris);
- enhancement of instream habitat;
- wetland connectivity; and
- increasing base flows over Rices Weir.

For some management actions such as modifying flow regimes, the multiple benefits and costs of management can not be assessed at a case study scale, but rather need to be assessed from a whole of river point of view. Management actions that fall into this category include:

- flow management;
- catchment management;
- capacity building (Land Care, Water Watch and education programs);
- planning activities (environmental flow strategy);
- heritage management;
- program management; and
- monitoring, evaluation and reporting.

These management actions have not been prioritised independently, however they have been included within the overall economic assessment of the Broken Creek Strategy.

6.1 Riparian Fencing & Revegetation

Introduction

Stock access and its impact on the riparian zone has largely been reduced since the 1998 Strategy. There are still hotspot areas for fencing & revegetation. Most frontages remaining are on Crown Land for which DSE has prime responsibility.

Reach 22 (32.5 km) has been used to assess the benefits and costs of Riparian Fencing and Revegetation. Within this reach (around Fairmans Bridge), the riparian vegetation is poor in areas that are grazed. Whilst grazing is a key issue, the CMA have found it very difficult to get the remaining landholders who have not already fenced to do so.

Environmentally Reach 22 is classified in RiVERS as moderate, with high social values and high economic values.

Project costs

Fencing

The cost of fencing depends on the shape of the frontage to be fenced. Generally, fencing river frontages is more expensive than typical boundary fences because of the number of bends involved. While typically fencing costs are in the order of $2.50 per metre for materials and as much again for labour, fencing of river frontages is estimated to cost as much as $6.00 to $7.00 per metre (D. Lavery pers comm.). We have assumed a cost of $6.50 per metre in this analysis. This costs is assumed equally split between labour and materials. Under current incentives, capital is provided by greater community whilst labour is usually supplied directly by resident.

Stock Watering Points

Many river frontages are important for stock watering[3]. Where a river frontage is fenced, it is necessary to provide an alternative source for stock water, such as by:

- Carting water to stock from another source
- Piping water from an existing supply
- Pumping water from the water source into tanks or dams

[3] In the case of orchardists, residential properties etc. fencing and water points may not be required.

The option that is appropriate for each landholder will depend on the relative cost of each alternative, which will depend on the availability of alternative water supplies and the presence/absence of existing reticulation infrastructure. While irrigators will have on-farm reticulation, this is unlikely to be the case for dryland farmers.

The cost of watering points varies significantly according to:

- Type of watering point (dam or reticulated trough)
- Number and type of stock which are serviced by the watering point

We have estimated the costs to supply water based on using reticulated troughs. The cost to construct a reticulated trough to provide off-stream watering is generally around $500.00 per point (D. Lavery pers comm.). Labour to install the trough is estimated at roughly 10 hours. Labour is assumed to cost $25 per hour. The cost of a pressure pump has been estimated at $2,250, and the cost of a meter is estimated at $5,000.

The average number of off-creek watering points will vary according to the length of stream frontage that is to be fenced. On average 2-3 watering points per kilometre of frontage fenced would be appropriate.

Revegetation

Costs are based on a Revegetation & Rehabilitation Costing Spreadsheet developed by Wearne and Warne (2002).

Description	Approximate Costs
Revegetation – indigenous grasses and sedges	$500 per hectare
Revegetation- indigenous trees and shrubs	$2,000 per hectare

Summary

It was estimated that 40 kilometres of stream (8 km/yr for 5 years) will be fenced and 120 hectare (based on 30 metre frontage) of bank revegetated. We have also assumed that 1 kilometre of fence will require 2 watering points. An annual maintenance cost of $300 per kilometre of fencing was also included.

The total present value cost of fencing and revegetating one kilometre of the Broken Creek is shown in Table 6-1.

Table 6-1: Costs associated with fencing and revegetating one kilometre of stream frontage

COSTS	Costs per km of fencing
Capital	
Fencing	$6,500
Revegetation	$3,750
Watering Points	$8,750
Operations	
O&M (present value 4% over 30 yrs)	$6,000
Total	$25,000

The costs to landholder of fencing & revegetating riparian zones includes the loss of grazing land, the loss of shade and the protection of pastures during high rainfall periods. These impacts have not been quantified within this analysis. For the estimated 40 kilometres of frontage to be fenced and revegetated over the next 5 years the cost was calculated at a present value of $890,364 (discounted at 4 per cent).

Project Benefit

The major thrust of the management program is to restore the riverine native vegetation to a healthy state. The possible outcome[4], in terms of the attributes valued by Bennett and Morrison (2001) that would be improved by management actions to fence and revegetate riparian zones is:

- an increase in the length of river with healthy native vegetation and wetlands.

The length of the entire Broken Creek is about 245 kilometres[5], or 490 kilometres of river frontage. The three points on the triangular distribution of the improvement in the length of the stream with healthy native vegetation and wetlands that would be restored with this action are:

- 4km (0.8 per cent of the river's length) worst outcome;

[4] "Outcome" refers to the level of benefits derived from implementing the program, that is, an outcome may be either avoided losses (in the case of preservation programs) or gains in river health (in the case of restoration or improvement works).

[5] We have assumed that the Bennett estimates of WTP are appropriate for the length of the Broken Creek only. Given that the Broken Creek diverts from the Broken River at Casey's Weir, it could be argued that the length of river from which to estimate benefits should include the length of the Broken River upstream of Casey's Weir. The length of this River reach is about 110 km. The impact of including this additional length would be to reduce the benefits of the management option.

- 10km (2 per cent of the river's length) most likely outcome; and
- 20km (4.1 per cent of the river's length) best outcome.

In the absence of the program, it is assumed that the condition of native vegetation would not become any worse than it currently is[6]. We are interesting in restoring the Broken Creek and therefore WTP is the appropriate measure of value.

Comparison of Benefits and Costs

The benefits and costs of fencing of 40 kilometres of the Broken Creek are shown in Table 6-2.

It was assumed that 'within catchment' comprised Moira East and Moira West Statistical Local Areas (SLAs) with 9,475 households (ABS 2002). It was assumed that Victoria was appropriate for 'outside catchment' with approximately 1.7 million households. Because of the low response rate to the Bennett and Morrison survey, only 38 per cent of these households were used to calculate benefits.

[6] As demonstrated in Figure 4-1, the health of the Broken Creek would probably decline without further management. The conservative assumption that the health of the Creek would be maintained without management will under-estimate the benefits of this management action.

Table 6-2: Estimated benefits and costs of fencing and revegetating for 40 kilometres of stream frontage.

	Best outcome		Most Likely Outcome		Worst Outcome	
Item	Within catchment	Outside catchment	Within catchment	Outside catchment	Within catchment	Outside catchment
Improvement as a percentage of total length	4.1%	4.1%	2.04%	2.04%	0.82%	0.82%
WTP per HH per 1 per cent of river length	$1.45	$2.17	$1.45	$2.17	$1.45	$2.17
WTP/WTA multiplier	1	1	1	1	1	1
WTA per HH per 1 per cent of river length	$1.45	$2.17	$1.45	$2.17	$1.45	$2.17
WTP per HH per outcome percentage of river length	$5.92	$8.86	$2.96	$4.43	$1.18	$1.77
No. HH (38% of total)	3,610	649,610	3,610	649,610	3,610	649,610
Value of outcome for each market ($m)	$21,365	$5,753,689	$10,683	$2,876,844	$4,273	$1,150,738
Total value of outcome ($m)	$5,775,054		$2,887,527		$1,155,011	
Present value of program cost at 4 per cent discount	$890,364		$890,364		$890,364	
Expected NPV	$4,884,689		$1,997,162		$264,646	
Expected BCR	6.5		3.2		1.3	

The results shown in Table 6-2 show that the management action to fence and revegetate areas of the Broken Creek is economic. Even for the worst case scenario, the benefits are greater than the costs.

Discussion of Results

If only the 'within catchment' market were considered, the NPV would be negative. This suggests that although individual households in the local community may have a WTP compensation for an increase in healthy native vegetation and wetlands, the local community by itself is too small to render the improvement of the creek a worthwhile investment. In other words, the assumption that the entire Victorian population is appropriate for assessing the benefits to the Broken Creek drives this economic result. Despite this, for the most likely option, this management action would remain positive when less than twenty per cent of Victorians value healthy vegetation along the Broken Creek.

The analysis of fencing and revegetating the Broken Creek assumed that the length of healthy native vegetation along the waterway would not decline further without management. If the length of healthy native vegetation did decline, then the benefits of this option would be substantially increased.

Adoption of fencing and revegetation has proven to be difficult with landholders in Reach 22. The results of this analysis suggest that there is a case for Government to pay the full cost of this management action.

6.2 Woody Weed Management

Introduction

In the past, the management of woody weeds has concentrated on the removal of willows. This is likely to change in the future as other woody weeds including peppercorn, desert ash, canary island date palm, olive, boxthorn, sweet briar are targeted.

It has been estimated that without management, woody weeds in particular willows will again become abundant within the Broken Creek. We have estimated that presently 20 kilometres of the Broken Creek is affected by woody weeds.

- Without any future management, it is estimated that the length of river affected by woody weeds will increase by 5 per cent compounding over the next 10 years. In year 10, without management, the length of river affected by woody weeds is estimated at 31 kilometres.
- With management, the length of river affected by woody weeds is estimated to decline by 15 per cent per year over the next 10 years. In year 10, with management, the length of river affected by woody weeds is estimated to decline to 4.6 kilometres.

Project costs

Over the last four years, the GBCMA have spent $20,000 per year to treat an estimated 4 km/yr of willows along the Broken Creek. Given the level of control observed with willow, it is expected that this level of expenditure will be required to achieve the targeted reduction in 'other' woody weeds along the River. This expenditure will include the physical removal of weeds as well as the continued maintenance of areas already cleared. A cost of $5,000 per annum was included for the on-going maintenance of these cleared areas.

Project Benefit

The major thrust of the management program is to restore the riverine native vegetation to a healthy state. The possible outcome, in terms of the attributes valued by Bennett and Morrison (2001) that would be improved by management actions to fence and revegetate riparian zones is:

- an increase in the length of river with healthy native vegetation and wetlands.

