MARY RIVER
CATCHMENT
COORDINATING COMMITTEE

MARY RIVER and tributaries REHABILITATION PLAN

Implementation Edition

19th July 2001

INTEGRATED
CATCHMENT
MANAGEMENT

This Plan was collaboratively developed by the Mary River Catchment Coordinating Committee. The main body of research and drafting was conducted by:

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PURPOSE OF THE PLAN

The principal purpose of this plan is to prioritise rehabilitation effort on a reach-by-reach basis. It aims firstly to identify the historical, sociological and environmental processes leading to the current condition of the river and tributaries.

It then uses this information to classify geomorphically similar reaches and develop key strategies that are required to be implemented by the Mary River Catchment community in order to halt the continued degradation of our waterways.

The long-term objective of the plan is to protect waterways of conservation value, while rehabilitating and restoring degraded reaches in a more strategic and cost-effective manner than has occurred in the past, to achieve a shared vision of the future.

The plan does not attempt to address the broad scope of issues identified in the Mary River Catchment Management Strategy, as it seeks only to implement those elements of the strategy relating directly to waterway management and rehabilitation.

OVERVIEW

Catchment–wide strategic river rehabilitation plans are rarely undertaken in Queensland. The *Mary River and Tributaries Rehabilitation Plan* adopts the process outlined in the Rehabilitation Manual for Australian Streams. The approach is recent, with the manual released by the Land and Water Resources Research and Development Corporation in mid-1999. The Mary is a large South-east Queensland catchment that retains some values and sub-catchments which are of regional conservation significance, but is significantly degraded in other locations. The waterways provide the last remaining habitat for the endangered Mary River Cod and Mary River Turtle. The plan prioritises strategies based on the 'Titanic' theory which argues that protection of natural assets (keeping good ships afloat) is more cost effective than rehabilitating highly degraded reaches (raising the Titanic). Reaches of relatively homogeneous geomorphic character and behaviour are classified along the lines of the "*Riverstyles* $_{TM}$" approach developed by Brierley. Assets, problems and the recovery trajectory are identified, before each reach is categorised into a seven tier hierarchy. Categories range from protecting and restoring reaches of regional conservation significance through to stabilising highly degraded reaches with little chance of natural recovery. The plan sets out a long –term ‘Life-time’ vision, and ten year goals. These aim to reverse current trends by motivating and empowering the community to adopt river rehabilitation techniques that are based on a solid understanding of river processes.
The methods, field survey, evaluation and strategy development are based on an extensive review of mainly Australian literature dealing with river processes, fluvial geomorphology and aquatic ecology and their application to river restoration. The results of the review are outlined in a detailed discussion of those processes involved in channel formation, channel degradation and recovery processes, as well as methods recommended for restoration strategy development and are outlined in Appendix 2 of the Plan. An in-depth review of previous research and surveys in the Mary River Catchment is presented dealing with the hydrology, geology, history, ecology, condition and use of streams and their resources. The plan aims to provide an understanding of the character and behaviour of streams in the Mary River Catchment and why it is important that management options consider these traits in a holistic fashion. It suggests that an appreciation of the physical, biological and cultural attributes of the catchment is an essential element of a strategic framework for river rehabilitation, if restoration is aiming to maximise the biological value flowing from physical works, and increase the chance of success of these endeavours.

Federal Government Natural Heritage Trust Funding together with Local Government grants and State Government in-kind contributions have been sourced to commence the implementation of the practical and targeted actions identified in the plan.

1.0 INTRODUCTION

WHY PREPARE A RIVER REHABILITATION PLAN?

1.1 Taking Stock of Where We Are and How We Got Here.

There was movement at the station for the word had got around,
That the river we regret had got away…. (apologies to Banjo Patterson)

Every Australian educated person will tell you that that's not the way it goes, the poem is about chasing wild horses not saving wild rivers. Yet while bards waxed lyrical about the taming of horse and land, the forging of a frontier was rapidly changing the character of the natural icons within their prose. If the writer had observed for long enough he would have found that the mighty Snowy River was undergoing significant change.

When E.L. Bruce mapped the Snowy River in 1865 it was 50-100 m wide, whereas 1934 surveys show it to be 375 m wide at Lyn's Gulch and is up to 150 m wide at Gilbert's Gulch (Gippel 1999). Available data suggest that the river widened catastrophically in the very early period of European settlement with at least a doubling in width in these sections some time between 1870 and 1920. The catastrophic flood of 1870 was a possible cause of, or trigger for, this widening. But other factors such as clearance of riparian vegetation by the first settlers, and the removal of large woody debris by the early snagging parties could have contributed to rapid widening (Gippel 1999).

If such dramatic widening is a difficult concept to grapple with, then consider the findings of Vincin (1999) who after 22 years of study of the first explorer's original journals and surveyors reports, found that expeditions led by Oxley, Sturt, Mitchell, Hume, Leichardt and botanists John and Allan Cunningham all repeatedly reported that watercourses ceased in reed barrier ponds (billabongs). Mitchell for example reported that watercourses - "unlike any other… with a total absence of water worn banks". Vincin's evidence suggests the Darling, Macquarie, Gwydir, Namoi, Lachlan, Murrumbidgee, Goulburn, Murray all 'died in the plains'. These watercourses were surface flush between trees and reed ponds. Cod and other species of fish lived in the cool reed barrier ponds and were observed moving up the catchment in times of flood.

Vincin (1999) has suggested that when Surveyors General returned after some years to their original routes, they were disturbed to find squatters had burnt reeds for their cattle and sheep and cleared areas adjacent to watercourses. Waterways were now rapid flowing "in deep trenches" and cutting new courses, often miles from their original path. Such trenches were no accident. In 1853 a Captain Cade had travelled to Albury and returned to South Australia with wool and grain after cutting a path from billabong to billabong, often travelling 6 miles to achieve one mile up the direction of flow. Archive reports tell how he went on to clear the Goulburn, Darling and other rivers between 1856 - 1863, through a steam powered saw machine for cutting through trees below the waterline. When floods occurred new river courses were cut into the soft soil and clays miles from the prior watercourses, undercutting and dropping large stretches down several feet. He was then contracted to return and clear the river of newly exposed obstructions (Vincin 1999).

So what's this lesson in history got to do with river restoration or the preparation of a rehabilitation plan for the Mary River? It identifies the single most important element, which guides the way we view and manage river systems, and that is, historically and contemporarily our waterway management has been strongly influenced by our cultural attitudes. In many cases we have been blinded by our perceptions of what rivers should look like, rather than be guided by how they really function. With tens of thousands of years of indigenous habitation of this continent, scientists have not been able to find any evidence that aboriginal occupation has lead to significant geomorphological changes in rivers (Nanson and Doyle 1999). How this has changed in the last two hundred years.

Most river management has been undertaken under the paradigm that emphasises control over geomorphological and hydrological processes, and often has involved introduction of artificial elements. The works are based on a vision of a river that is predictable in its behaviour, and efficient in economic terms (Gippel 1999). As a result most research into river rehabilitation has centred on disturbance (erosion) and much less effort has gone into understanding how streams recover (Bartley and Rutherfurd 1999). Many stabilisation programs have been 'catastrophe' driven. In the Marybnong River in Victoria, Fisher (1999) found that farmers only saw the need to stabilise banks once productive land was slumping into the adjoining river. Further, negotiations to retire a riparian strip from cultivation have only succeeded in that catchment once river processes were generating economic loss.

While this project spent $1,000,000 to stabilise approximately 1000 m of severely eroded banks with single sized large rock, the majority of sites without associated riparian plantings failed (Fisher 1999).

A review of existing and proposed river management works in the Williams River catchment in the Hunter Valley concluded that the former river training works treated accelerated channel instability by addressing the problem on a site-by-site basis with largely structural works. As a result, there were many detrimental environmental impacts on the channel and the riparian zone (Erskine and Webb 1999). They reported that a pre-occupation with the large-scale removal of vegetation and large woody debris from channels was apparent in the works program that aimed to establish stable banks on a suitable alignment with an adequate waterway free from obstructions. Eskine and Webb (1999) suggest that this is easily understood when it is realised that river training evolved from flood mitigation. This history has resulted in short-term flood mitigation benefits being disproportionately weighted at the expense of longer-term biogeomorphic and ecological detriment.

The Hunter, like many catchments across the continent has suffered from poor river "improvement" work practices including:

- the extensive removal of gravel armour layers, and boulder and log steps resulting in the initiation of bed degradation;
- wholesale loss of pools by degradation and the removal by bulldozing of boulder and log steps;
- excessive removal of large woody debris and trees;
- planting of enormous quantities of exotic trees;
- extensive dozing of channels to remove bars, particularly mid channel bars; and
- lack of consideration of the needs of fish and riparian vegetation (Erskine and Webb 1999);

Considerable scientific and popular debate has occurred regarding the appropriate process for assessing environmental flow requirements and the realistic restoration targets for the river.

1.2 The Evolving Paradigm - An Australian River Character?

It is still asserted that many contemporary river management strategies have tended to repeat the mistakes of the past in that they:

- have an overemphasis on river stability at the expense of ecological needs;
- concentrate on channel forms, with limited appreciation of biophysical processes on floodplains;
- incorporate only a limited sense of 'off-site' impacts;
- are hindered by a lack of affective auditing procedures;
- have an inherent bias towards the need for river rehabilitation rather than a concern for river conservation (Rutherfurd, Jerie and Marsh 1999);
- have concentrated on site specific issues rather than a reach based understanding;
- feature reactive responses to degradation as opposed to proactive planning for river integrity;
- use traditional European or North American based engineering techniques, rather than biophysical approaches based on Australia's distinctive stream processes.

Breen et al. (1999) argue that our focus on physical stabilising works has lead us to accept the "Field of Dreams" hypothesis. The hypothesis plays on the concept espoused by Kevin Costner in the popular movie of the same title, where the character builds a base ball field in the middle of the cornfield on the assumption that it will attract great, but deceased players to make a comeback. He proudly proclaims that *"Build it and they will come!"*. The hypothesis as applied to river restoration goes like this:

- human disturbance of fluvial systems reduces the natural geomorphic complexity of streams;
- geomorphic complexity is important as highly structured habitats with heterogeneous physical structure, tend to contain more species than simply structured ones; and
- therefore, if you design physical river rehabilitation works which increase geomorphic complexity you will attract back an increased abundance and diversity of organisms.

The only problem with the hypothesis is that when Breen put it to the test in the waterways around Melbourne he found it did not predict the recovery pathways of the ecosystems subject to works (Breen et al. 1999). Impacts on the waterway from the broader catchment outweighed the benefits flowing from the physical restoration works.

Considerable research has been carried out describing the impacts of disturbance on stream geomorphology, yet few studies have investigated the subsequent recovery of streams. An ability to determine the time scales of recovery will be extremely useful for prioritising stream rehabilitation (Bartley and Rutherfurd 1999). To assess the river condition and likely pathways for recovery, primary research into river evolution, including analysis of controls on river behaviour, must be undertaken. Such assessment needs to identify the relative influence of human impacts as discerned from natural process variability (Brierley 1999).

As rivers are dynamic, river management procedures based on static appraisals of river condition are of limited application. Analysis of form without an appreciation of processes, will not yield sustainable river rehabilitation practices (Brierley 1999). Management efforts need to move beyond site specific reactive strategies, to catchment-framed proactive works. The character and behaviour of individual river styles, and their downstream pattern (including channel geometry and vegetation associations), provide an appropriate biophysical framework with which to develop river rehabilitation schemes (Newbury and Gaboury 1993 (a); Brierley 1999).

"*If we wish to maintain a truly Australian river character, with naturally adapted flora and fauna, our target conditions for river management must replicate the natural variability in river structure and flow inherent in the Australian landscape. Hence, effective management is contingent on improving our knowledge of geomorphological interactions with ecological functioning in aquatic ecosystems*" (Brierley 1999).

1.3 But What Should We Aim For?

If we are moving from a predictable and economically efficient vision for our rivers where are we heading? A currently fashionable vision is one that restores the condition of the stream to that which existed prior to significant disturbance by humans (Gippel 1999). But is this realistic?

Brooks' work (1999a) in the Cann has revealed that over the last 100 years, and particularly the last 30 years, Cann River has increased its channel capacity by 700%, bankfull flow has increased 45 fold, sediment transport capacity has increased 1000 fold, bank stability parameters have fundamentally changed, as have form and Large Woody Debris (LWD) resistance characteristics. Flood plain sedimentology suggests that these changes are unprecedented over at least the last 26 900 years Brooks (1999a). He argues it would take at least 1500 years of accretion at prior sediment supply rates to return the channel to its former dimensions, and this is based on the implausible assumption that all the sediment is trapped within the degraded reach. If we consider realistic management time frames, rehabilitation targets for the Cann and many equally altered rivers, such as the Mary, must be set within the framework of fundamental post-European channel changes.

Before we can set realistic visions and achievable rehabilitation targets, it is important to identify lessons learnt from past mistakes, the theory which underpins our current knowledge base, and the current management strategies and techniques being promoted to address the restoration/rehabilitation of our rivers and waterways.