The benefit of woody weed management is the difference between the length of the Broken Creek affected by weeds with and without management. We have estimated this length at 26.4 km for woody weeds (in year 10). The management of weeds does not equate to an increase in the length of river with

healthy native vegetation and wetlands[7]. We have used the following proportions to estimate the increased area of healthy native vegetation given best, median and worst case scenarios.

	Best	Median	Worst
Woody weeds	0.25	0.1	0

If for example 1 km of woody weeds were managed and removed, under the best case scenario, this is assumed to correspond to an increase in 0.4km of native vegetation.

The estimated length of the Broken Creek is 245 kilometres. The improvement in the length of the stream with healthy native vegetation and wetlands that would be restored with this action are:

- 0 km (0 per cent of the river's length) worst outcome;
- 2.6 km (0.5 per cent of the river's length) most likely outcome; and
- 6.6 km (1.3 per cent of the river's length) best outcome.

Comparison of Benefits and Costs

The benefits and costs of managing weeds on the Broken Creek are shown in Table 6-3.

[7] Woody weed management may even affect the structural habitat of the Broken Creek negatively.

Table 6-3: Estimated benefits and costs – woody weed management

	Best outcome		Most Likely Outcome		Worst Outcome	
Item	Within catchment	Outside catchment	Within catchment	Outside catchment	Within catchment	Outside catchment
Improvement as a percentage of total length	1.3%	1.3%	0.54%	0.54%	0.00%	0.00%
WTP per HH per 1 per cent of river length	$1.45	$2.17	$1.45	$2.17	$1.45	$2.17
WTP per HH per outcome percentage of river length	$1.95	$2.92	$0.78	$1.17	$0.00	$0.00
No. HH (38% of total)	3,610	649,610	3,610	649,610	3,610	649,610
Value of outcome for each market ($m)	$7,049	$1,898,302	$2,820	$759,321	$0	$0
Total value of outcome ($m)	$1,905,351		$762,140		$0	
Present value of program cost at 4 per cent discount	$202,772		$202,772		$202,772	
Expected NPV	$1,702,579		$559,368		-$202,772	
Expected BCR	9.4		3.8		0	

The results shown in Table 6-3 show that for the best outcome and the most likely outcome, the management action to manage woody weeds in the Broken Creek is economic. For the most likely outcome, the benefits are almost four times greater than the costs.

Discussion of Results

If only the 'within catchment' market were considered, the NPV would be negative. This suggests that although individual households in the local community may have a WTP compensation for the loss of healthy native vegetation and wetlands, the local community by itself is too small to render the improvement of the creek a worthwhile investment.

Past management has been estimated to remove approximately 90-95 per cent of mature willows downstream of Katamatite. Without continued maintenance, willows will regenerate, which will eventually reduce the area of healthy native vegetation along the Broken Creek. It is estimated that there is less than one kilometre of river frontage, mostly close to urban areas, that remains heavily infested with willows.

6.3 Aquatic Weed Management

Introduction

Aquatic weeds such as arrowhead, cumbungi and azolla are becoming an increasingly serious problem in irrigation areas[8]. Without future management, it is likely that the risks proposed by aquatic weeds will become substantially worse. Presently it is estimated that there are 100 hot spots where outbreaks of Arrowhead require management. At each of these hotspot areas, the length of river affected is estimated at 50 metres. Therefore the length of the Broken Creek heavily affected by weeds is estimated at 5.0 kilometres.

- Without any future management, it is estimated that the length of river affected by weeds will increase by 25 per cent compounding over the next 10 years. In year 10, without management, the length of river affected by aquatic weeds is estimated at 37 kilometres.
- With an increased management regime, the length of river affected by aquatic weeds is estimated to decline by 5 per cent per year over the next 10 years. In year 10, with increased management effort, the length of river affected by aquatic weeds is estimated to decline to 3 kilometres.

Project costs

Management options for Arrowhead are limited. In the past, a herbicide called D24 was used with some success and also with some inherent risks, however the EPA no longer allow its use. For the past two years glyphosate has been applied with very limited success, and has failed to prevent the weed from spreading. G-MW have recently been granted a permit to increase the application rates of glycosine, however it is doubtful that this will be effective.

- The costs to manage Arrowhead and other important weeds[9] have been estimated at $80,000 for three years for labour and materials. The planned spraying program aims to repeatedly treat infested areas of the creek over a 3-year period. An annual cost of $40,000 has been included to maintain the treated areas (Kevin Preece G-MW pers. comm.).
- The past management of cumbungi has included targeted spraying where the weed is causing issues relating to reduced flows and other hydrological factors. The costs to manage Cumbungi are estimated at $10,000 per annum for the Broken Creek (Kevin Preece G-MW pers. comm.).

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8 Cumbungi and azolla mainly threaten the capacity of irrigation channels.

9 Other aquatic weeds on the Broken Creek include Umbrella Sedge, Alligator Weed, Starwort, Isolepsis, Jointed Rush, Creeping Buttercup, Celery Buttercup, Peruvian Primrose, Sengal Tea, Sagitaria, Dock, Paspalum and Water Couch.

- It has been estimated that 13.5 GL (Average of 50 ML per day for 270 days) of passing flow is required for the Broken Creek to ensure that populations of azolla do not establish and choke the waterway. The cost of this water is included for the management action to increase base flows over Rices Weir in Section 6.6 below.

Project Benefit

The major thrust of the management program is to restore the riverine native vegetation to a healthy state. The possible outcome, in terms of the attributes valued by Bennett and Morrison (2001) that would be improved by management actions to fence and revegetate riparian zones is:

- an increase in the length of river with healthy native vegetation and wetlands.

The benefit of weed management is the difference between the length of the Broken Creek affected by weeds with and without management. We have estimated this length at 3.4 km for aquatic weeds and 13.2 km for woody weeds. The management of weeds does not equate to an increase in the length of river with healthy native vegetation and wetlands. We have used the following proportions to estimate the increased area of healthy native vegetation given best, median and worst case scenarios.

	Best	Median	Worst
Aquatic weeds	0.25	0.1	0

If for example 1 km of aquatic weeds were managed and removed, under the best case scenario, this is assumed to correspond to an increase in 0.25km of native vegetation.

The estimated length of the Broken Creek is 245 kilometres. The estimated improvement in the length of the Creek with healthy native vegetation and wetlands that would be restored with this action are:

- No change (0 per cent of the river's length) worst outcome;
- 3.4 km (1.4 per cent of the river's length) most likely outcome; and
- 8.5 km (3.5 per cent of the river's length) best outcome.

Comparison of Benefits and Costs

The benefits and costs of managing aquatic weeds on the Broken Creek are shown in Table 6-3.

Table 6-4: Estimated benefits and costs – aquatic weed management

	Best outcome		Most Likely Outcome		Worst Outcome	
Item	Within catchment	Outside catchment	Within catchment	Outside catchment	Within catchment	Outside catchment
Improvement as a percentage of total length	3.5%	3.5%	1.4%	1.4%	0.0%	0.0%
WTP per HH per 1 per cent of river length	$1.45	$2.17	$1.45	$2.17	$1.45	$2.17
WTP per HH per outcome percentage of river length	$5.05	$7.55	$2.02	$3.02	$0.00	$0.00
No. HH (38% of total)	3,610	649,610	3,610	649,610	3,610	649,610
Value of outcome for each market ($m)	$18,215	$4,905,258	$7,286	$1,962,103	$0	$0
Total value of outcome ($m)	$4,923,473		$1,969,389		$0	
Present value of program cost at 4 per cent discount	$488,798		$488,798		$488,798	
Expected NPV	$4,434,675		$1,480,591		-$488,798	
Expected BCR	10.1		4.0		0.0	

The results shown in Table 6-3 show that with our stated assumptions, the management action to manage aquatic weeds in the Broken Creek is economic. If however, the management of aquatic weeds does not result in healthy native vegetation, then this outcome is likely to change.

Discussion of Results

If only the 'within catchment' market were considered, the NPV would be negative. This suggests that although individual households in the local community may have a WTP compensation for the loss of healthy native vegetation and wetlands, the local community by itself is too small to render the improvement of the creek a worthwhile investment.

The reach of the Broken Creek where the risks associated with weeds are greatest include:

Reach 24 (Worst infestation)
Reach 21 (arrowhead & azolla)
Reach 22 (aim to eradicate arrowhead)
Reach 25 (small area in the weir pool)
Reach 28 (Nine Mile)

Other benefits that have not been assessed are the benefits associated with improved irrigation supply. In addition, the treatment of aquatic weeds should reduce the spread of these weeds and any associated negative impacts on agricultural production.

We have also not valued any improvements to amenity and associated increases in recreational use.

6.4 Enhancement of Instream Habitat

Introduction

Large woody debris (LWD) is an important component of instream habitat. Amongst other things, LWD dissipates flow energy, resulting in improved fish migration and channel stability.

Instream management works will improve the diversity of fish within the Nine-Mile Creek. Large woody debris has been assessed as in good condition throughout the remainder of the study area.

Project costs

The main problem with improving the instream habitat of the Nine Mile Creek is being able to source suitable logs. The CMA are now seeking to source timber from old bridges, where the wood is no longer required and is not being used for terrestrial habitat. The costs of installing large woody debris are estimated at $700 per log. We have assumed that 100 logs are required per kilometre and that one-third of the Nine-Mile Creek (10 kilometres) requires treatment. Therefore the cost of improving instream habitat is estimated at $700,000.

Project Benefit

The benefits of improving instream habitat include the provision of a stable habitat for invertebrate fauna. This improved habitat should increase the number and abundance of fish species and macroinvertebrate taxa found in the Nine-Mile Creek. In addition, LWD provides a base for the colonisation of algae and thus will contribute to the reduction in nutrients.

The overall benefits of this management action can be measured as:

- an improvement in the number and abundance of native fish species;
- increased values for recreational fishing; and
- a reduction in algal blooms.

Native Fish Species (Number and Abundance)

The main benefit of this management action will be to improve the number and abundance of native fish species within the Nine-Mile Creek. With no management, the population of exotics would build up and these would compete with native species and further reduce species diversity. With management, the increased diversity of fish in the Nine-Mile Creek could include Murray cod, catfish, and hardy heads.

Presently, no data exists to quantify the environmental value of improved species diversity within the Nine-Mile Creek. Whilst values do exist for losing native fish species from an entire river (see Table 4-1), these values are not appropriate for use where only a tributary or a particular reach are affected. For more information see Bennett and Morrison (2001).

If for example, this management action was going to prevent the loss of one native fish species from the entire Broken Creek, then the benefit could be calculated as is shown in Table 6-5.

We are interesting in preserving the Broken Creek and therefore WTA is the appropriate measure of value. We have used the WTP/WTA multiplier calculated for the Nine-Mile Creek that is shown in Appendix A.

Table 6-5: Example calculation of the value of preventing the loss of one native fish species,

	Outcome	
Item	Within catchment	Outside catchment
WTP per HH per fish species	$2.58	$3.81
WTP/WTA multiplier	2.3	1.3
WTA per HH per fish species	$5.93	$4.95
No, of fish species lost	1	1
WTA per HH per outcome number of fish species lost	$5.93	$4.95
No. HH (38% of total)	3,610	649,610
Value of outcome for each market ($m)	$21,422	$3,217,518
Total value of outcome ($m)	$3,238,940	

The value of preventing the loss of one native fish species in the Broken Creek is $3.2 million, however, as stated previously, this value is not appropriate for assessing the benefits of this management action.

Recreational Fishing

Published estimates of visitor numbers for the Nine-Mile Creek are not available. We assessed visitor numbers by undertaking informal interviews with a small number of persons who regularly observe visitors to the Creek. We estimated the number of visitors at an average of 10 per day or 3,650 visits per annum.

We have valued recreational fishing based on a 'standard net economic value' for local day visits of $3 per visit. The total annual value of recreational fishing on the Nine-Mile Creek is therefore estimated at $10,950 per annum.

With this management action, we have assumed that recreational fishing on the Nine Mile will increase. Three estimates of the increased recreational use that would be achieved with this action are:

- No change in visitor numbers — worst outcome;
- Visitor numbers double — most likely outcome; and
- Visitor numbers increases four-fold — best outcome.

Table 6-6 shows the distribution of benefits due to an increase in recreational fishing over a 30-year period at a discount rate of 4 per cent.

Table 6-6: Benefits from increasing recreational use – Nine-Mile Creek

	Worst Outcome	Most Likely Outcome	Best Outcome
NPV of benefits due to increased fishing	$2,310	$185,400	$435,608

Water quality

The present frequency of algal blooms along the Broken Creek from Katamatite to Barmah is estimated to be about 43 weeks every 10 years, on average, about four weeks per year. This management action is expected to bring about an improvement in water quality by reducing the frequency of blooms.

The outcomes are estimated to be:

- no change in the number of weeks (43) of blooms per decade — worst outcome;
- the number of weeks of blooms reduced by 5 per decade — most likely; and
- the number of weeks of blooms reduced by 15 per decade — best outcome.

The anticipated average annual cost of a bloom under current conditions (43 per decade) in the Broken Creek between Katamatite and Barmah is about $67,000 (URS 2002).

Table 6-7 shows the distribution of savings in the costs of blooms over a 30-year period at a discount rate of 4 per cent.

Table 6-7: Benefits from reducing algal blooms – Nine-Mile Creek

	Worst Outcome	Most Likely Outcome	Best Outcome
NPV of savings in the costs of algal blooms	$1,648	$132,563	$311,464

Comparison of Benefits and Costs

The benefits and costs of improving the instream habitat of the Nine-Mile Creek are shown in Table 6-8.

Table 6-8: Estimated benefits and costs – instream habitat

	Best outcome	Most Likely Outcome	Worst Outcome
Present value of benefits at 4 per cent over 30 years			
Native Fish	NA	NA	NA
Recreational Fishing	$435,608	$185,400	$2,310
Algal Blooms	$311,464	$132,563	$1,648
Present value of management action costs at 4 per cent	$567,763	$567,763	$567,763
Expected NPV	$179,310	-$249,799	-$563,805
Expected BCR	1.32	0.56	0.01

The only benefits that were quantified for improving instream habitat were those associated with recreational fishing and algal blooms. The results show that where these benefits are quantified that the benefits outweigh the costs for the best outcome only.

Discussion of Results

Sourcing wood to use in the Creek has been difficult due to the value of fallen wood as terrestrial habitat. The GBCMA are seeking to source wood that has been used in structures such as bridges where such terrestrial habitat values are not present.

The main benefit of improving instream habitat is an increase in the number and abundance of native fish species, however, these benefits were unable to be quantified within the analysis. The value of preventing the loss of one native fish species in the Broken Creek is $3.2 million, however, as stated previously, this value is not appropriate for assessing the benefits of this management action. Where the benefits to the number and abundance of native fish could be valued, the attractiveness of this management action would be substantially improved.

6.5 Wetland connectivity

Wetland health is one of the major aims of the Goulburn Broken Regional River Health Strategy. Some confirmation of significant unpriced values on the Broken Creek is provided by the fact that the 2,500 ha the Broken Creek floodplain is regarded as a “nationally important” wetland (ANCA 1996).

There are likely to be a number of sites, which if "opened up" would allow floodwaters or high flow to enter the floodplain wetlands and improve their condition (as long as grazing was controlled). These sites

could vary in size from a few hectares to tens of hectares at any one site where works might be able to be of benefit.

Presently **no** information is available to determine the area of wetlands in the lower Broken Creek that would benefit from being opened up and therefore no benefits have been assessed.

Once these areas have been determined, then the process would be to decide how to allow water to enter that wetland. It could be by:

A - Removal of levee and letting flows enter;

B - Removal of levee and building a replacement structure around wetlands (if other areas were at risk of flooding); or

C - Building a structure to allow water to flow into the wetlands (construction to allow for fish and other animals movements) - this might be a simple pipe structure or a weir or similar other structure which allows flows to enter and exit but controlled at a certain rate and level (to prevent off site flooding).

Given the high values associated with healthy native vegetation including wetlands, it is recommended that information on wetlands is obtained.

6.6 Increasing base flows over Rices Weir

Introduction

The largest floating fern bloom in recent years occurred during 2002 in Rices Weir just upstream of the junction with the Murray River. The costs of this bloom were likely to include:

- environmental costs due to fish kills;
- reduced visitors to the weir for recreation;
- farmers being unable to divert stock and irrigation water; and
- costs to manage the bloom.

During the 2003/04 irrigation-season, the risk of another bloom has been managed by releasing excess water into the Murray River. This process minimises the chance of an algal bloom developing. This option involves a permanent increase in the base flow over the weir throughout the summer period when stratification can persist. The purpose of increasing base flow over the weir is to increase the flow above a critical minimum level that will destratify the water column and prevent azolla from establishing.

Project costs

Water is the major cost of this option. The current market price for permanent trade in water entitlements is approximately $1 200 per ML (Watermove website 2004). It was estimated that 13.5 GL per year would be required to increase the flow to 50 ML per day over the gates at Rices Weir. Presently this water is diverted from the Murray River, passes through the Broken Creek and then re-enters the Murray River at Rices Weir. Apart from the estimated 10 per cent of water that is lost within the Broken Creek system, this water is a non-consumptive flow. In other words, the only cost of the water is for the 10 per cent of water that is lost.

At a cost of $1 200 per ML, the total one off payment required for this option is equal to $1.62 million.

The water that is passed through the Broken Creek will also be of poorer quality (increased nutrient and sediment loads) than water that otherwise would have travelled down the Murray. The economic cost of this water quality differential has not been estimated.

Project Benefit

The key benefit of this management action is the prevention of build-ups of azolla along the Broken Creek including Rices Weir. Azolla impacts on recreational amenity and was reputedly associated with the 2002 algal-bloom at Rices Weir. We have accessed the benefits of increased base flows as:

- an improvement in water quality; and
- a reduction in blooms.

Water Quality

Water quality is categorised as boatable (see Section 4.2 for this water quality definition) and is assumed to remain so in the absence of this management action. This action is expected to bring about an improvement in quality by changing water quality from boatable to fishable for a proportion of the Creek. The outcomes are estimated to be:

- no change in water quality — worst outcome;
- change in water quality for 5 per cent of the Creek (boatable to fishable) — most likely; and
- change in water quality for 15 per cent of the Creek(boatable to fishable) — best outcome.

We are interested in restoring the Broken Creek and therefore WTP is the appropriate measure of value. Based on these assumptions, the total economic value of improved water quality is shown in Table 6-9.

Table 6-9: Benefits from an improvement in water quality

	Best Outcome		Most Likely Outcome		Worst Outcome	
Item	Within catchment	Outside catchment	Within catchment	Outside catchment	Within catchment	Outside catchment
Water Quality:Boatable to Fishable	$53.43	$30.50	$53.43	$30.50	$53.43	$30.50
WTP/WTA multiplier	1	1	1	1	1	1
WTA per HH	$53.43	$30.50	$53.43	$30.50	$53.43	$30.50
Improvement (% length)	15%	15%	5%	5%	0%	0%
WTA per HH per water quality outcome	$8.01	$4.58	$2.67	$1.53	$0.00	$0.00
No. HH (38% of total)	3,610	649,610	3,610	649,610	3,610	649,610
Value of outcome for each market ($m)	$28,932	$2,971,966	$9,644	$990,655	$0	$0
Total value of outcome ($m)	$3,000,898		$1,000,299		$0	

Algal Blooms

The present frequency of algal blooms along the Broken Creek from Katamatite to Barmah is estimated to be about 43 weeks every 10 years, on average, about four weeks per year. The program is expected to bring about an improvement in water quality by reducing the frequency of blooms.

The three points of the triangular distribution of outcomes are estimated to be:

- the number of blooms reduced by 25 per cent per decade worst outcome;
- the number of blooms reduced by 50 per cent per decade most likely; and
- the number of blooms reduced by 100 per cent per decade best outcome.