1.4 Overview of Project

The preparation of the river rehabilitation plan has been adopted as a priority by the Mary River Catchment Coordinating Committee (MRCCC), who have applied for funding for its implementation. The preparation of the plan has generally followed the process recommended by Rutherfurd, Jerie and Marsh (1999) that brings together scientific, management and community aspects of rehabilitation planning. The Riverbank Stabilisation Strategy Working Group of the MRCCC is acting as a project reference group with consultation through existing community groups and Councils underway.

The plan process closely follows that recommended by the recent manual for river rehabilitation developed by the Land and Water Resources Research and Development Corporation (Rutherfurd, Jerie and Marsh 1999). The theoretical and philosophical framework underpinning this process is summarised by the evocatively named "Titanic Theory". In the blockbuster Titanic they put the women and children on the lifeboats first. They prioritised where they could best expend their effort and protected the young, healthy and those that care for them.

Rutherfurd et al. (1999) believe that similar principles can be applied to planning for river restoration. They suggest a model that plans to protect the good before repairing the degraded is both financially and ecologically responsible. Their argument suggests that most of our current river rehabilitation effort is akin to loading the lifeboats of the 'Titanic' with old and sick men from the infirmary, or worse trying to raise the Titanic from the bottom of the sea while we let other intact boats crash into known icebergs.

Rehabilitation effort is frequently directed to the most degraded sites within the landscape. In river rehabilitation terms this has resulted in rehabilitation activity largely being constrained within an erosion control and stabilisation paradigm. The Mary River Rehabilitation Plan therefore advocates a primarily biophysical approach to prioritisation of rehabilitation effort, based on river reaches, geomorphic assessment of recovery potential of river and conservation status. As part of the consultation process social, economic and cultural values of the river system have also been identified and a set of secondary prioritisation rules have been developed to effect the broader principles of ecological sustainability.

2.0 DEFINING KEY ELEMENTS

While it is not possible to define all terms and concepts outlined in this work it is important to outline the meaning of some key elements. We may think that terms such as rivers are universally understood yet Thomas has challenged the common understanding of the term when he stated: "*Floodplains and rivers are all part of the one system, because the floodplain is the bed of the river when it floods*" (cited in Anon 1999).

The terms ***river*** and ***stream*** will be used to describe an open permanently or intermittently flowing channel and its boundaries. The boundaries of a river are generally termed the ***riparian zone*** and include the structural formation and vegetation of the banks of the river at least to the bankfull flood height. It generally includes a further vegetated 'buffer' back from the top of the high bank, but the definition of its maximum extent is subject to popular and scientific debate. Lovett (1998, pp.3) adopts a simple functional definition which identifies 'any land which adjoins, directly influences, or is influenced by a body of water' as part of the riparian zone.

A river can be divided into ***reaches,*** which are homogeneous units within which the controlling factors do not change appreciably. A newer concept is that of defining ***Riverstyles*** $_{TM}$, which are classes of reaches which in their natural state represent sections of a river system which display similar and distinct character and behaviour (Brierley 1999). The width and shape of a river's valley, channel slope and stream power are fundamental, direct controls on river style. The fundamental ***control*** on Riverstyles $_{TM}$ on a catchment-scale is the landscape unit. Landscape units reflect the underlying geological controls, which include lithological controls (variation in rock type) and structural controls (influence of faults and folds) (Ferguson 1999). Within this plan the term ***Reach*** is used to define discrete management sections of similar geomorphic character, along the lines of a Riverstyle $_{TM}$ as depicted in Figure 2.1. The various names used are determined by referencing the Reach Naming Tree (Figure 2.2). Where appropriate, isolated sections of the river which remain in good condition within an otherwise degraded ***Reach*** are considered to be an ***Asset*** and identified as ***Remnant Management Sections***. An **Asset** for the purposes of this plan is any aspect of the stream that is considered good enough condition to meet the goals of the plan.

The morphology of a stream is determined by several factors including:

- ***Flow variability,*** which is generally a function of channel shape. Specific flow types produce specific morphological forms and vice versa. The more variable the channel morphology the more varied the flow types for a given reach (Bartley and Rutherfurd 1999)
- ***Substrate composition,*** which is a measure of grain size variation. Grain size is considered an essential variable to the distribution and abundance of organisms (Bartley and Rutherfurd 1999).
- ***Suspended load*** in rivers is that portion of the load borne by the upward momentum or flux of momentum in turbulent eddies in the flow (Leopold et al. 1964).
- ***Bed load*** applies to the sediment that moves by sliding, rolling, or saltating on or very near the bed (Leopold et al. 1964).
- ***Wash load***, which, because of its fine size has such a small settling velocity, is held in suspension as colloidal particles (Leopold et al. 1964).

As discussed earlier, complex stream morphology and the hydraulic environment is often considered to be one of the primary targets of stream rehabilitation. In this respect the broader term ***geomorphic complexity*** is used to describe the variation in channel shape, flow variability, substrate composition and vegetation characteristics of a channel (Bartley and Rutherfurd 1999).

Restoration ecology often grapples with the precise meaning of the terms restoration and rehabilitation of a degraded ecosystem. A ***degraded stream*** is defined as any stream that is not functioning at it's hydrologic or biologic potential. ***Restoration*** of such a stream involves returning it to its previously undisturbed condition by reconstructing the structure and function of the pre-disturbance ecosystem. ***Reclamation*** is another approach that aims to achieve a similar, but not identical, end point by re-establishing an ecosystem that develops along the original successional pathway so that it assumes a similar function and composition of the original ecosystem. ***Rehabilitation*** of the stream on the other hand, involves the enhancement of ecological functioning of the system on a recovery pathway toward an improved target condition.

Figure 2.1
Scale of Catchment Geomorphology
Source: "An Introduction to Fluvial Geomorphology"
Gary Brierley and Kirstie Fryirs

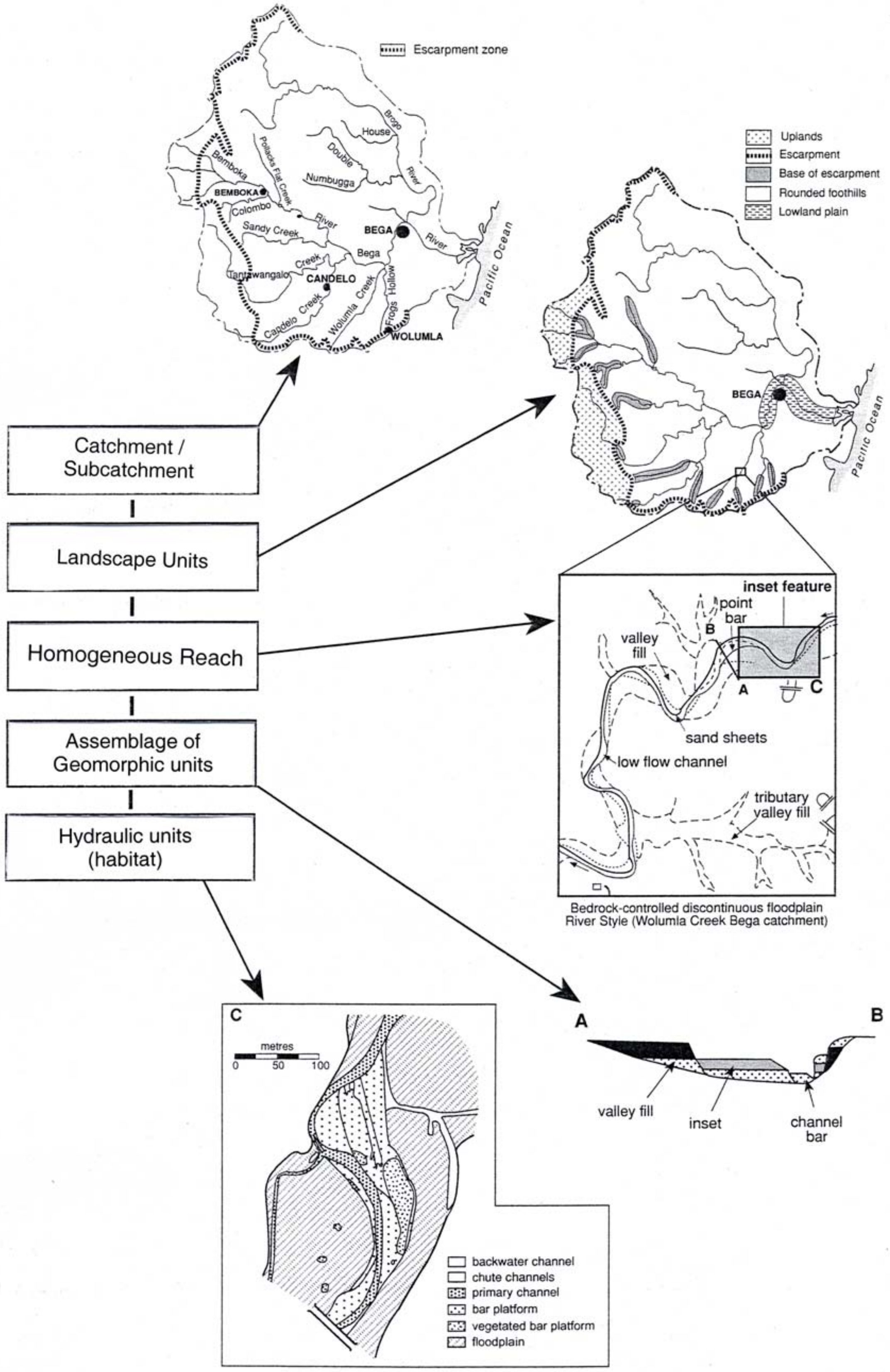
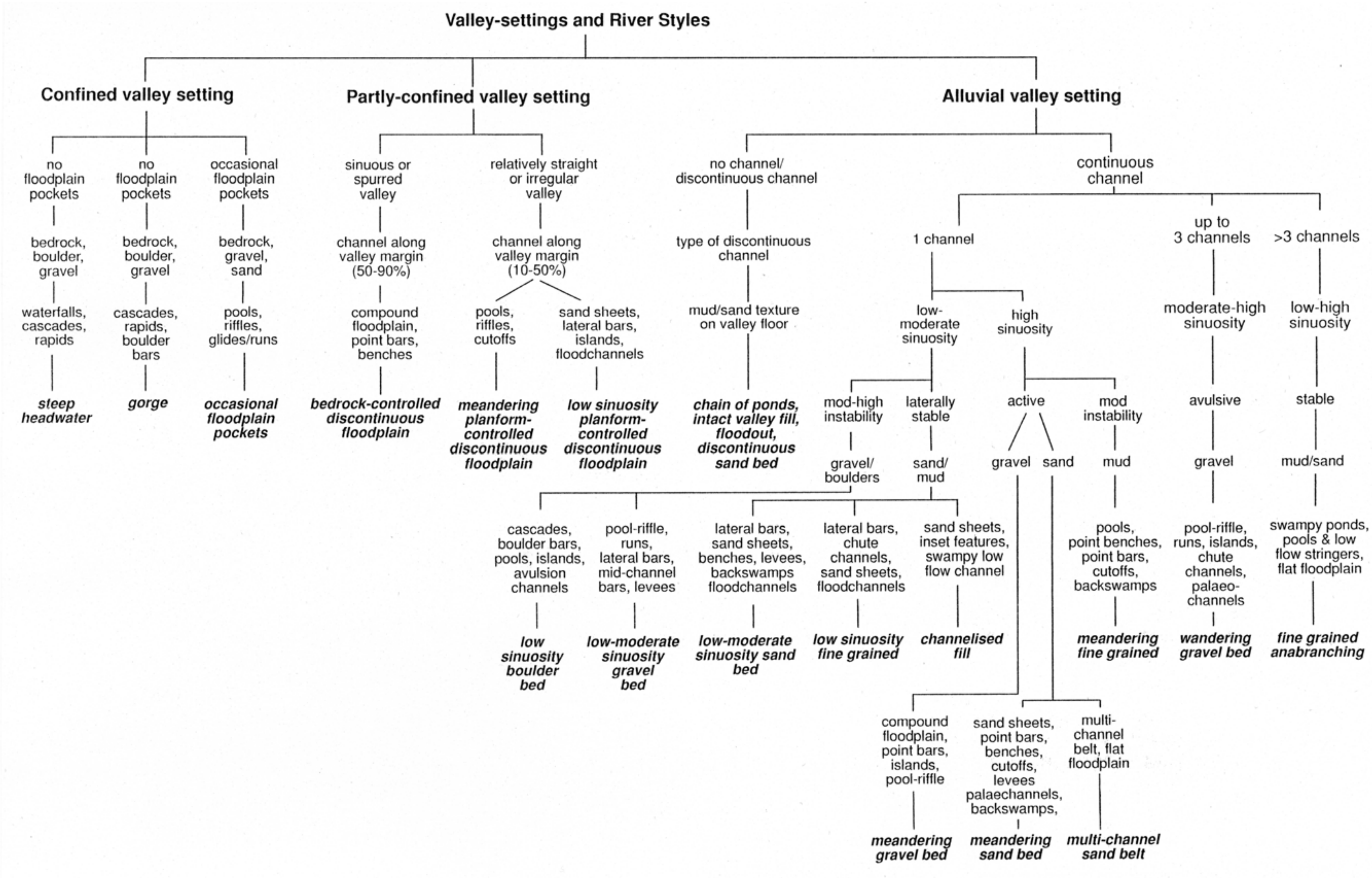