The anticipated average annual cost of a bloom under current conditions (43 weeks per decade) in the Broken Creek between Katamatite and Barmah is about $67,000 (URS 2002).

Table 6-10 shows the distribution of savings in the costs of blooms over a 30-year period at a discount rate of 4 per cent.

Table 6-10: Benefits from reducing algal blooms – Broken Creek

	Worst Outcome	Most Likely Outcome	Best Outcome
NPV of savings in the costs of algal blooms	$292,815	$655,767	$1,146,889

Comparison of Benefits and Costs

The benefits and costs of increasing base flows over Rices Weir are shown in Table 6-11.

Table 6-11: Estimated benefits and costs – Increased Base Flows

	Best outcome	Most Likely Outcome	Worst Outcome
Present value of benefits at 4 per cent over 30 years			
Water Quality	$2,980,088	$1,273,558	$3,322
Algal Blooms	$1,146,889	$655,767	$292,815
Total Benefits	$4,126,977	$1,929,325	$296,137
Present value of management action costs at 4 per cent	$1,620,000	$1,620,000	$1,620,000
Expected NPV	$2,506,977	$309,325	-$1,323,863
Expected BCR	2.55	1.19	0.18

The only benefits that were quantified for increased base flows over Rices Weir were those associated with water quality and algal blooms. The results show that where these benefits are quantified that the benefits outweigh the costs for the most likely outcome and the best outcome. However, given these assumptions, for the worst case scenario increasing base flows is uneconomic.

Discussion of Results

The results show that this management action to increase base flows over Rices Weir to reduce outbreaks of azolla, increase water quality and reduce the likelihood of algal blooms is economic for the most likely and best case scenarios. However, if only the 'within catchment' market was considered, for improvements in water quality, the NPV would be negative. This suggests that although individual households in the local community may have a WTP compensation for an improvement in water quality, the local community by itself is too small to render the improvement of the Creek a worthwhile investment.

Other costs that have not been assessed are associated with increased sediment and nutrient load to downstream catchments, which may increase the likelihood of algal blooms in these catchments. In addition, no costs have been included for the operation of this flow, or its impact on capacity sharing of the Broken Creek.

Other benefits that have not been assessed are the benefits associated with improved habitat for native fish improved amenity and improved irrigation supply.

6.7 Flow management

Introduction

The Broken Creek has also been profoundly affected by flow regulation. Flow in this section of Broken Creek is greatly influenced by discharge from the East Goulburn Main Channel and a series of irrigation drains associated with the Murray Valley and Shepparton irrigation districts, and creek heights are maintained at high levels due to the presence of a series of weirs. It is likely that flows will become more constant through time. The operators of the new automatic channel regulation technology are reducing channel fluctuations, which are likely to increase azolla infestations.

Flow management that vary the supply height of water in the Creek has been raised as a management action that will have substantial impacts on the occurrence of exotic vegetation and improve the aquatic habitat of the Creek and environs. Any modifications to the supply height will involve trade-offs with irrigation and stock and domestic diverters. For these reasons, a planning management action to investigate the potential to vary flows is recommended.

No data has been made available to assess the benefits and costs of various flow regimes on the Broken Creek. It is recommended as part of the revised Strategy that environmental flow options be developed for the Broken Creek, and that these options are evaluated economically.

6.8 Catchment Management

Water quality is unlikely to become substantially worse in the Broken Creek. Trend data is showing that catchment management including the implementation of BMPs, increased water use efficiency, and improved irrigation technology will reduce diffuse pollution of the Broken Creek and lead to improved water quality. Improved water quality is likely to reduce the likelihood of algal blooms and associated impacts on water users. Concentrations of TP and TN are increasing; however, reduced flow has meant that loads have been substantially reduced.

No costs and therefore benefits of catchment management have been evaluated as part of this Strategy. These costs have been included within other strategies including the Goulburn Broken Water Quality Strategy and the Shepparton Irrigation Region Drainage Strategy.

6.9 Summary of Findings

The benefits and costs for different management actions are summarised in Table 6-12. The results are shown using net present values (NPV) and benefit cost ratios (BCR). Where investment dollars are limiting, and the aim is to maximise returns, the highest BCR shows which actions should be priorities. The highest BCRs are associated with *Woody Weed Management* and *Aquatic Weed Management*. However, the highest NPVs are associated with *Fencing and Revegetation* and *Aquatic Weed Management.*

Table 6-12: Summary of the costs and benefits for different management actions

	Best outcome		Most Likely Outcome		Worst Outcome	
	NPV	BCR	NPV	BCR	NPV	BCR
Fencing & Revegetation	$4,884,689	6	$1,997,162	3	$264,646	1.3
Woody Weed Management	$1,702,579	9	$559,368	4	-$202,772	0
Aquatic Weed Management	$4,434,675	10	$1,480,591	4.0	-$488,798	0.0
Improve Instream Habitat	$179,310	1.3	-$249,799	0.6	-$563,805	0.01
Increase Wetland Connectivity	Not Assessed					
Increase Base Flows over Rices Weir	$2,506,977	2.5	$309,325	1.2	-$1,323,863	0.18
Flow Management	Not Assessed					
Catchment Management	Not Assessed					

Note that for a number of management actions, the benefits include improved aquatic habitat, which should lead to an increase in the number and abundance of native fish species. Presently no economic data exists for determining the value of species abundance. Where such values exist, it is likely that the benefits of *Improving Instream Management* and *Increasing Base Flows over Rices Weir*, would look substantially better.

7.1 Introduction

Within this Section, the overall benefits and costs of the revised Broken Creek Strategy are compared. Current management responses are categorised under the following headings that have been taken from the statewide Regional Catchment Investment Plan (RCIP) Guidelines:

- Resource Assessments
- Planning
- Capacity Building
- On-ground works

It is difficult to assess the relative merits of isolated management options due to the synergies created when programs are developed and subsequently implemented. For example, it would not make sense to assess an environmental flows study (Planning), without assessing what management responses will be implemented to manage flows. For this reason, the costs and benefits of the overall strategy are assessed as a whole.

7.2 Costs of the Strategy

The management responses that have been costed in this benefit cost analysis are outlined in Table 23 and Table 26 of the revised Strategy (GHD 2005). The cash flow budget for the management responses is shown in Appendix B. A summary of these costs is shown in Table 7-1 and Table 7-2.

Table 7-1: Summary of Strategy Costs by management type.

Management Response	PV Costs	% of PV Total Costs
Resource Assessment	$563,512	12%
Planning	$333,581	7%
Works	$2,293,762	48%
Capacity Building	$53,846	1%
Implementation	$1,488,224	31%
Total	**$4,732,925**	**100%**

Table 7-1 shows that almost 50 per cent of the Strategy costs are associated with on-ground works. Over 30 per cent of the costs are associated with implementing the Strategy.

Table 7-2: Summary of Strategy Costs by Management Program

N.o.	Management Response	PV Costs	Total Cost	% of PV Total Costs
1	Fencing & Revegetation	$965,210	$1,040,000	20%
2	Enhance Instream habitat	$595,096	$705,000	13%
3	Improve Flow Regime	$144,231	$150,000	3%
4	Water Quality Management	$94,148	$100,000	2%
5	Catchment Management	$0	$0	0%
6	Drainage Management	$0	$0	0%
7	Woody Weed Management	$230,114	$270,000	5%
8	Aquatic Weed Management	$537,965	$620,000	11%
9	Bank Erosion & Habitat Managem	$9,615	$10,000	0%
10	Enhance Fish Passage	$13,335	$15,000	0%
11	Enhance Wetlands connectivity	$71,475	$60,000	2%
12	Protect cultural heritage	$10,000	$10,000	0%
13	Planning	$49,038	$50,000	1%
14	Communication	$34,615	$36,000	1%
15	Monitoring and Evaluation	$480,613	$560,000	10%
16	Research & Development	$9,246	$10,000	0%
All	Implementation Costs	$1,488,224	$1,760,000	31%
	Total	**$4,732,925**	**$5,396,000**	**100%**

Apart from Implementation Costs, Table 7-2 shows that the greatest costs are associated with the Fencing and Revegetation, Enhance Instream Habitat, Aquatic Weed Management and Monitoring and Evaluation Strategy Programs.

7.3 Benefits of the Strategy

The benefits of the Strategy are shown in Table 7-3.

Table 7-3: Summary of Strategy Benefits

	Best outcome	Most Likely Outcome	Worst Outcome
Present value of benefits at 4 per cent over 30 years			
Fencing & Revegetation	$5,775,054	$2,887,527	$1,155,011
Woody Weed Management	$1,905,351	$762,140	$0
Aquatic Weed Management	$4,923,473	$1,969,389	$0
Improve Instream Habitat	$747,072	$317,963	$3,958
Increase Wetland Connectivity	$0	$0	$0
Increase Base Flows over Rices Weir	$2,506,977	$309,325	-$1,323,863
Flow Management	$0	$0	$0
Catchment Management	$0	$0	$0
Total Benefits	**$15,857,926**	**$6,246,345**	**-$164,894**

As shown in Table 7-3, the greatest benefits are associated with Fencing and Revegetation and Aquatic Weed Management. The benefits that have been quantified vary between $15.9 million for the best outcome and minus $165,000. The most likely benefits are estimated at $6.2 million.

The assessment of benefits was not able to quantify all of the benefits of the Broken Creek Strategy. For example, no benefits were quantified due to an increase in the abundance of native fish species associated with improved water quality and instream habitat (for more information see Section 6.4).

7.4 Comparison of Benefits and Costs

The comparison of benefits and costs is shown in Table 7-4.

Table 7-4: Comparison of Benefits and Costs (discounted at 4% over 30 years)

	Best outcome	Most Likely Outcome	Worst Outcome
Present value of benefits at 4 per cent over 30 years	$15,857,926	$6,246,345	-$164,894
Present value of costs at 4 per cent over 30 years	$4,732,925	$4,732,925	$4,732,925
NPV	$11,125,001	$1,513,419	-$4,897,820
BCR	3.4	1.3	0.0

For the most likely outcome the Broken Creek Strategy has a NPV of $1.5 million and a BCR of 1.3. If however, the best environmental outcomes of the Strategy are achieved, the NPV increases to $11.2

million and the BCR increases to 3.4. Alternatively, should the worst environmental outcomes be realised, the NPV of the Strategy is minus $4.9 million.

Where a discount rate of 8 per cent is used, the net benefits of the Broken Creek Strategy are slightly improved (see Table 7-5).

Table 7-5: Comparison of Benefits and Costs (discounted at 8% over 30 years)

	Best outcome	Most Likely Outcome	Worst Outcome
Present value of benefits at 4 per cent over 30 years	$15,857,926	$6,246,345	-$164,894
Present value of costs at 4 per cent over 30 years	$4,132,258	$4,132,258	$4,132,258
NPV	$11,725,668	$2,114,086	-$4,297,152
BCR	3.8	1.5	0.0

7.5 Conclusion

The Broken Creek Strategy is economic using both a four per cent and eight per cent discount rate. At a four per cent discount rate, the most likely NPV for the Strategy is $1.5 million with a BCR of 1.3. The main benefits quantified in the analysis were associated with improvements in the health of riparian zones, increases in tourism and reductions in toxic algal blooms. No benefits were able to be quantified for the increase in the abundance of native fish species associated with improved water quality. Where such benefits were quantified, it is likely that the attractiveness of the Strategy would be improved substantially.

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Appendix A

A1.1 Intermediate Multipliers for the Broken Creek Management Strategy

A1.1.1 Broken Creek – Reach 21 to Reach 24

Within Catchment

	River Environment Substitutes		River Attributes and Accessability		Moral Responsibility	
Index	**Description**	**Score**	**Description**	**Score**	**Description**	**Score**
1	Near perfect substitutes		Common & Easy to access		Low	
2	Many similar alternatives		Relatively common but difficult to access		Low-Medium	
3	Similar alternatives	3	Average commonality and accessability		Medium	
4	Some similar alternatives		Relatively rare but easy to access	4	Medium-High	4
5	Unique (no substitutes)		Rare & difficult to access		High	

Substitute Score 3 River attribute Score 4 Responsibility Score 4

Intermediate Multiplier 3.7

Outside Catchment

	River Environment Substitutes		River Attributes and Accessability		Moral Responsibility	
Index	**Description**	**Score**	**Description**	**Score**	**Description**	**Score**
1	Near perfect substitutes		Common & Easy to access		Low	
2	Many similar alternatives	2	Relatively common but difficult to access		Low-Medium	
3	Similar alternatives		Average commonality and accessability	3	Medium	3
4	Some similar alternatives		Relatively rare but easy to access		Medium-High	
5	Unique (no substitutes)		Rare & difficult to access		High	

Substitute Score 2 River attribute Score 3 Responsibility Score 3

Intermediate Multiplier 2.7

A1.1.2 Broken Creek – Reach 25 & Reach 26

Within Catchment

Index	River Environment Substitutes		River Attributes and Accessability		Moral Responsibility	
	Description	Score	Description	Score	Description	Score
1	Near perfect substitutes		Common & Easy to access		Low	
2	Many similar alternatives		Relatively common but difficult to access		Low-Medium	
3	Similar alternatives	3	Average commonality and accessability	3	Medium	3
4	Some similar alternatives		Relatively rare but easy to access		Medium-High	
5	Unique (no substitutes)		Rare & difficult to access		High	

Substitute Score 3 River attribute Score 3 Responsibility Score 3

Intermediate Multiplier 3.0

Outside Catchment

Index	River Environment Substitutes		River Attributes and Accessability		Moral Responsibility	
	Description	Score	Description	Score	Description	Score
1	Near perfect substitutes	1	Common & Easy to access		Low	
2	Many similar alternatives		Relatively common but difficult to access	2	Low-Medium	2
3	Similar alternatives		Average commonality and accessability		Medium	
4	Some similar alternatives		Relatively rare but easy to access		Medium-High	
5	Unique (no substitutes)		Rare & difficult to access		High	

Substitute Score 1 River attribute Score 2 Responsibility Score 2

Intermediate Multiplier 1.7

A1.1.3 Boosey Creek – Reach 32

Within Catchment

Index	River Environment Substitutes		River Attributes and Accessability		Moral Responsibility	
	Description	Score	Description	Score	Description	Score
1	Near perfect substitutes		Common & Easy to access		Low	
2	Many similar alternatives	2	Relatively common but difficult to access		Low-Medium	2
3	Similar alternatives		Average commonality and accessability	3	Medium	
4	Some similar alternatives		Relatively rare but easy to access		Medium-High	
5	Unique (no substitutes)		Rare & difficult to access		High	

Substitute Score 2 River attribute Score 3 Responsibility Score 2

Intermediate Multiplier 2.3

Outside Catchment

Index	River Environment Substitutes		River Attributes and Accessability		Moral Responsibility	
	Description	Score	Description	Score	Description	Score
1	Near perfect substitutes	1	Common & Easy to access		Low	1
2	Many similar alternatives		Relatively common but difficult to access	2	Low-Medium	
3	Similar alternatives		Average commonality and accessability		Medium	
4	Some similar alternatives		Relatively rare but easy to access		Medium-High	
5	Unique (no substitutes)		Rare & difficult to access		High	

Substitute Score 1 River attribute Score 2 Responsibility Score 1

Intermediate Multiplier 1.3

A1.1.4 Nine Mile Creek – Reach 28

Within Catchment

Index	River Environment Substitutes		River Attributes and Accessability		Moral Responsibility	
	Description	Score	Description	Score	Description	Score
1	Near perfect substitutes		Common & Easy to access		Low	
2	Many similar alternatives	2	Relatively common but difficult to access		Low-Medium	2
3	Similar alternatives		Average commonality and accessability	3	Medium	
4	Some similar alternatives		Relatively rare but easy to access		Medium-High	
5	Unique (no substitutes)		Rare & difficult to access		High	

Substitute Score 2 River attribute Score 3 Responsibility Score 2

Intermediate Multiplier 2.3

Outside Catchment

Index	River Environment Substitutes		River Attributes and Accessability		Moral Responsibility	
	Description	Score	Description	Score	Description	Score
1	Near perfect substitutes	1	Common & Easy to access		Low	1
2	Many similar alternatives		Relatively common but difficult to access	2	Low-Medium	
3	Similar alternatives		Average commonality and accessability		Medium	
4	Some similar alternatives		Relatively rare but easy to access		Medium-High	
5	Unique (no substitutes)		Rare & difficult to access		High	

Substitute Score 1 River attribute Score 2 Responsibility Score 1

Intermediate Multiplier 1.3

Appendix B
Cash Flow Budget

		PV Total Costs	Sum	Costs									
				1	2	3	4	5	6	7	8	9	10
				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	**Fencing & Revegetation**												
1.1	Resource Assessment	$15,000	$15,000	$15,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
1.2	Resource Assessment	$5,000	$5,000	$5,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
1.3	Capacity Building	$19,231	$20,000	$0	$20,000	$0	$0	$0	$0	$0	$0	$0	$0
1.4	Works	$925,979	$1,000,000	$200,000	$200,000	$200,000	$200,000	$200,000	$0	$0	$0	$0	$0
2	**Enhance Instream habitat**												
2.1	Planning	$4,623	$5,000	$0	$0	$5,000	$0	$0	$0	$0	$0	$0	$0
2.2	Works	$590,473	$700,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000
3	**Improve Flow Regime**												
3.1	Planning	$144,231	$150,000	$0	$150,000	$0	$0	$0	$0	$0	$0	$0	$0
3.2	Works			To be determined									
4	**Water Quality Management**												
4.1	Planning	$4,623	$5,000	$0	$0	$5,000	$0	$0	$0	$0	$0	$0	$0
4.2	Planning	$9,246	$10,000	$0	$0	$10,000	$0	$0	$0	$0	$0	$0	$0
4.3	Planning	$17,780	$20,000	$0	$0	$0	$20,000	$0	$0	$0	$0	$0	$0
4.6	Works	$48,077	$50,000	$0	$50,000	$0	$0	$0	$0	$0	$0	$0	$0
4.7	Resource Assessment	$14,423	$15,000	$0	$15,000	$0	$0	$0	$0	$0	$0	$0	$0
5	**Catchment Management**												
6	**Drainage Management**												
7	**Woody Weed Management**												
7.1	Resource Assessment	$19,231	$20,000	$0	$20,000	$0	$0	$0	$0	$0	$0	$0	$0
7.2	Works	$168,707	$200,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000
7.3	Works	$42,177	$50,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
8	**Aquatic Weed Management**												
8.1	Resource Assessment	$20,000	$20,000	$20,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
8.2	Works	$295,237	$350,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000
8.4	Planning	$9,615	$10,000	$0	$10,000	$0	$0	$0	$0	$0	$0	$0	$0
9	**Bank Erosion & Habitat Management - Nine Mile Creek**												
9.1	Planning	$9,615	$10,000	$0	$10,000	$0	$0	$0	$0	$0	$0	$0	$0
10	**Enhance Fish Passage**												
10.1	Planning	$13,335	$15,000	$0	$0	$0	$15,000	$0	$0	$0	$0	$0	$0
10.2	Works			To be determined									