Figure 2.2
Reach Naming Tree
Source: "An Introduction to the Riverstyles TM Framework"
Gary Brierley and Kirstie Fryirs



The recovery pathway in rehabilitation will be on a similar trend to that of restoration but with a different end point that is likely to feature an altered species composition. ***Stabilisation,*** on the other hand, which is a type of ***remediation,*** aims to establish a stream condition that maintains its dimension, pattern and profile, such that over time it neither aggrades nor degrades (Jennings and Harman 1999 - Figure 2.3)

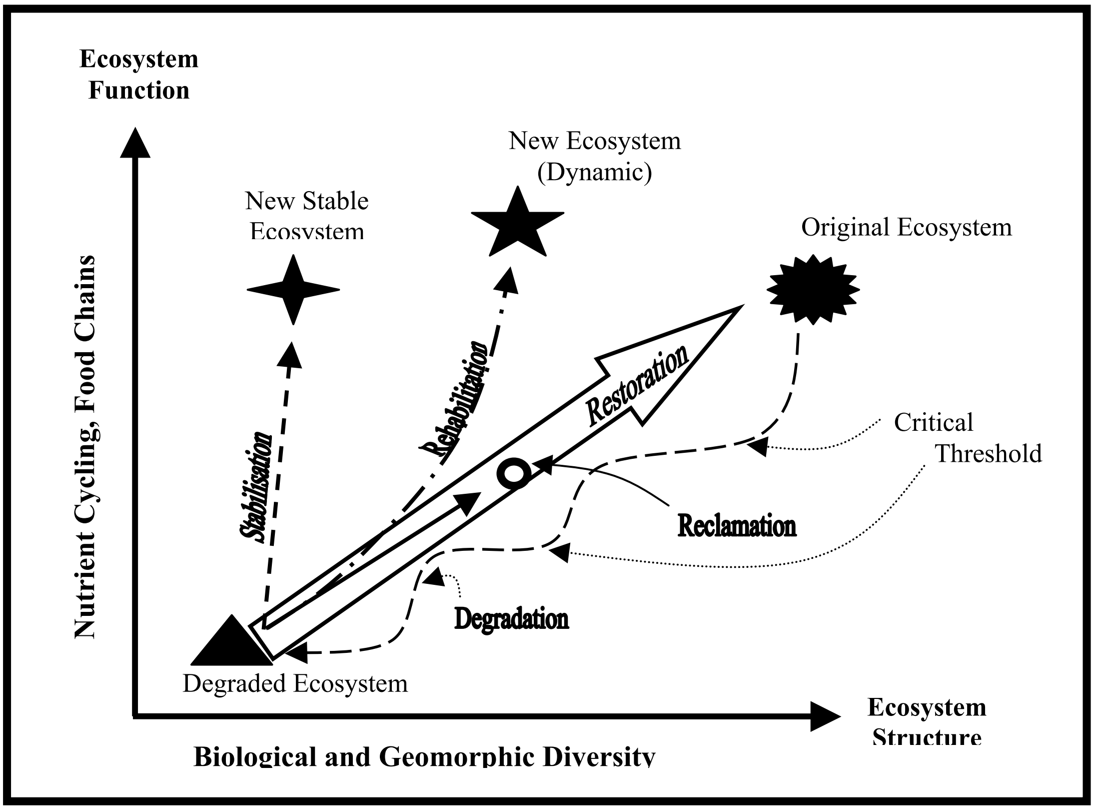


Figure 2.3 Schematic of Rehabilitation - Restoration
The differences between restoration, rehabilitation, and remediation
(adapted from Breen et al. 1999 and Bradshaw 1987).

Channel scour and ***fill*** are terms used to define bed cutting and sedimentation during relatively short periods of time, whereas the terms ***degradation*** and ***aggradation*** apply to similar processes over a longer period of time (Leopold et al. 1964). The incision of the channel can lead to ***head cuts*** or ***nickpoints*** which, similar to gully erosion on land, can migrate back upstream as the bed endeavours to regrade to a slope which is in equilibrium with new hydraulic and geomorphic conditions. Streambank instability can be broadly classified into two categories; that caused by fluvial activity and that which is a result of mass movement (Figure 2.4 - Kapitzke et al. 1998). ***Fluvial erosion*** is the direct removal of soil by the forces exerted by moving water and is closely linked to the process of sediment transport and deposition. ***Mass movement*** (slumping) is the bulk movement of material, generally as a result of decreased material strength or, in some cases, increased loading on the streambank.

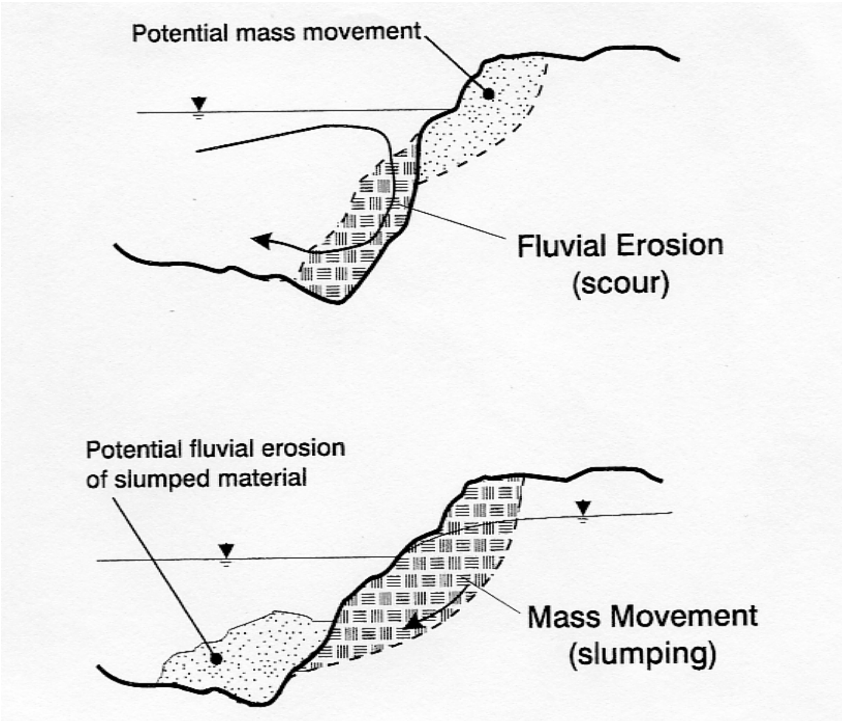


Figure 2.4 Fluvial erosion, mass movement and their interrelationships
(Source: Kapitzke et al. 1998).

Different reaches of rivers can have varying recovery potentials. ***Recovery potential*** is defined as the capacity of a river reach to attain a suitable river structure and function for the position it occupies in the catchment, and the boundary conditions under which it operates. Assessment of recovery potential can be used to assess how far away from this structure and function differing reaches of river are, and the 'idealised' condition can be used as a target condition for management efforts at river rehabilitation (Brierley 1999). The premise is that those sections of the catchment displaying high recovery potential have the greatest likelihood of rehabilitation success. By understanding the processes and structures of the river reach under consideration, appropriate strategies can be used to attain the target condition. Once attained, sustainable ecological and geomorphological conditions result (Fryirs 1999).

A substantial review of river processes, fluvial geomorphology and ecological concepts and their application to a river rehabilitation plan is available as an Appendix to this plan. This review outlines the underlying research and current theory upon which this plan is based.

3.0 METHODS TO DEVELOP THE MARY RIVER REHABILITATION PLAN

The overall method used in the development of this plan is summarised in Table 3.1. Only small adaptions were made to the recommendations of Land and Water Australia's manual for river rehabilitation. It provides a holistic approach to whole of catchment planning for waterway rehabilitation. Technical and community consultation processes ran in parallel, with each step informing the next. The full consultation process is outlined in Figure 3.1.

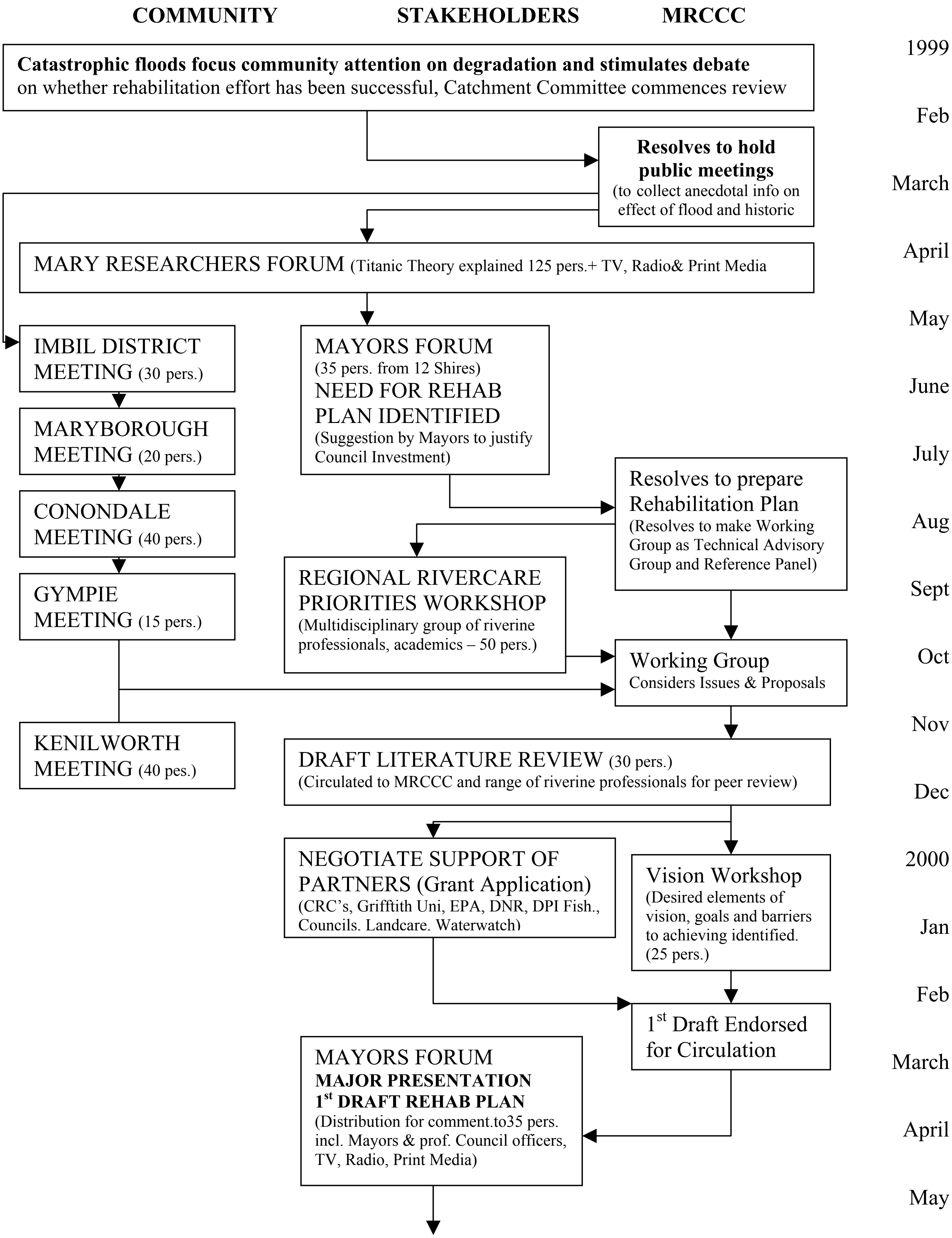
3.1 Goal Setting

Seven years of Integrated Catchment Management activities in the catchment had resulted in a body of data being available from community consultation. Previously stated goals and objectives for river rehabilitation in the Mary were compiled and analysed. Subsequently a vision workshop was conducted with the MRCCC that allowed them to identify elements of a 10 and 50 year vision for the river and its tributaries and the barriers to achieving this vision. An invitation was circulated to approximately 100 members of Landcare, industry and community groups, Councils and State Government officers to nominate their own elements of this vision. Suggestions and ideas from this process were collated, and major themes reworked into draft vision and goal statements. These statements were further discussed and refined with the project reference group and broader public input into the visioning process was conducted with suggestions and comments considered by the MRCCC.

This process resulted in the;

1. A concise Life Time Vision – for everyone to strive for in their lifetime.
2. A set of sustainability indicators – which can be used to evaluate achievement of attributes related to the vision.
3. A set of concise 10 year goals.
4. Sustainability indicators for each goal.