Appendix B
Cash Flow Budget

		PV Total Costs	Sum	Costs									
				1	2	3	4	5	6	7	8	9	10
				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
11	**Enhance Wetlands connectivity**												
11.1	Planning	$53,340	$60,000	$0	$0	$0	$60,000	$0	$0	$0	$0	$0	$0
11.2	Works			To be determined									
11.3	Planning	$18,136	$20,000	$0	$0	$10,000	$10,000	$0	$0	$0	$0	$0	$0
12	**Protect cultural heritage**												
12.1	Works	$10,000	$10,000	$10,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
13	**Planning**												
13.1	Planning	$10,000	$10,000	$10,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
13.2	Planning	$9,615	$10,000	$0	$10,000	$0	$0	$0	$0	$0	$0	$0	$0
13.3	Planning	$14,423	$15,000	$0	$15,000	$0	$0	$0	$0	$0	$0	$0	$0
13.4	Planning	$15,000	$15,000	$15,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
14	**Communication**												
14.1	Capacity Building	$14,423	$15,000	$0	$15,000	$0	$0	$0	$0	$0	$0	$0	$0
14.2	Capacity Building	$9,615	$10,000	$0	$10,000	$0	$0	$0	$0	$0	$0	$0	$0
14.3	Capacity Building	$10,577	$11,000	$0	$11,000	$0	$0	$0	$0	$0	$0	$0	$0
15	**Monitoring and Evaluation**												
15.1	Resource Assessment	$421,767	$500,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000
15.2	Resource Assessment	$30,000	$30,000	$30,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
15.4	Resource Assessment	$28,846	$30,000	$0	$30,000	$0	$0	$0	$0	$0	$0	$0	$0
16	**Research & Development**												
16.1	Resource Assessment	$9,246	$10,000	$0	$0	$10,000	$0	$0	$0	$0	$0	$0	$0

	Implementation Costs												
	People												
	Implementation Officer	$590,473	$700,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000	$70,000
	Communication Strategy	$46,299	$50,000	$10,000	$10,000	$10,000	$10,000	$10,000	$0	$0	$0	$0	$0
	Review & Revise	$83,837	$100,000	$0	$0	$0	$0	$50,000	$50,000	$0	$0	$0	$0
	Community Education & Extension	$168,707	$200,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000
	Fairness	$42,177	$50,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
	Cultural Heritage	$84,353	$100,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
	Technically Rigorous	$421,767	$500,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000
	Accountable	$8,435	$10,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
	Continuous Improvement	$42,177	$50,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000

Appendix C

RiVERS Environmental Values & Threat Scores

Environmental Values

(s) Denotes statewide dataset– **should not** be edited within RiVERS unless data is '0 – no data'.

	Significant flora (s)
0	No Data
1	No VROTs OR AROTs listed
3	VROTs present in bioregional categories 2c, 3b, 3c, 4b, 4c OR if no bioregional category then in Victorian threatened species categories Data Deficient or Poorly Known
4	VROTs present in bioregional categories 1c,2b,4a OR if no bioregional category then Victorian threatened species category Vulnerable or rare
5	AROT present with no Victorian classification OR VROTs in bioregional category 1a,1b,2a,3a OR if no bioregional category then Victorian threatened species category Presumed extinct, Critically Endangered, or Endangered OR listed as Threatened in Victoria but no classification of degree

Point data of significant flora within 100m buffer.

	Bioregional Conservation Status of EVCs (s)
0	No Data
1	Least concern
3	Rare or Depleted
4	Vulnerable
5	Endangered or Presumed Extinct

EVC with 100m buffer.

	Significant fauna (s)
0	No Data
1	No VROTs or AROTs listed
2	
3	VROTs present in bioregional categories 2c, 3b, 3c, 4b, 4c OR if no bioregional category then in Victorian threatened species categories Data Deficient or Poorly Known
4	VROTs present in bioregional categories 1c,2b,4a OR if no bioregional category then Victorian threatened species category Vulnerable or rare

5	AROT present with no Victorian classification OR VROTs in bioregional category 1a,1b,2a,3a OR if no bioregional category then Victorian threatened species category Presumed extinct, Critically Endangered, or Endangered OR listed as Threatened in Victoria but no classification of degree

Point data of significant fauna within 100m buffer.

	Stream Invertebrate Community Condition (s)
0	N/A No data
1	The only site in the reach falis 2 or more objectives if 4 indicators are used, or fails 1 objective if only 3 indicators are used.
3	One of several sites in the reach fails 2 or more objectives if 4 indicators are used, or fails 1 objective if only 3 indicators are used.
4	Fails to meet 1 objective where 4 indicators are used
5	Meets all required biological objectives in SEPP (Waters of Victoria)

Indicators include AUSRIVAS O/E, SIGNAL, EPT, No Families. In biological regions 1 – 3 four indicators are required to be used; in regions 4 and 5 only 3 indicators are required. This is due to low diversity of one indicator (EPT) in regions 4 and 5 making it unsuitable for use as a biological indicator.

	Width of riparian vegetation (s)	
	Large Stream	**Small Stream**
0	No Data	No Data
1	<0.25 x baseflow width (0)	Less than 5m (0)
2	0.25 x bfw < 0.5 x bfw (1)	Between 5m and 10m (1)
3	0.5 x bfw < 1.5 x bfw (2)	Between 10m and 30 m (2)
4	1.5 x bfw < 3 x bfw (3)	Between 30m and 40m (3)
5	> 3 x bfw (4)	Greater than 40m (4)

	Longitudinal continuity of riparian vegetation (s)
0	No data
1	Very poor
2	Poor
3	Moderate
4	Good
5	Excellent

	Structural intactness of riparian vegetation (s)
0	No Data
1	Very low
2	Low
3	Moderate
4	High
5	Very high

	Native fish – observed/expected (s)
0	No Data
1	0%
2	1 - 30%
3	31 - 60%
4	61 - 80%
5	81 - 100%

The number of species recorded / number of species expected at site

	Fish – proportion introduced (s)
0	No Data
1	70 - 100%
2	30 - 69%
3	10 - 29%
4	1 - 9%
5	0%

The number of introduced species recorded at site / total; number of species (native & introduced).

	Native fish migration (s)
0	No Data
1	Reach not thought to be used by migratory species
2	Migratory species use reach for passage (facultative)
3	Migratory species use reach for passage (obligatory)
4	VROT migratory species use reach for passage (facultative)
5	VROT migratory species use reach for passage (obligatory)

	Wetland significance (s)
0	No data
1	Not listed
2	Regionally significant (nominated by CMA)
3	NA
4	Wetland of National significance (listed in Directory of Important Wetlands) OR colonial waterbird breeding site*
5	Wetlands listed on Ramsar OR national/ international significance for shore birds**

Link polygon data to ISC reaches within 100m buffer

* Either a colonial waterbird breeding site with >=5 nests or a site with breeding records for>1 colonial waterbird species. Data from NLWRA

** NLWRA

	Rarity and depletion of wetland type (s)
0	No data
1	>20% total area or number for Victoria
2	10% - 19% total area or number for Victoria
3	5% - 9% total area or number for Victoria
4	1% - 4% total area or number for Victoria OR Vulnerable* in the bioregion
5	<1% total area or number for Victoria OR Endangered* in the bioregion

Link polygon data to ISC reaches within 100m buffer

* National Land and Water Resources Audit

	Heritage or Representative River
0	No data
1	Not listed as Heritage River or 'Representative River'
3	Representative River
5	Listed as Heritage River

	Sites of significance
0	No data
1	No listing
5	Listed in technical or scientific report as significant

Sites of significance can only include sites that have not been covered elsewhere in RiVERS eg: geomorphological site of significance.

	Ecologically healthy river (s)
0	No data
1	Not considered Ecologically Healthy River
5	Ecologically Healthy River

Listed in Victorian River Health Strategy

Ecological health criteria as listed in Victorian River Health Strategy

Criteria	Rating	Meaning
Riparian vegetation (structural intactness)	>= 1	A movement of no more than 1 class away from existing structure (<20%, 20 – 80%, >80%)
Cover of exotic vegetation	>= 2	<40% exotic cover for tree, shrub and groundcover layers
Instream physical habitat	>= 3	lowland – numerous to abundant debris from native vegetation upland - >30% stable habitat
Barriers	>= 2	Barrier may occasionally impede some migration
Longitudinal continuity	>= 3	>80% of bank vegetated with no more than five significant discontinuities
Bed condition	>= 2	Stable or limited stability
Aquatic life	>= 9	Combined SIGNAL and AUSRIVAS rating of at least 9

Threats to values

(s) Denotes statewide dataset – can not be edited

	Loss of bank stability (bank erosion) (s)
0	No Data
1	Stable (4)
2	Limited erosion (3)
3	Moderate erosion (2)
4	Extensive erosion (1)
5	Extreme instability (0)

	Loss of bed stability (bed erosion) (s)
0	N/A No Data
1	Stable (4)
3	Limited instability (2)
5	Extensive instability (0)

	Barriers to native fish migration (s)
0	No Data
1	In typical year, no artificial barriers in basin downstream of the reach interfere with the migration of indigenous fish endemic to the stream(4)
3	Situations where there are artificial barriers in the basin downstream of the reach that may intermittently interfere with the migration of indigenous fish endemic to the stream (2)
5	In typical year, at least one artificial barrier in the basin downstream of the reach completely blocks the migration of indigenous fish species (0)

	Channel modification
0	N/A No Data
1	Natural
2	Natural with minor modification
3	Some de-snagging and/or minor realignment
4	Extensive de-snagging and/or extensive re-alignment
5	Concrete lined

	Changes to flow (flow deviation) (s)
0	No Data
1	Very small deviation from natural 0.1 - <.1 AAPFD (9,10)
2	Minor >.2 - 1 AAPFD (8, 7,6)
3	Moderate >1 - 2 AAPFD (5,4)
4	Extensive >2 - 4 AAPFD (3,2)
5	Extreme >4 - >5 AAPFD (1,0)

	Water quality trends (s)
0	No data
1	Sufficient data collected but no trends identified
2	Not enough data to identify trend
3	Suspect trend in at least 1 parameter but not statistically significant
4	Statistically significant trend in 1 parameter
5	Statistically significant trend in more than 1 parameter

	Water quality attainment (s)
0	No data
1	Meets all SEPP objectives
2	Fails to meet the objective for any one of these indicators
5	Fails to meet the objectives for 2 or more indicators

SEPP objectives for DO, EC, Turbidity, TN, TP, pH

	Water quality SIGNAL (s)
0	No Data
1	Meets SIGNAL objective in SEPP (waters of Victoria)
5	Fails to meet SIGNAL objective

	Changes to water temperature
0	No Data
1	No dams, dams that do not discharge to natural streams, release from surface water
2	Dams >5m and are artificially destratified
3	Dams >5m with releases from 6 – 10m below FSL or with only occasional releases
4	Dams >5m discharging regularly with offtakes >10m below FSL
5	Dams >5m discharging regularly with offtakes >10m below FSL and there exists evidence of cold water pollution