CONSULTATION PROCESS FLOWCHART
(STAGE 1 – From Conception to First Draft)



CONSULTATION PROCESS FLOWCHART
(STAGE 2 – From First Draft to Implementation)

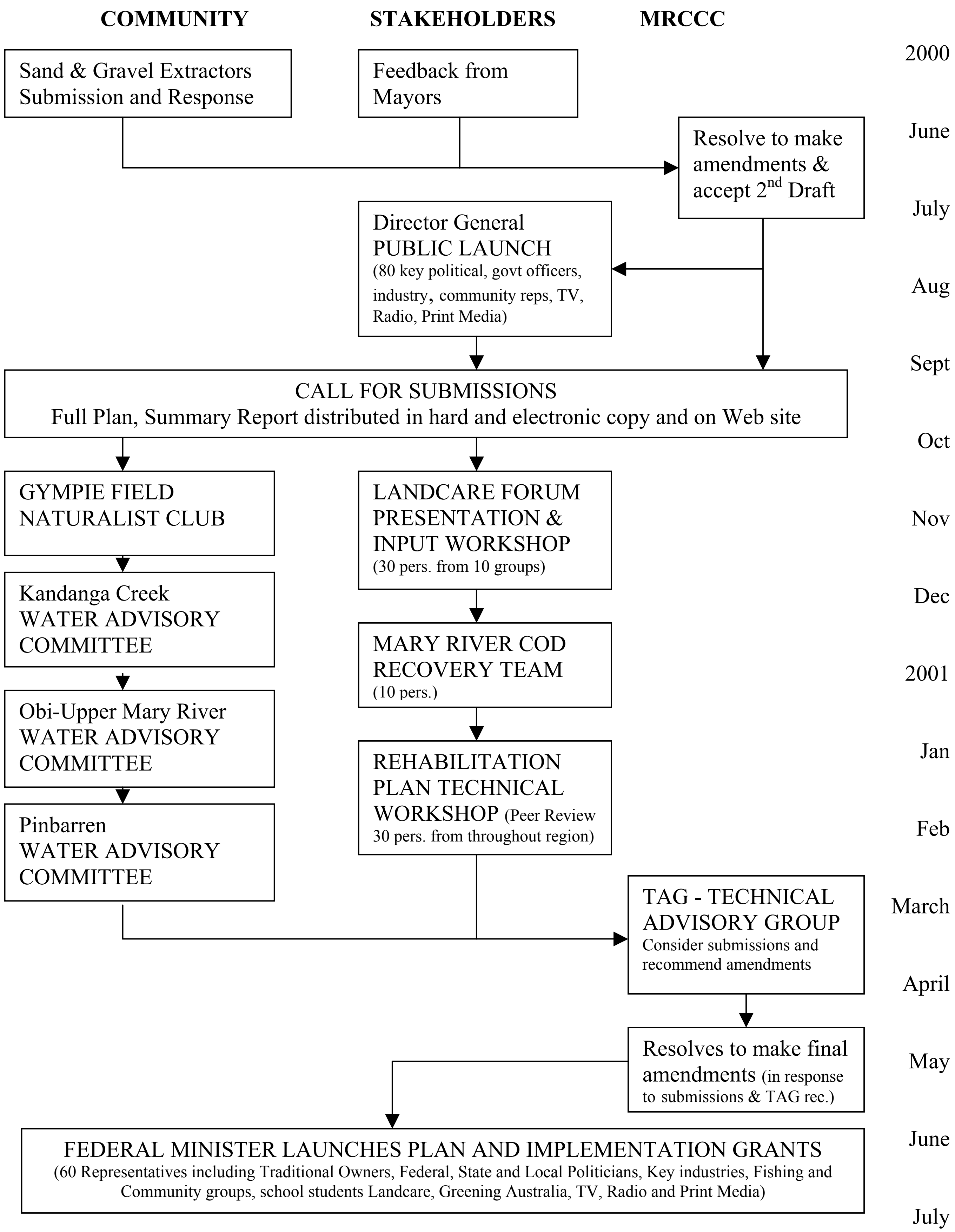


TABLE 3.1

Methods Used in Developing This Plan

Recommended Elements/Steps in Models	Brierley 1999	Rutherfurd, Jerie and Marsh 1999	Used in this Plan
Set goals and vision for rehabilitating of your stream.		X	X
Do other people share your vision of an ecologically rehabilitated stream?		X	X
Baseline survey of catchment boundaries, topographic and geological maps, sketch long profiles, identify discontinuities.	X		X
Baseline Survey of river character and behaviour: Classification of (geomorphologically homogeneous) reaches.	X	X	X
Assessment of river condition, framed in terms of river evolution and recovery potential following disturbance.	X	X	X
Catchment Audit -What are your stream's main assets and problems? - biophysical and cultural characteristics to evaluate linkages between catchment processes and river instability.	X	X	X
Historical Analysis - to establish and understand links between catchment controls, local factors and river channel changes and to determine whether the pre-disturbance channel form can be reinstated or a different morphology designed because of altered catchment conditions.		X	X
Identify relevant utilities that are affected by the problems.			X
Setting priority reaches- which reaches and problems should you work on first, considering conservation, ecological and recovery trends in selecting reaches (as opposed to focusing on erosion control and stabilisation).	X	X	X
Identification of reference reaches (relatively natural channel that is to provide a rehabilitation template).	X	X	X
Create detailed, specific and measurable objectives that will be the core of your stream rehabilitation plan.		X	X
Develop strategies to protect natural assets and improve your stream - identify and list the things that you can do to protect and improve the important natural assets in the reaches that you identified as a high priority in the last step.		X	X
Integrate Hydraulics, Hydrology, Geomorphology and Ecology - create a Multi-functional team; community consultation and ownership is essential.		X	X
Test feasibility of objectives - many factors, such as cost, politics, and undesirable consequences for other users of the stream, may require alteration of priorities.		X	X
Develop assessment criteria to evaluate project - measurable becomes the basis for evaluating the project.		X	X
Monitoring and Auditing		X	X

3.2 Describing Changes Since European Settlement

A review of literature relating to Mary catchment was undertaken, including previous archaeological, historical, environmental and social investigations. This review provided baseline information from which to assess the current condition of the catchment. While limited time was available for historical research, analysis involved collecting data from previously compiled histories, cross-sections; historic aerial photography; and local interviews. In addition a series of four public meetings were held along the river between Conondale and Maryborough, following the February 1999 flood at which anecdotal accounts of river changes within living memory were noted. Without the constraints of time and resource more historical research would have been justified and may occur during the consultation period.

A "*riverstyles*" type approach (s 1.2, Brierley, 1999) was initially used to divide streams into segments of similar geomorphological and behavioural characteristics. Field inspection to fine-tune these draft style boundaries included assessment of pressures, biota and habitat with data recorded on a combination of field sheets developed by Chessman (1999) and Choy (1997).

Data was collected on:

- longitudinal profile and cross sections;
- flow regime and velocity;
- structural complexity and substrate type;
- bed and bank stability;
- large woody debris abundance,
- macrophyte abundance;
- water quality and diagnostic physico-chemical indicators;
- macroinvertebrate communities;
- riparian vegetation condition and structure;
- floodplain interconnectivity; and
- adjacent land use.

Analysis of this data enabled river styles/segments to be divided into homogeneous reaches of similar biophysical condition and conservation integrity. The method of scoring and ranking condition is contained in Table 3.2.

Insufficient time and resources were available to undertake a complete survey of the waterways of the catchment. Quantitative, and semi-quantitative data was obtained from a range of unpublished data from previous surveys to identify attributes of reference reaches and conditions in the catchment generally to gain a more complete appreciation of relevant parameters (Pers Comm. Electronic copy of data e-mailed from- DNR–Water Quality Team 2000 , DNR – Hydrographic Section 1999, DNR – Forest Services, Dudgeon and Stockwell – DNR, 1999, Mark Kennard - Griffith University, 2000). Ground truthing revealed that mapping generated from continuous recording of in-stream Mary River Cod habitat and ordinal ranking of riparian condition by Pickersgill (1997) over approx. 380 km of river and streams was both reliable and useful in terms of describing overall condition.

Ground truthing of the State of the Rivers Report mapping (Johnson, 1997) produced from the qualitative Anderson method revealed a number of consistent problems with classification and reliability. The latter data was therefore only used as a fall back where streams could not be sampled, due to access constraints, time or resource limitations.

On the main river channel survey work was conducted using a dumpy level, 100m tape and staff. With rough profiles and cross sections in tributaries drawn from clinometer readings, tape and foot traverse. A calibrated 'Horiba U-10 Water Quality Checker' was used to test for the parameters of pH, Temperature, Conductivity, Dissolved Oxygen and turbidity. Macroinvertebrate sampling followed the AusRivAS protocol with 10 m kick samples (and five rocks of various sizes in riffle zones) taken from two different habitat types (if available) at each sampled reach. Specimens were live picked for 30 minutes and placed in 80% methylated spirits for transport to the laboratory for identification. Hawking and Smith's (1997) taxanomic guide was utilised to identify invertebrates to a family level and ascertain their functional feeder groups. SIGNAL pollution sensitivity scores were calculated according to Chessman (1995, 1997).

TABLE 3.2
BIOPHYSICAL CONDITION

Waterway Attribute	Green Rating Good Condition Score - 0	Yellow Rating Minor Disturbance Score - 1	Pink Rating Moderate Disturbance Score - 3	Red Rating Major Disturbance Score - 5	Score
GEOMORPHOLOGY					
a. Bed Material Character	Character consistent with location in catchment. Stones are clear with no sediment smothering.	Partial sediment veneers or slight reduction in expected bed material character considering position in catchment, geology and topography.	Evidence of moderate disturbance in character of sediments as a result of sedimentation, scouring or stripping.	Evidence of significant overrepresentation of one sediment size eg. dense sediment veneer, or overlarge particle size for positioning catchment.	
b. Instream Geomorphic Diversity	Abundant LWD pools, riffles, bank overhangs, rock ledges and tree roots in water consistent with position in catchment.	Minor disturbance of instream features eg. LWD common but not abundant, reduction in trailing vegetation etc.	Moderate disturbance of features eg. only occasional LWD, tree roots in water, bank overhangs and alteration of stream controls	Major or complete disturbance eg. channelisation, no LWD present, removal of all vegetation features acting as geomorphic features	
c. Floodplain Connectivity	Floodplain (where present) has no artificial drainage or levee.	Landscape alteration has created minor discontinuity between channel and wetlands.	Artificially drained floodplain, eg. significant filling of off-stream wetlands.	Artificially leveed floodplain, eg. flood mitigation works, or increased volume due to channelisation.	
d. Hydrologic Regime / Hydraulic Influences	No or very limited (eg. camp grounds) abstraction of water from waterways.	Minor unregulated abstraction, with or without minor farm weirs, which divert flow	Extensive abstraction and/or large weirs, which alter flow regimes.	Major dams or significant regulation of flows causing significant impacts.	
e. Bed Stability	Bed stabilised by abundant LWD, and / or rock, vegetated point bar, riffles etc. consistent with location in catchment, no evident degradation.	Some evidence of minor instability due to factors such as LWD removal, altered hydraulic, regime, increased stream power. Patchy scour and fill, but mostly stable features.	Historic Incision and minor current instability, eg. sediment deficit or moderate infilling eg. sand slugs. Partly shifting sand / head cuts, unvegetated bars.	Extensive bed instability / lowering evident over long periods of time. Eg. low flow channel wandering between banks, riffle migration, large shifts in sand etc.	
Sub – Total A	**Sum of two highest scores for criteria a. to e.**				
RIPARIAN ZONE					
f. Vegetation Structure and Condition	Native vegetation on verge and bank with intact canopy, mid and lower strata for majority of reach.	Overstorey of native vegetation on bank and verge with some disturbance in mid and lower strata for majority of reach.	Riparian vegetation significantly disturbed with removal of whole strata, verge vegetation or significant weed growth.	No native bank or verge vegetation for the majority of the reach with invasion of grasses and/or weeds.	
g. Bank Stability	Only isolated minor disturbance consistent with natural levels of accretion and deposition.	Occasional to common minor erosion and / or only isolated moderate erosion.	Frequent moderate disturbance - occasional major disturbance.	Frequent Major erosion and or abundant moderate disturbance along reach.	
h. Land Use Influences	Largely intact forested subcatchment with managed access to waterways with minimal or no evidence of impacts on waterways.	Mainly Extensive agricultural land use with reasonable riparian buffers or more intensive land use with good riparian buffers.	Evidence of moderate impacts from poorly managed stock access or poorly buffered intensive land uses.	Major riparian impacts from adjoining land use as a result of active clearing / development or intensive rural activities within zone.	
i. Canopy Cover	Intact Riparian vegetation provides optimum canopy cover for position in catchment	Minor loss of canopy cover results in increased lighting / heating of waterway.	Moderate canopy disturbance significantly disturbs ecosystem values in stream	Almost complete loss of canopy cover leading to major instream disturbance.	
Sub-Total B	**Sum of two highest scores for criteria f. to i.**				

Table 3.2 continued					
Waterway Attribute	**Green Rating Good Condition Score - 0**	**Yellow Rating Minor Disturbance Score - 1**	**Pink Rating Moderate Disturbance Score - 3**	**Red Rating Major Disturbance Score - 5**	**Score**
WATER QUALITY					
j. Physico-Chemical Properties	All Physical/Chemical properties comply with ANZECC Guidelines <800 Ec DO>85 and<110% <5 NTU Chl a <2ug/l	Minor changes in water quality evident 800-1500 Ec DO 75-75% or 110-115% 5-25 NTU Chl a 3-5 ug/l	Moderate changes in water quality 1500-8000Ec DO75-85% or 115-120% 26-50 NTU Chl a 6-10 ug/l	Major sustained pollution / sediment / salinity problems >8000 Ec DO<65% or >120% >50NTU Chl a >10 ug/l	
k. Macro-invertebrate Indicators	SIGNAL Score >6 Family # >12 PET Richness 6or > Or O/E 0.88-1.13	SIGNAL Score 5-6 Family # 10-12 PET Richness 4,5 Or O/E 0.63-0.87	SIGNAL Score 4-5 Family # 6-9 PET Richness 3 Or O/E 0.38-0.62	SIGNAL Score <4 Family # <6 PET Richness <3 Or O/E <0.38	
l. Algal Populations and Distribution	Algae present or absent on substrate and in water column as would be expected for position in catchment.	Minor occurrence of enhanced algal growth on substrate and/or in water column.	Moderate occurrence of enhanced algal growth on substrate and/ or in water column.	Excessive algal growth eg. eutrophic conditions, blue green algae outbreak etc.	
m. Physical Attributes	Odour of water and sediments is normal, there is no unusual foaming or plumes.	Minor disturbance evident with small areas of surface scums, anaerobic sediments.	Moderate deterioration of physical attributes eg. chemical or organic pollution or odours in water suggesting anaerobic conditions or contamination.	Major deterioration of physical attributes evident. Eg. anoxic odours in sediment / water, significant petroleum, chemical plumes or sheens on water surface, profuse oils in sediment.	
Sub-Total C	**Sum of two highest scores for criteria j. to m.**				
INSTREAM HABITAT					
n. Macrophyte Richness and Abundance	Macrophyte diversity, abundance and distribution consistent with intact condition for positioning catchment.	Minor changes in the diversity, abundance or distribution, eg. minor invasion of exotics.	Moderate changes to the diversity, abundance or distribution significantly altering available habitat.	Major changes to macrophyte assemblage resulting in almost complete alteration of habitat.	
o. Fish Species Richness	Abundant native fish present as would be expected for position in catchment, no exotic species present.	Abundant native fish species present but minor changes to assemblage due to exotics or habitat loss.	Moderate changes to fish assemblage due to significant habitat loss, fish barriers, hydraulic changes exotic species.	Major changes to fish assemblage, exotic fish dominate due to change habitat, hydraulic or fish passage.	
p. Large Woody Debris Abundance	Abundant large woody debris of size and species reflecting intact conditions.	Common large woody debris with evidence of only minor disturbance to composition.	Only occasional large woody debris and/or moderate disturbance to the size and species composition.	No large woody debris, through historic removal, riparian clearing removing source etc.	
q. Bank Overhang	Ample, relatively stable bank overhangs consistent with position in catchment.	Good sections of bank overhang with only minor impacts or threats from changes to vegetation or soil movement.	Only small areas of stable bank overhang, with loss of edge vegetation and active soil movement threatening habitat.	No bank overhang due to removal of binding vegetation, erosion, infilling etc.	
Sub-Total D	**Sum of two highest scores for criteria n. to q.**				
TOTAL SCORE	**Sum of Sub-Totals A+B+C+D**				

3.3 Identification of Assets and Problems

Assets, and problems that are degrading those assets, were identified by comparison of the current condition against reference reaches. At this stage the value of an asset needed to be determined in order to develop the prioritisation framework discussed below. Based on the sustainability and biodiversity principles that drive this rehabilitation plan it was necessary to determine the known reaches/localities of conservation significance. This entailed compiling:

- distributional data on rare, endangered, threatened, or listed species within aquatic, riparian and floodplain habitats;
- existing and proposed (under Regional Forest Agreement) protected areas;
- 'of concern' regional ecosystems that have a linkage with riverine ecosystems;
- known remnants of high integrity on private lands; and
- valuable features within the riverine system;
- in addition to analysis of data from stream surveys.

Despite numerous studies there appears to be no previous attempt to classify/prioritise the natural assets of catchments, rivers and streams in South East Queensland from either a State or regional perspective. In order to provide some regional overview for the rarity and conservation status of sub-catchments within the Mary a regional workshop involving approximately 50 river management professionals, technical officers, environmental scientists, aquatic ecologists, fish biologists and catchment management representatives was facilitated to develop a draft set of regional 'Rivercare' priorities.

After identifying assets and their relative value, threatening or degrading processes that impacted upon them were identified. Once potential causation was established the trajectory (degrading – recovering) of the assets and problems was assessed using records of physical and biological indicators obtained during survey work (refer to Table 3.3). Where GIS coverage existed, assets and problems were mapped, otherwise data was recorded on reach summary sheets.

TABLE 3.3
DETERMINATION OF TRAJECTORY

CHARACTERISTIC	ATTRIBUTES	TRAJECTORY
CHANNEL	Channel naturally reprofiling, bench forming, bed lowering being infilled, rehabilitation effort working , point bars and islands being stabilised by vegetation	**Recovering**
	Active bed instability/lowering, head cuts migrating through system, mobile bars and islands sediment veneer increasing, LWD reducing.	**Degrading**
RIPARIAN ZONE	Any erosion being stabilised by rock, vegetation or LWD or rehabilitation effort working, effective stock &/or property management combined with local seed source facilitating regeneration of native species	**Recovering**
	Active soil movement, slipping or slumping, not being stabilised by rock vegetation or LWD. No or ineffective stock exclusion or active horticultural use of riparian zone or verge. Regeneration or species diversification is mainly of alien species	**Degrading**
IN-STREAM	Point source pollution treatment is being upgraded to tertiary standard, diffuse sources are being actively managed. Conservation assets are being protected or voluntarily conserved. Clearing and development phase has ended or best practice sediment and erosion controlled implemented.	**Recovering**
	Point source or diffuse pollution sources continue to reduce in-stream values. Clearing, development and landuse threaten in-stream values.	**Degrading**

3.4 Setting Priorities

Homogeneous reaches and isolated remnant management sections were identified according to the above process and then assigned to 7 categories. The reach prioritisation generated is based on a combination of the classifications proposed by Rutherfurd et al. (1990) and Brierely (1999 - Table 3.4). The process has involved setting priorities taking into account the following features:

- rarity (rare before common);
- condition (good before bad);
- trajectory (degrading before recovering); and
- ease to fix (easy before hard).

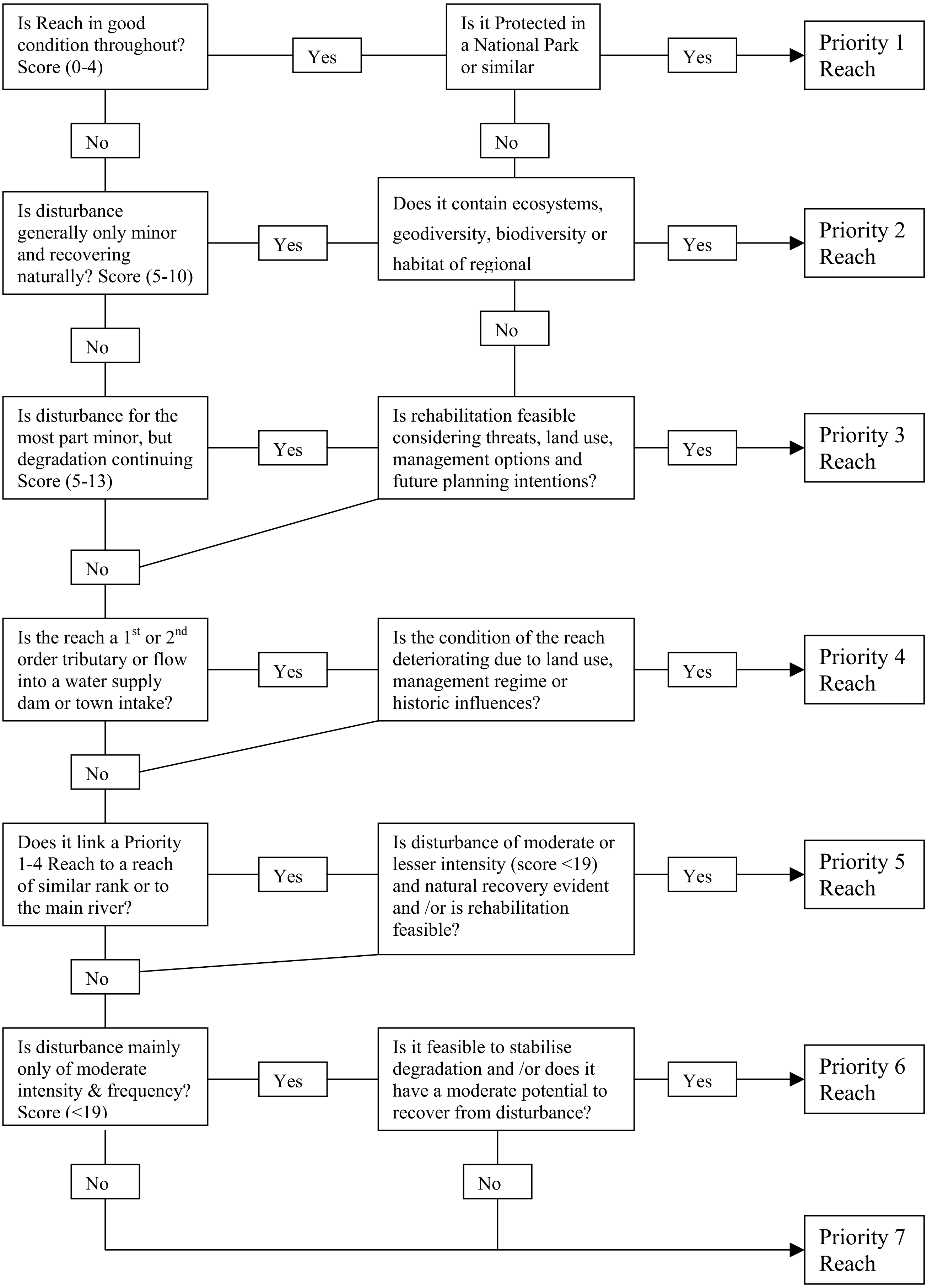
Condition ratings derived from criteria in Table 3.2 were used in conjunction with assessments of conservation status, trajectory and recovery potential to categorise reaches using the principles set out in the Reach Prioritisation Decision Tree (Figure 3.2). Problems were also prioritised within each reach. Assessments as to what the problem causing degradation and what problems are impeding the recovery of the system were made. A hierarchy of problems was developed based on the importance of the problem to ecological functioning of the reach along a continuum from fatal to nuisance problems. The prioritisation conducted as part of this study is incomplete. A tour by an expert panel consisting of aquatic ecologists, fish biologists, riparian botanist, fluvial geomorphologist, water quality scientist and a restoration ecologist has been undertaken and upon receipt of their report a review of both the style boundaries / homogeneous reaches and the recommended priority given to them will be undertaken.

TABLE 3.4
REACH PRIORITISATION FRAMEWORK

Rutherfurd et al (1999) Model	Brierley (1999) Model	Used in this Plan
Reaches in good condition throughout, that are already protected.	**Conservation reaches -** least disturbed - require strategies to maintain	**Protected Reaches in good condition throughout**
Protecting Regional Conservation Value Reaches - The highest priority is to preserve those reaches with assets that are important nationally or regionally.		**Unprotected Reaches of Regional Conservation Significance**
Protecting Local Conservation Value - These are reaches in such good condition that they can be considered to be surviving remnants of the original stream (a possible template reach) - unlike the above they are common in the region.		**Reaches of Local Conservation Value**
Protecting and improving deteriorating reaches. Some reaches are already damaged but their condition is continuing to deteriorate.	**Strategic Reaches -** sensitive to disturbance and may trigger off-site impacts - pre-emptive management strategies	**Deteriorating Strategic Reaches**
Improve close reaches expanding an area in good condition, rather than trying to create a new island of improved stream amongst degraded reaches.	**Connected reaches with high recovery potential -** signs of natural recovery **Isolated reaches with high recovery potential**	**Linking Reaches and Significant Remnant Sections**
Improve impeded recovery reaches (easily fixed reaches) - These are reaches in poor but stable condition (ie although degraded their condition is not deteriorating).		
Improve moderately damaged reaches (more difficult to fix) - these reaches that are damaged by human impact, have good potential to recover at reasonable cost.	**Moderate recovery potential -** river structure and vegetation require improvement	**Reaches with Moderate Recovery Potential**
Improve basket-case reaches These are reaches that are in poor condition, that do not threaten other reaches, but have little chance of recovering themselves over time.	**Highly degraded reaches -** Little natural recovery potential - signs of continued degradation, such as accelerated sedimentation or erosion	
Improve basket-case reaches with hope. These are reaches that are in very poor condition, that do not threaten other reaches, but that have some chance of recovering themselves with time.		**Reaches with Little Chance of Natural Recovery**

Figure 3.2

REACH PRIORITISATION DECISION TREE
Conservation Status, Trajectory and Recovery Potential



A Social Prioritisation Matrix has been developed as a result of submissions made to the draft plan and recommendations of a multidisciplinary technical advisory group. The key elements of this framework are presented in Table 3.5 below and provide a secondary mechanisms for ranking projects seeking to implement the plan.