	Occurrence of algal blooms
0	No Data
1	No Algal Bloom
5	Known Algal Bloom

	Introduced exotic flora (s)
0	No data
1	0% cover of exotic vegetation (4)
2	1 - 10% cover of exotic vegetation (3)
3	11 - 40% cover of exotic vegetation (2)
4	41 - 60% cover of exotic vegetation (1)
5	> 60% cover of exotic vegetation (0)

	Degraded riparian vegetation (s)
0	No data
1	Riparian zone sub index score 9 - 10
2	Riparian zone sub index score 7 - 8
3	Riparian zone sub index score 5 - 6
4	Riparian zone sub index score 3 - 4
5	Riparian zone sub index score 0 - 2

	Introduced exotic fauna
0	No Data
1	Not present
2	One species occasionally inhabits reach
3	One or more species inhabits reach in high numbers
4	Obvious problems on river bank or impacting on native flora and fauna
5	Population rampant requires immediate action

	Loss of instream habitat (s)	
	Lowland	Upland
0	No Data	No Data
1	Excellent habitat (4)	Excellent habitat (4)
2	Good habitat (3)	Good habitat (3)
3	Marginal habitat (2)	Marginal habitat (2)
4	Poor habitat (1)	Poor habitat (1)
5	Very poor habitat (0)	Very poor habitat (0)

	Loss of wetland connectivity
0	No data
1	Appears that wetlands do not and did not exist
2	Natural conditions, wetland connected to waterway with natural flow regime
3	Wetlands connected to waterway but flooded less frequently than natural
4	Wetlands artificially permanently inundated
5	Wetlands no longer connected to waterway under any flow conditions

	Uncontrolled stock access (s)
0	No Data
1	No stock access
5	Stock access recorded

Appendix D

Risk Assessment Results

Interactions between key values and threats for the Lower Broken Creek

Appendix D Risk Assessment Results – Interactions between key values and threats for the Lower Broken Creek

Table D1 Management Response Reach 21

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
AusRivas	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EVC	5	-	Low 1	-	-	-	-	Low 1	Very High	-	Medium 2	Very High	-	Medium 2	High 1	-	High 1
Fauna Rarity	5	-	Low 1	Low 1	Low 1	Low 1	-	Low 1	Very High	Low 1	Medium 2	Very High	-	Medium 2	Very High	-	High 1
Fish Mig	4	-	-	Low 1	-	Low 1	-	-	High 2	Low 1	-	-	-	Medium 2	High 2	-	Medium 1
Fish Obs	4	-	Low 1	Low 1	Low 1	Low 1	-	-	High 1	Low 1	Medium 2	High 2	-	Medium 2	High 2	-	High 2
Fish Prop	2	-	-	-	-	-	-	-	Low 2	-	-	-	-	-	Low 2	-	Low 2
Flora Rarity	5	-	-	-	-	-	-	Low 1	High 1	-	-	High 1	-	-	-	-	-
Her Riv	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long Cont	5	-	Low 1	-	-	-	-	Low 1	High 1	-	Medium 2	Very High	-	-	-	-	-
Natural	1	Low 2	-	-	-	-	-	-	Low 2	-	-	Low 2	-	-	Low 2	-	Low 2
Sites Sig	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Struc Intact	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wetland Rar	5	-	-	-	-	-	-	Low 1	Very High	-	-	Medium 1	-	Medium 2	High 1	-	High 1
Wetland Sig	5	-	-	-	-	-	-	Low 1	Very High	-	-	Medium 1	-	Medium 2	High 1	-	High 1
Width Veg	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Camping	5	Very High	-	-	-	-	-	-	Medium 1	-	-	High 1	-	-	-	-	-
Euro Heritage	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
Fishing	5	High 1	Low 1	Low 1	Low 1	Low 1	-	Low 1	High 1	Low 1	-	High 1	-	-	High 1	-	Medium 1
Flagship Species	5	High 1	Low 1	Low 1	Low 1	Low 1	-	Low 1	Very High	Low 1	Medium 2	High 1	-	Medium 2	Very High	-	High 1
Listed Landscape	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mot Sports	5	High 1	-	-	-	-	-	-	High 1	-	-	-	-	-	-	-	-
Non Motor Sports	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passive Rec	2	Low 2	-	-	-	-	-	-	-	-	-	Low 2	-	-	-	-	-
Swimming	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Infra	5	-	Low 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Land Value	5	Medium 1	Low 1	-	-	-	-	Low 1	-	-	-	-	-	-	Medium 1	-	Medium 1
Power Gen	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tourism	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Supp Irr	5	Very High	Low 1	-	-	-	-	-	-	-	-	High 1	-	-	Very High	-	High 1
Water Supp PC	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table D2 Management Response Reach 22

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
AusRivas	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EVC	5	-	Low 1	-	-	-	-	Low 1	High 1	-	Medium 2	Very High	-	-	-	-	-
Fauna Rarity	5	-	Low 1	Low 1	Low 1	Low 1	-	Low 1	Very High	Medium 2	Medium 2	High 1	-	Low 1	-	-	-
Fish Mig	4	-	-	Low 1	-	Low 1	-	-	High 2	Medium 2	-	-	-	Low 1	-	-	-
Fish Obs	4	-	Low 1	Low 1	Low 1	Low 1	-	-	High 1	Medium 2	Medium 2	High 2	-	Low 1	-	-	-
Fish Prop	2	-	-	-	-	-	-	-	Low 2	-	-	-	-	-	-	-	-
Flora Rarity	5	-	Low 1	-	-	-	-	Low 1	High 1	-	Medium 2	Very High	-	-	-	-	-
Her Riv	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long Cont	2	-	-	-	-	-	-	-	Low 2	-	-	Low 2	-	-	-	-	-
Natural	1	-	-	-	-	-	-	-	Low 2	-	-	Low 2	-	-	-	-	-
Sites Sig	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Struc Intact	4	-	Low 1	-	-	-	-	Low 1	High 2	-	Medium 2	High 1	-	-	-	-	-
Wetland Rar	5	-	-	-	-	-	-	Low 1	Very High	-	-	Medium 1	-	Low 1	-	-	-
Wetland Sig	4	-	-	-	-	-	-	Low 1	High 1	-	-	Medium 1	-	Low 1	-	-	-
Width Veg	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Camping	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euro Heritage	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fishing	5	Low 1	Low 1	Low 1	Low 1	Low 1	-	Low 1	High 1	Medium 2	-	High 1	-	-	-	-	-

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
Flagship Species	5	Low 1	Low 1	Low 1	Low 1	Low 1	-	Low 1	Very High	Medium 2	Medium 2	Very High	-	Low 1	-	-	-
Listed Landscape	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mot Sports	5	Low 1	-	-	-	-	-	-	High 1	-	-	-	-	-	-	-	-
Non Motor Sports	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passive Rec	2	-	-	-	-	-	-	-	-	-	-	Low 2	-	-	-	-	-
Swimming	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Infra	4	-	Low 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Land Value	5	-	Low 1	-	-	-	-	Low 1	-	-	-	-	-	-	-	-	-
Power Gen	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tourism	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Supp Irr	5	Low 1	Low 1	-	-	-	-	-	-	-	-	High 1	-	-	-	-	-
Water Supp PC	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table D3 Management Response Reach 23

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
AusRivas	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EVC	5	-	Medium 2	-	-	-	-	Medium 2	Very High	-	Medium 2	Very High	-	Low 1	-	-	-
Fauna Rarity	5	-	Medium 2	Low 1	Low 1	Low 1	-	Medium 2	Very High	Low 1	Medium 2	Very High	-	Low 1	-	Low 1	-
Fish Mig	1	-	-	-	-	-	-	-	Low 2	-	-	-	-	-	-	-	-
Fish Obs	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fish Prop	2	-	-	-	-	-	-	-	Low 2	-	-	-	-	-	-	-	-
Flora Rarity	5	-	Medium 2	-	-	-	-	Medium 2	High 1	-	Medium 2	Very High	-	-	-	-	-
Her Riv	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long Cont	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natural	1	Low 2	-	-	-	-	-	-	Low 2	-	-	Low 2	-	-	-	-	-
Sites Sig	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Struc Intact	4	-	Medium 2	-	-	-	-	Medium 2	High 2	-	Medium 2	High 1	-	-	-	-	-
Wetland Rar	5	-	-	-	-	-	-	Medium 2	Very High	-	-	Medium 1	-	Low 1	-	Low 1	-
Wetland Sig	4	-	-	-	-	-	-	Medium 2	High 1	-	-	Medium 1	-	Low 1	-	Low 1	-
Width Veg	2	-	-	-	-	-	-	-	-	-	-	Low 2	-	-	-	-	-
Camping	2	Low 2	-	-	-	-	-	-	-	-	-	Low 2	-	-	-	-	-
Euro Heritage	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fishing	5	High 1	Medium 2	Low 1	Low 1	Low 1	-	Medium 2	High 1	Low 1	-	High 1	-	-	-	Low 1	-

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
Flagship Species	5	High 1	Medium 2	Low 1	Low 1	Low 1	-	Medium 2	Very High	Low 1	Medium 2	Very High	-	Low 1	-	Low 1	-
Listed Landscape	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mot Sports	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Non Motor Sports	5	High 1	-	-	-	-	-	-	High 1	-	-	Medium 1	-	-	-	-	-
Passive Rec	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Swimming	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Infra	5	-	Medium 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Land Value	5	Medium 1	Medium 2	-	-	-	-	Medium 2	-	-	-	-	-	-	-	-	-
Power Gen	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tourism	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Supp Irr	5	Very High	Medium 2	-	-	-	-	-	-	-	-	High 1	-	-	-	Low 1	-
Water Supp PC	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table D4 Management Response Reach 24