TABLE 3.5

SOCIAL PRIORITISATION MATRIX

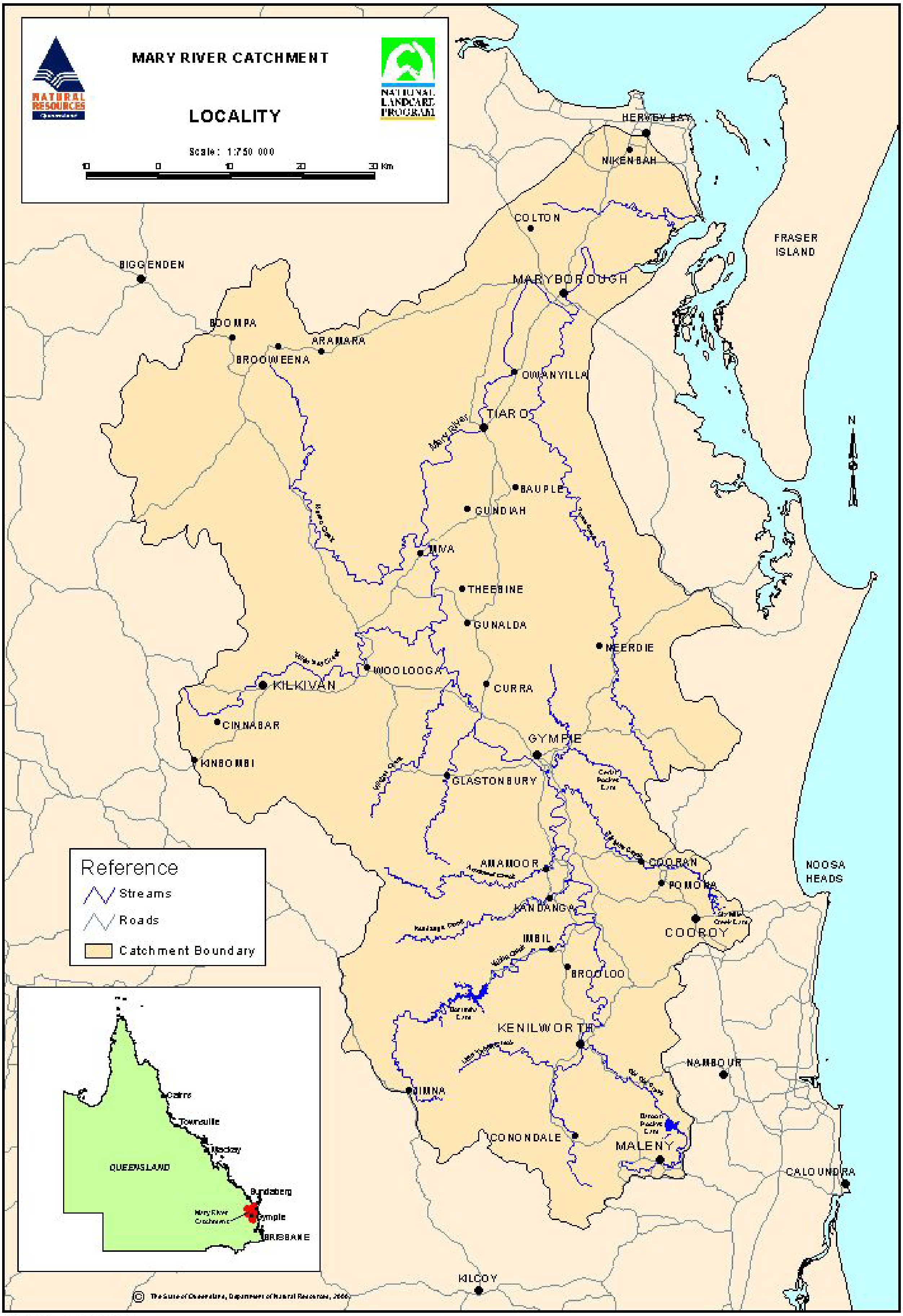
CRITERIA	RANK 1 - Score 0	RANK 2 - Score 1	RANK3 - Score 5	RANK 4 - Score 10
Projects builds on demonstrated community enthusiasm	Involves 1 landholder	Involves two or more neighbours working together	Involves a community group working on project in area of community concern	Involves collaborative community partnership working on site / issue which is driving community attitudes/action
Project links to or with previous rehabilitation effort	Involves one of site	Situated near / adjacent to existing rehabilitation works	Situated in a reach where multiple previous successful rehabilitation has been undertaken	Provides critical link between previous rehabilitation work to achieve continuity
Project provides a highly visible and accessible demonstration site	Site visible from within property only and accessible only by 4WD or long walk	Site visible from local road and accessible by short walk or 4WD	Site visible from arterial road and accessible by 2WD and short walk	Site visible from Major Arterial Rd and accessible by coach with only short walk
Project has the potential to enhance the recreational or tourism potential of the waterway or integrity of heritage elements	Site provides recreational opportunity for landowner only and only general benefit to catchment tourism/recreational/ cultural potential	Site is used by more than one of the adjoining properties for recreational purposes	Site is a recreational / tourism / cultural asset of sub-catchment significance	Site is a key recreational/tourism or cultural asset of catchment wide or regional significance
Project demonstrates inititiative of landholder and an uptake of the principles of the Rehabilitation Plan	Landholder motivation is limited to gaining access to funds to carry out works more aligned to enterprise development than rehabilitation plan goals	Landholder motivation is limited to gaining access to funds to protect private infrastructure/ stabilise waterway etc. with limited interest in rehabilitation	Landholder demonstrates an appreciation of rehab plan principles & has developed a project based on prioritising effort at a property scale accordingly	Key Landholder or group have developed a project aiming to increase the uptake of the principles of the plan and overcome a critical blockage to its uptake
Project protects private or community infrastructure that, if lost would disadvantage community	Threatened infrastructure is poorly located, designed and its continuation and/or counter to normal river process or it is unauthorised	Threatened infrastructure is reasonably designed and located and its loss would result in landholder productivity loss leading to some economic loss to the community	Reasonably designed community Infrastructure & loss would disadvantage community and works proposed are not normally considered core business of owner	Key community infrastructure, threat is unexpected, loss would result in significant community disruption or significant downstream ecological impacts

3.5 Developing Restoration Strategies and Setting Measurable Objectives

Generic strategies were set for different priority reaches. Strategies are holistic in that they matched those which propose physical changes to stream characteristics with those that aim to facilitate behavioural changes in people responsible for managing assets or problems. These general strategies for rehabilitation were then considered in the light of the overall goals and visioning process discussed earlier. Clear and measurable objectives were set to make the necessary linkage between these two elements. Objectives, where feasible, outline the level of change in stream condition desired and the length of time for the desired response to be attained. The feasibility of these objectives were analysed as part of the community consultation process discussed above and were supported.

3.6 Design and Evaluation

There are several more stages in the twelve-step process outlined by Rutherfurd, Jerie and Marsh (1999). There is a copious amount of literature on river rehabilitation prescriptions and designs, and it is beyond the scope of a strategic catchment level rehabilitation plan to address these steps. However, several past rehabilitation projects were evaluated to identify successful rehabilitation methods, required changes in approach and the feasibility of potential strategies (Stockwell 1999). Furthermore, the data collected as part of the preparation of the plan will provide a partial baseline against which future conditions can be compared. Prior to the completion of the River Rehabilitation Plan, a more detailed evaluation plan needs to be developed.



Source: Pointon 1998

Figure 4.1 Mary River Catchment Locality Map

4.0 STUDY AREA

4.1 Overview

The headwaters of the Mary River originate in the Conondale Ranges near Maleny, two hours north of Brisbane in sub-tropical South-east Queensland. Three hundred and seven kilometres downstream the waters of the Mary empty into the Great Sandy Straits west of Fraser Island, at River Heads (Figure 4.1). The rainforest covered ranges which define the headwaters of the catchment provide the foothold for Bunya Pines (*Auracaria bidwilli*) which were an important aboriginal food source that enabled large ceremonial gatherings (McNiven, 1992). The Bunya 'festivals' drew people from up to 450 kilometres away in the summer time (Sullivan, 1977). The plentiful food sources of the Mary combined with the large winter fish runs on the adjoining Cooloola Coast has led some to suggest that the area carried the greatest density of aboriginal population in the continent (Mary River Study Task Force, 1992).

The upper and lower Mary River regions were under pastoral occupation by the late 1840s. Runs were initially established for wool production, with Maryborough being the port for export of this product. As pastoralists settled in the upper Mary River the locality soon became known for its timber wealth also, and the dense rainforests were soon being exploited. Timber was transported down the river to where it could be used or exported. Gold was discovered by James Nash in Gympie in 1867 and all the watercourses from there to Jimna in the upper catchment were worked by prospectors (Mary River Catchment Coordinating Committee, 1997). The Mary River today is the result of the cumulative impacts of these land use changes and those that followed. Tutt (1994) a local historian simplified these historic impacts when he wrote, *"trees went, sand came"*. While some reaches of the river remain in good condition, much has been degraded. According to Tutt (1994, p.14) the river:

> *Changed beyond comprehension of those who knew it even 50 years ago. It has changed from a deep clean stream guarded by shaded scrub (rainforest) which reached back to the ranges, or by the open forest flats saddle high in the native kangaroo grass, to a sand clogged watercourse fighting for its life between eroded banks held by thinly scattered trees.*

- Tutt's observations are true for much of the Mary River. Riparian zones throughout the 9600 km^2 catchment have been significantly degraded by 150 years of intensive utilisation of the floodplain for forestry and agricultural purposes, combined with a lesser period of mining of instream resources. The State of the Rivers report for the catchment rated riparian vegetation as very poor for 40% of the stream length and poor for a further 23% and ranked the majority of streams in the catchment as moderate to poor in terms of channel diversity and aquatic habitat (Johnson 1997). However, some reaches along the 2947 km of waterways in the catchment contain remnant freshwater riparian communities of national conservation significance. These areas contain habitat for a range of rare and endangered freshwater fish, frogs, a turtle and a number of riparian vegetation species. Estuarine riparian communities in the lower Mary are of international significance for wader birds, with these areas being added to the RAMSAR list during 1999, as part of the Great Sandy Straits nomination.

Based on the literature review, field study and historic photographs the most feasible explanations for the observed patterns of degradation appear to be:

- By the beginning of the 20^{th} Century forestry, pastoral and mining activities had greatly reduced riparian and flood plain vegetation cover and altered physical and hydrological characteristics of waterways, at least in the more closely developed areas;

- Following the initial clearing loss of riparian and floodplain vegetation continued and impacts exacerbated by unmanaged stock access to waterways and wetlands, and poor retention of riparian buffers adjacent to horticultural, industrial and residential uses. This appears to have increased the velocity, intensity and power of both small annual floods and large less common events (eg.1893, 1955, 1989, 1992 and 1999); leading to catastrophic scouring of remaining vegetation and failure of stream banks along major channels. Slumping, slips, liquefaction and fluvial scouring eroding banks weakened by the loss of binding root systems;

- As sandy material became exposed by bank failure alluvial reaches began to widen entraining sediment and increasing the volume of water carried within the banks and hence power of the stream leading to significant bed instability.

- Commencing in the 1970s rapid development on the Sunshine Coast resulted in an unsustainable demand for the extraction of sand and gravel from these streams potentially increasing bed instability with removal of sand accretions on point bars etc. Poor practices in some instances have removed channel controls and increased undercutting of banks.
- Continued invasion of woody weeds (eg. *Celtis Sinensis*) that out-compete early native colonising species and viny weeds (eg. *Macfadyena unguiscati*) that strangle mature vegetation and reduce the diversity and structure of riparian vegetation.
- The combination of the above factors have resulted in limited stream shade cover, poor retention, and constrained production, of snags, reduced water quality, and a depletion of aquatic, wetland and riparian habitat. The cumulative impacts have lead to a reduction in primary production aquatic species of both commercial and environmental value such as estuarine and Hervey Bay fisheries and the endangered Mary River Cod (*Maccullochella peelii mariensis*) and Mary River Turtle (*Elusor macrurus*); as well as a general reduction in the social and cultural value of the waterways for recreation and passive enjoyment. (Doak 1995; Flakus 2000; Johnson 1997; Pickersgill 1998; Simpson and Jackson, 1996).

The negative pressures and degradation within the catchment are, however, being matched by a significant growth in community based action to address the problems. Enthusiasm for restoration of the riparian zone is tempered by the constraining climatic and hydrologic characteristics of the catchment.

4.2 Hydrology, Sediment Transport and Climate

The summer dominated rainfall pattern varies extremely and is often of high intensity, which can result in destructive flooding. At higher altitudes around Maleny annual rainfall averages 2000 mm but this falls to less than 800 mm in the west of the catchment. While the catchment generally enjoys a sub-tropical climate, valley floors and lowlands frequently experience several severe frosts during winter.

Topography also plays a role in the hydrology of the Mary. From its headwaters in the Conondale ranges the river drops from 500 m above sea level to 200 m in the first five kilometres, at an average bed gradient of 6%. From this point down to Conondale the bed gradient is 0.62% with the gradient reducing as it moves towards the coast. Between Conondale and Kenilworth it averages 0.17% with a gentle slope of 0.04% down to the tidal barrage at Tiaro (DPI 1995).

With an annual mean discharge of 2,309,000 ML from the 9,600 km^2, the Mary River is one of the most reliable Queensland coastal river systems in terms of base stream flow, however, it displays a highly variable run-off pattern. The oldest continually recording stream gauge at Miva in the lower Mary has records varying between 122 000 to 4,665,000 megalitres per annum (DPI 1995). The location rather than the size of tributaries is the major determinant of the relative volume of discharge from the major tributaries. An inverse relationship between catchment size and discharge is evident in the data from the Obi Obi Creek in the moist south east, to that of the Wide Bay Creek in the west (Baxter et al. 1990 – Table 4.1).

TABLE 4.1
Estimates of Mean Annual Discharge for Major Streams in the Catchment

Stream	Catchment Area (km^2)	Mean Annual Discharge (ML)	Mean Annual Runoff (mm)
Mary River	**9595**	**2,309,000**	**241**
Tinana Creek	**1310**	**313,000**	**239**
Munna Creek	**1475**	**296,000**	**201**
Wide Bay Creek	**775**	**86,000**	**110**
Obi Obi Creek	**202**	**156,000**	**772**

Horn et al. (1998, 1999) have developed a bed material load rating curve, derived from direct flood measurements in the Mary River (Figure 4.2 (a) and (b)). From these they have predicted annual averages for bed material load (70,500 tonnes) and wash load (700,000 tonnes). These figures also show the highly stochastic flooding regime in the Mary River and the variability within the catchment. At Dagun Pocket in the middle of the catchment the 1974 and 1992 floods were the largest in recent times (prior to 1999), whereas at Bellbird Creek Station on the upper Mary these flows were small in comparison to the 1989 flood.

4.3 Geology

The shape of the catchment, the river itself and sediment type are largely dependent on the underlying geology. The region has been geologically stable since a volcanic episode in the mid-Tertiary times. The last twenty-five million years has seen the gradual but steady erosion of valleys into the areas once covered by basalt and the exposing of volcanic plugs. In association with this, alluvial sediments have been deposited along stream valleys (Wilmott and Stevens 1988).

The river's course reflects the north-south structural trend of the regional geology. Upstream of Gympie, where the river has dissected Palaeozoic sedimentary and volcanic rocks (Amamoor and Gympie Group), it has generally incised deeply into the bedrock. The river is not as incised in the area downstream of Conondale, however, where it flows through a broad valley as it passes through granitic rocks that are part of Neurum Tonalite. Downstream of Gympie, the river has cut a deep gorge into the resistant Myrtle Creek Sandstone. Subsequently, it passes through the granitic rocks of the Station Creek Adamelllite becoming more sinuous before entering the softer sedimentary rocks of the Tiaro Coal Measures. In this area wide alluvial flats adjoin the river (DPI 1995).

The gradual retreat of escarpments in the catchment since tertiary times has left large volumes of rock and soil debris accumulated on benches on the sides of mountains and hills.

Due to their unconsolidated nature, they are sensitive to landslides and consist of clays that swell and lose strength on wetting. Perched water tables, or groundwater springs, directed outwards from the mountain by horizontal lavas can contribute significantly to the wetting of these clays (Wilmott 1984), which can add significant sediment loads to waterways as a result of mass movement. Comparison of sediment transport graphs derived from a limited number of flood events, with those derived from traditional empirical formulae based on Northern Hemisphere streams, suggests that sediment transport in the Mary River is significantly less than derived from Northern Hemisphere streams (Horn et al. 1998, 1999).

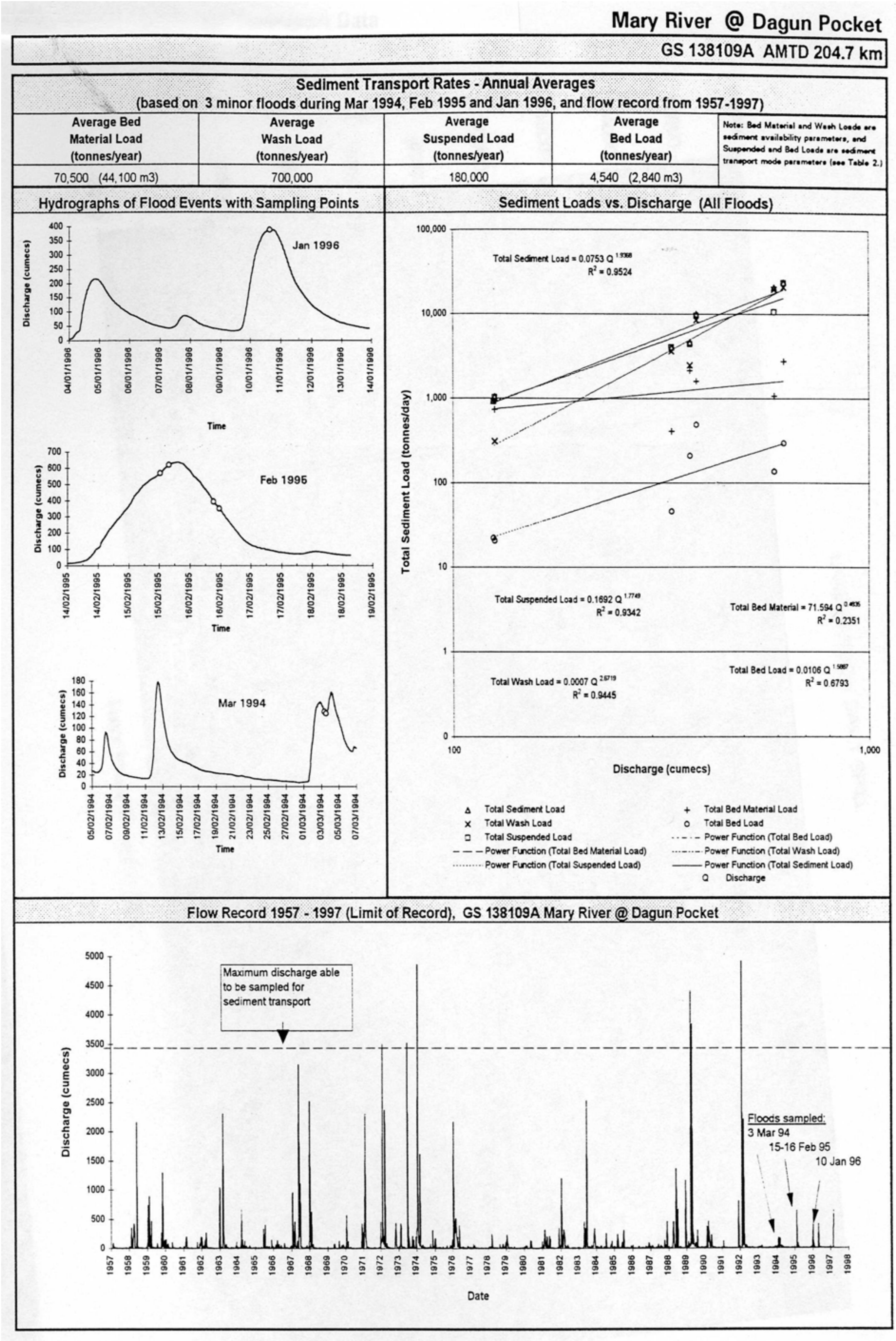


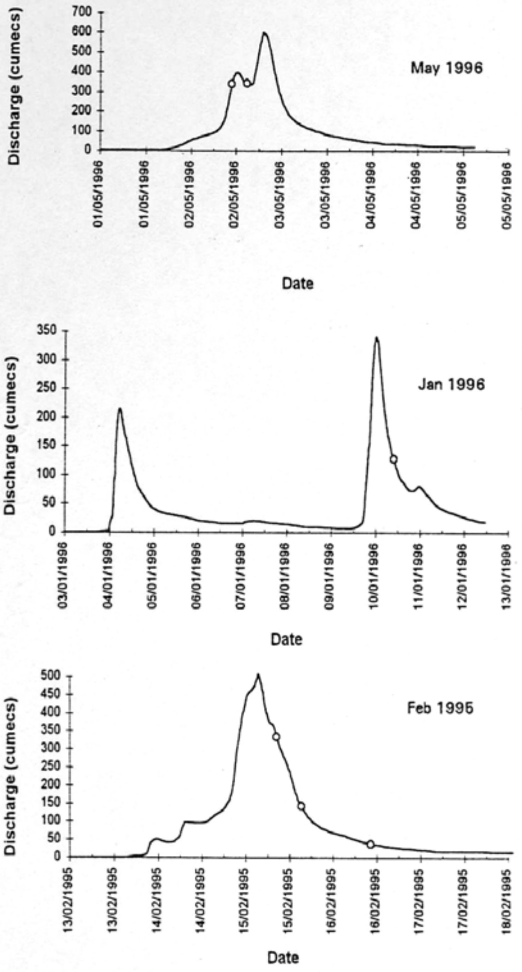
Figure 4.2 Bed Material rating Curves for (a) Dagun Pocket and (b) Bellbird Gauging Stations in the middle and upper Mary River and comparison with predictions from Northern Hemisphere models (Source: Horn et al. 1998, 1999).

Mary River @ Bellbird Creek

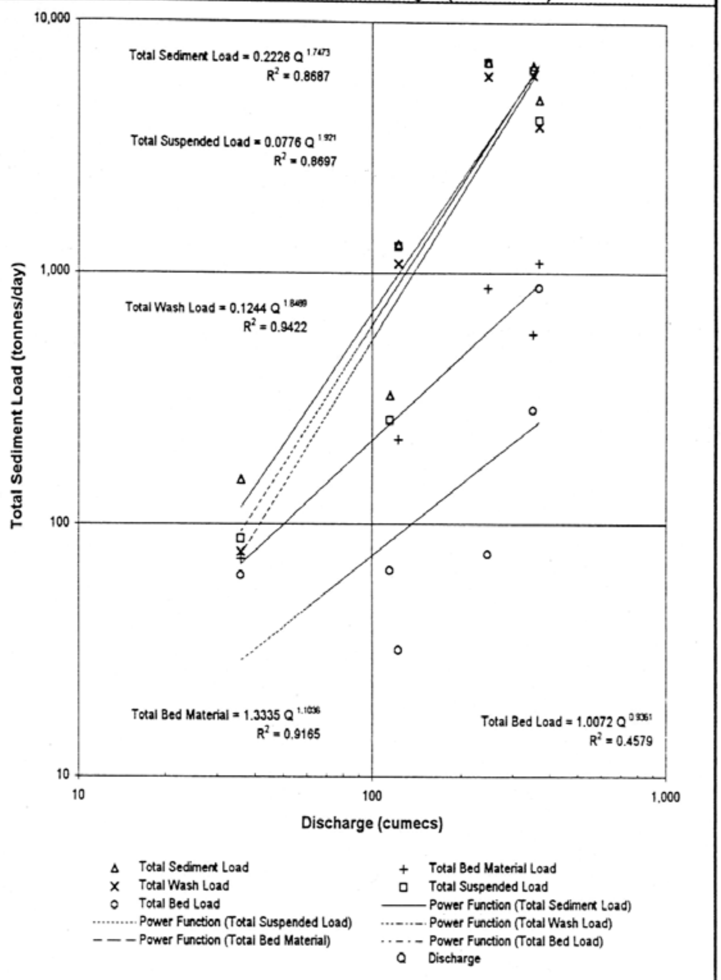
GS 138110A AMTD 270.0 km

Sediment Transport Rates - Annual Averages (based on 3 small floods during 1995, Jan and May 1996, and flow record from 1959-1997)				
Average Bed Material Load (tonnes/year)	**Average Wash Load (tonnes/year)**	**Average Suspended Load (tonnes/year)**	**Average Bed Load (tonnes/year)**	**Note: Bed Material and Wash Loads are sediment availability parameters, and Suspended and Bed Loads are sediment transport mode parameters (see Table 2.)**
4,230 (2,640 m3)	32,300	32,800	1,590 (994 m3)	

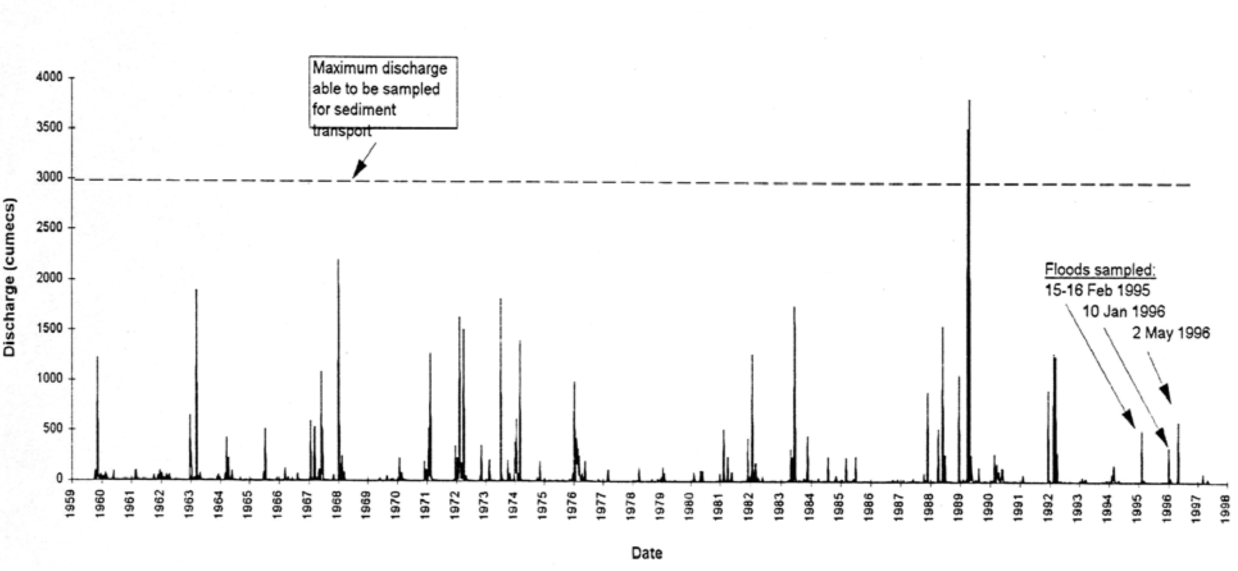
Hydrographs of Flood Events with Sampling Points