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
AusRivas	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EVC	5	-	Low 1	-	-	-	-	Low 1	Very High	-	Medium 2	Very High	-	Low 1	-	-	-
Fauna Rarity	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fish Mig	1	-	-	-	-	-	-	-	Low 2	-	-	-	-	-	-	-	-
Fish Obs	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fish Prop	2	-	-	-	-	-	-	-	Low 2	-	-	-	-	-	-	-	-
Flora Rarity	5	-	Low 1	-	-	-	-	Low 1	High 1	-	Medium 2	Very High	-	-	-	-	-
Her Riv	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long Cont	4	-	Low 1	-	-	-	-	Low 1	High 2	-	Medium 2	High 1	-	-	-	-	-
Natural	1	-	-	-	-	-	-	-	Low 2	-	-	Low 2	-	-	-	-	-
Sites Sig	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Struc Intact	4	-	Low 1	-	-	-	-	Low 1	High 2	-	Medium 2	High 1	-	-	-	-	-
Wetland Rar	5	-	-	-	-	-	-	Low 1	Very High	-	-	Medium 1	-	Low 1	-	-	-
Wetland Sig	4	-	-	-	-	-	-	Low 1	High 1	-	-	Medium 1	-	Low 1	-	-	-
Width Veg	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Camping	4	Low 1	-	-	-	-	-	-	Medium 1	-	-	High 2	-	-	-	-	-
Euro Heritage	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fishing	4	Low 1	Low 1	Low 1	Low 1	Low 1	-	Low 1	High 2	Medium 2	-	High 2	-	-	-	-	-

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
Flagship Species	5	-	Low 1	Low 1	Low 1	Low 1	-	-	Very High	Medium 2	Medium 2	High 1	-	Low 1	-	-	-
Listed Landscape	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mot Sports	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Non Motor Sports	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passive Rec	5	Low 1	Low 1	-	-	-	-	-	Medium 1	-	Medium 2	High 1	-	-	-	-	-
Swimming	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Infra	5	-	Low 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Land Value	5	-	Low 1	-	-	-	-	Low 1	-	-	-	-	-	-	-	-	-
Power Gen	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tourism	4	Low 1	-	-	-	-	-	-	Medium 1	-	Medium 2	-	-	-	-	-	-
Water Supp Irr	5	Low 1	Low 1	-	-	-	-	-	-	-	-	High 1	-	-	-	-	-
Water Supp PC	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table D5 Management Response Reach 28

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
AusRivas	2	-	-	-	-	-	-	-	-	-	-	Low 2	-	-	-	Low 2	-
EVC	5	-	Low 1	-	-	-	-	Medium 2	Low 1	-	Low 1	Very High	-	Low 1	-	-	-
Fauna Rarity	5	-	Low 1	-	-	-	-	Medium 2	Low 1	-	Low 1	Very High	-	-	-	-	-
Fish Mig	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fish Obs	2	-	-	-	-	-	-	-	-	-	-	Low 2	-	-	-	-	-
Fish Prop	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flora Rarity	5	-	Low 1	-	-	-	-	Medium 2	Low 1	-	Low 1	Very High	-	-	-	-	-
Her Riv	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long Cont	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natural	1	-	-	-	-	-	-	-	-	-	-	Low 2	-	-	-	Low 2	-
Sites Sig	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Struc Intact	4	-	Low 1	-	-	-	-	Medium 2	Low 1	-	Low 1	High 1	-	-	-	-	-
Wetland Rar	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wetland Sig	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Width Veg	5	-	Low 1	-	-	-	-	Medium 2	-	-	Low 1	Very High	-	-	-	-	-
Camping	2	-	-	-	-	-	-	-	-	-	-	Low 2	-	-	-	-	-
Euro Heritage	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fishing	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
Flagship Species	5	-	-	-	-	-	-	Medium 2	Low 1	-	-	High 1	-	Low 1	-	-	-
Listed Landscape	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mot Sports	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Non Motor Sports	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passive Rec	2	-	-	-	-	-	-	-	-	-	-	Low 2	-	-	-	-	-
Swimming	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Infra	5	-	Low 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Land Value	5	-	Low 1	-	-	-	-	Medium 2	-	-	-	-	-	-	-	-	-
Power Gen	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tourism	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Supp Irr	5	Low 1	Low 1	-	-	-	-	-	-	-	-	High 1	-	-	-	High 1	-
Water Supp PC	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table D6 Management Response Reach 32

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
AusRivas	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EVC	5	-	Low 1	-	-	-	-	Low 1	Medium 2	-	Medium 2	Low 1	-	Low 1	-	-	-
Fauna Rarity	5	Low 1	Low 1	High 1	Low 1	Low 1	-	Low 1	Medium 2	-	Medium 2	Low 1	-	Low 1	-	-	-
Fish Mig	1	-	-	Low 2	-	-	-	-	-	Low 2	-	-	-	-	-	-	-
Fish Obs	4	-	Low 1	High 1	Low 1	Low 1	-	-	Medium 2	High 2	Medium 2	Low 1	-	Low 1	-	-	-
Fish Prop	2	-	-	Low 2	-	-	-	-	-	Low 2	-	-	-	-	-	-	-
Flora Rarity	5	-	Low 1	-	-	-	-	Low 1	Medium 2	-	Medium 2	Low 1	-	-	-	-	-
Her Riv	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Long Cont	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natural	1	-	-	Low 2	-	-	-	-	-	Low 2	-	-	-	-	-	-	-
Sites Sig	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Struc Intact	4	-	Low 1	-	-	-	-	Low 1	Medium 2	-	Medium 2	Low 1	-	-	-	-	-
Wetland Rar	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wetland Sig	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Width Veg	4	-	Low 1	-	-	-	-	Low 1	-	-	Medium 2	Low 1	-	-	-	-	-
Camping	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euro Heritage	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Value_Name	Value	Algal	Bank	Barr	Bed	Chan	Exotic Fauna	Exotic Veg	Flow	LOIH	SSZ	Stock Con	Temp	Wetland Con	WQ Level	WQ Signal	WQ Trend
Fishing	4	Low 1	Low 1	High 1	Low 1	Low 1	-	Low 1	Medium 2	High 2	-	Low 1	-	-	-	-	-
Flagship Species	4	-	Low 1	High 1	Low 1	Low 1	-	-	Medium 2	High 2	Medium 2	Low 1	-	Low 1	-	-	-
Listed Landscape	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mot Sports	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Non Motor Sports	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passive Rec	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Swimming	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Infra	4	-	Low 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Land Value	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Power Gen	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tourism	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Supp Irr	5	Low 1	Low 1	-	-	-	-	-	-	-	-	Low 1	-	-	-	-	-
Water Supp PC	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix E

Unit Cost Assumptions for Costing of Programs and Actions

Appendix E Unit cost assumptions for costing of programs and actions

The attached table is taken from Appendix 8 of the GB Regional River Health Strategy. For many actions, both a high and low estimate of costs are given, depending on the assumptions made. For costings in the Regional River Health Strategy, the average of the two estimates were used, and a similar approach has been taken for the Broken Creek Strategy.

Actions and Outputs	$/Unit - Est 1	$/Unit - Est 2	UNIT
INSTREAM AQUATIC RESTORATION			
Construction of Fish Ladder	100,000	100,000	vert m of barrier
Fish survey	10,000	6,500	km
Macroinvertebrate survey	3,000	1,200	project area/site
Reinstatement of Large Woody Debris		70,000	km
SEARS	20,000		km
Native fish stocking (for conservation)		8,000	1000 fish
RIPARIAN MANAGEMENT			
Fencing (materials only)	3,500	3,000	km
Fencing (construction)	3,500	2,500	km
Riparian weed management for site preparation (ground cover)		900	km
Riparian weed management for site preparation (woody weeds)		1,000	km
Aquatic Weeds (heavy)	20,000		km
Aquatic Weeds (medium - light)	5,000		km
Woody weed management (heavy)		5,000	km
Willow management (light)	5,000	2,300	km
Willow management (heavy)	15,000	18,000	km
Off stream watering	1,000	2,500	km
Revegetation (plants, stakes and guards only)	3,750	650	1000 plants
Revegetation (plants, stakes, guards and planting crew - labour)	5,000	1,500	1000 plants
Direct seeding		300	km
Weed Maintenance in high rainfall areas (after revegetation)		5,000	km
Bird Survey		160	km
URBAN ENHANCEMENT			
Weed management (light)		12,000	km
Weed management (heavy)		21,000	km
Urban Stormwater Education	10,000		per mun. per annum
EROSION CONTROL			
Gully stabilisation - rock chute (minor)	5,000	5,000	site
Gully stabilisation - rock chute (major)	13,000	12,000	site
Stream Stabilisation - rock chute (minor)	7,500	8,000	site
Stream Stabilisation - rock chute (major)	25,000	18,000	site
Stream stabiliation - rock beaching (minor)	5,000	4,000	km
Stream stabilisation - rock beaching (major)	10,000	7,000	site
Alignmant training		25,000	site
STRATEGIES AND PLANS			
Development of Streamflow Management Plan	150,000	40,000	each
Development of Restoration Plan for Specific Waterway		30,000	each
Development of Waterway Action Plan for sub-catchment		10,000	each
Groundtruthing Nutrient Action Plan Priorities		25,000	entire region
Groundtruthing River Health Plan Priorities		50,000	entire region

Actions and Outputs		$/Unit - Est 1	$/Unit - Est 2	UNIT
EDUCATION				
	Half day workshop (CMA lead eg Riparian Workshop)		1,500	each
	Half day workshop (Expert lead eg Freshwater Circus)		2,500	each
	Media Release		200	each
	Forum (eg River Health Forum)		2,000	each
	Educational material		1,000	1000 units
	Curriculum aids for schools - water quality/waterway related topics		10,000	topic
	Special event (eg World Environment Day)		30,000	each
OTHER				
	Monitoring (ISC)	200		per rep reach
	Monitoring (Bugs , Ariv)	3,000		per site
	Monitoring (fish)	10,000		per km
	Longitudinal Surveys	1,000		per km

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Draft B	A Roy	K Fung		D Petch	*D. Petch	30/03/05
0	A Roy	K Fung		D Petch	*D Petch	12/07/05
1	A Roy	K Fung		D Petch	*D Petch	14/07/05
2	A Roy	D Petch		D Petch		19/8/05

*Denotes signature on original