Sediment Loads vs. Discharge (All Floods)



Flow Record 1959 - 1997 (Limit of Record), GS 138110A Mary River @ Bellbird Creek



4.4 Prehistory of the Catchment

The catchment has been the focus for significant archaeological interest with 350 sites registered by the Environment Protection Agency on the Gympie 1:250 000 map sheet. One of these sites, at a rockshelter above Glastonbury Creek, provides the earliest dated record of habitation of the catchment at c.2800 BP (McNiven 1988), however coastal sites in the region have been dated to over c.20,000 BP (Neal and Stock 1986). The identification of scrub turkey eggs and fresh water mollusc shells, along with seeds from the yellow boxwood (*Planconella pohlmaniana*) and hoop pine (*Araucaria cunninghamii*), in the Glastonbury excavation suggests the exploitation of the riparian areas was an integral (but minor) aspect of the intermittent occupation of the rockshelter during summer hunting camps (McNiven 1988). The date of occupation of the rockshelter is consistent with other archaeological investigations that suggest aboriginal populations increased significantly in the region around this time (Morwood 1986). Increased deposits of silts, dating to the last 3000 years, in Moreton Bay, 180 km south of the catchment, have been linked with the more frequent and less intense aboriginal burning regime (Singh et al. 1981).

4.5 History of the River and Catchment Changes

It wasn't until five years after explorer Andrew Petrie sailed for three days up what was then known as Monoboola to Tiaro in 1842 that the river got its current name (Armstrong 1997). Petrie's name of Wide Bay River was replaced by Governor Fitzroy in honour of his wife Mary (Armstrong 1997). This was the first of many changes made to the river by white settlement. In 1843, a team consisting of a doctor, reverend, four mounted police and two convicts journeyed to the Bunya country along the river. The team left from near Kilcoy and upon reaching a summit at the headwaters of then Numabulla (Upper Mary), recorded an abundance of grass and fine timber (Armstrong 1997). The diary of the trip describes grassy flats almost clear of timber (possibly a result of aboriginal burning regimes), apple tree flats and ridges and Bunya scrubs with very good soil. On the Cambroon flats above Kenilworth they noted that while the grass was luxuriant the ground was swampy. Other early explorers described the vegetation fringing the Mary River as fine ironbark, blackbutt and cedar (Pedley 1979; Vickery-Lockwood 1964).

Extensive rainforests in the vicinity of the river supported a large red cedar cutting industry in the early days of settlement (Pedley 1979). These areas would have been separated by areas of open forest where rocky valley margins met the river (Smith 1987).

By the late 1840s both the upper and lower Mary were under pastoral land use. Squatters virtually controlled the Mary Valley by the 1850s. Cattle and sheep runs were the main users of the fertile alluvial floodplains in the lower Mary in the 1850s. Sugar quickly replaced sheep as settlers found the area unsuitable for sheep production (Armstrong 1997). Commercial timber operations started in the lower Mary in 1849 when 70,000 feet of timber was cut and floated down the river (Mary River Study Taskforce 1992). Timber operations were first recorded in 1853 in the upper catchment with much of the sediment generated from the first major phase of clearing being introduced to the river during the 1890s floods (DPI 1995). The first commercial horticulture in the central catchment commenced in the 1860s when the Chinese established farms to feed the miners during the gold rush (Pedley 1979). The discovery of gold throughout the middle and upper catchment saw a rise in demand for agricultural and timber production. Dairying became well established in the late 1890s and continued to grow until the mid to late 1960s, when the beef industry began to gain popularity (Armstrong 1997). The Gympie Butter Factory was the largest in the Southern Hemisphere (Kerr 1996). As land uses intensified, the government adopted a policy of closer land settlement with the large runs of Widgee, Kenilworth, Imbil and Obi Obi sold off between 1912 and 1930 (Armstong 1997).

In the 1850s, the river also became the major trade route for the produce of the Wide Bay Burnett pastoral district with ocean going ships registering at Maryborough and immigrants alighting there (Mary River Study Task Force, 1992). Fishing became both a pastime and source of food for the young settlement. Simpson and Jackson (1996) discuss the earliest official accounts of the Mary River Cod including a report from the Voyage of H.M.S. Challenger during the years 1873-76 (Wyville Thomson 1880) with a record of a fish caught near Tiaro. Macleay (1883) collected a cod from the Maryborough area and a report in 1890 described the fish as being highly valued for sport and consumption, being abundant in Tinana Creek and frequently weighing as much as 30 or 40 lb (Saville-Kent 1890). The largest cod caught by Simpson using electro-fishing in this same area in 1994 was 3 kg (6.6lb).

The Department of Primary Industries (1995) has studied historic changes in the Mary River Catchment. Original maps and historical records were studied to identify changes prior to 1940 with aerial photos available for assessment subsequent to that date. Mining, timber operations and agriculture caused the major impacts on the river prior to 1940. Up until 1904, tailings from gold mining operations were released directly into the river causing the river to be choked with artificial sediment at Gympie. Records indicate that the large floods of the 1890s degraded grazing land as a result of sand deposition.

A comparison of the cadastral boundaries of the river surveyed in the late 1870s and 1940 aerial photography reveals differences in the upper reaches of the Mary. It is likely that the river began responding to catchment changes during the floods of the 1890s by straightening and widening. The land settlement programs after World War I resulted in large areas of native forest being cleared, however, much of the sediment liberated after 1898 would have remained on the hillslopes and alluvial flats until at least the 1920s, when a series of moderate flood events occurred. A large amount of the sediment may not have entered the river until the large floods of the 1950s (DPI 1995). While the 1920s floods were relatively modest in size they had the potential to be influential in the changing river form due to the long dry period that preceded them and possibly high rainfall intensities (DPI 1995). The continued straightening and widening of the river is evident from aerial photographs taken of the Conondale–Kenilworth reach in 1958. In comparison to the 1940 photographs, the pictures taken in 1958 soon after a decade of large floods events show significant in-channel sand deposits (DPI 1995). Plantation grown Hoop Pines were first established in 1944 (Armstrong 1997). Anecdotal evidence (Bryant,C. pers. comm. conversation 1999) suggests plantations establishment on steep sided valley margins in the Conondale district resulted in significant sedimentation of the river in the 1950s floods and planform changes in the Upper Mary in reaches where the river is not controlled by bedrock. At the confluence of the Obi Obi Creek, there is evidence of significant changes with the right bank retreating eastward and the left bank upstream of the bridge on the Kenilworth–Eumundi Road eroding northward (DPI 1995).

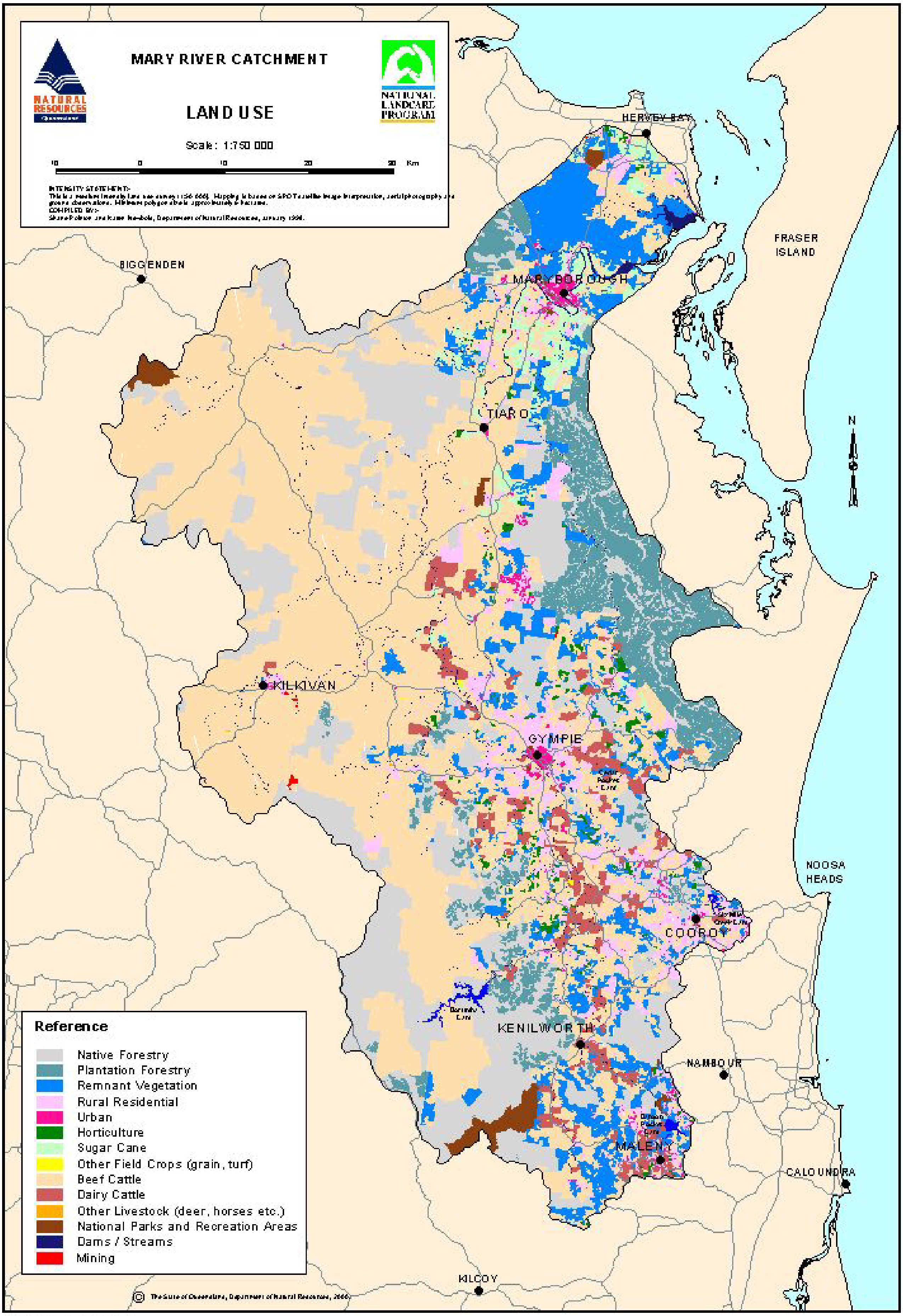
While the peak of agricultural activity occurred in the 1920s and 1930s with sugar cane, bananas, pineapples and dairy farms being economic mainstays, irrigation did not come into general use until after 1945 when electricity was connected to most areas (Armstrong, 1997).

Construction of Borumba Dam on Yabba Creek commenced in 1960 and the dam was opened in 1964, while the Baroon Pocket Dam, which supplies the urban settlements of the Sunshine Coast, was not constructed until the 1980s. Commercial scale sand and gravel extraction operations in the Mary did not commence until the early 1970s.

4.6 Current Land Use and Catchment Condition

Climate to a large extent controls the location of land uses within the catchment. Extensive grazing industries predominate the drier areas in the west and consume 48.5% of the land area of the catchment. The higher rainfall areas in the south and east however attract the majority of the residential, horticultural and more intensive livestock pursuits. Forestry, which occupies nearly 29% of the catchment, is the second largest land use, with residential (5.8%), dairying (3%), sugar cane (1.8%), national parks (1%) and horticulture (1%) also important elements of the local economy (Pointon, 1998 - Figure 4.3).

Johnston and Wylie (1984) were the first to map tree clearing in the catchment. Their investigations revealed that a relationship exists between the pattern of tree clearing and land use with stream salinity and the occurrence of dieback in riparian *Eucalyptus* and *Casuarina* species. Smith (198x), however, studied two of the subcatchments and found that while there was some correlation between *Casuarina* regrowth and high ionic levels in the adjacent waterways, it was not the dominant cause of impeded recovery. The prime factor, which appeared to be leading to the lack of recovery of the species, was cattle grazing of saplings and compaction and damaging of streambanks. The extent of current tree cover is strongly influenced by the suitability of the topography and rainfall pattern for higher value land uses, with the percentage cover reduced most in areas of fertile soils, gentle slopes, adequate rainfall and proximity to reliable water supply (Pointon 1998). While only around 1% of the catchment is maintained in a natural state, a further 5% is largely intact and impacted only by seasonal grazing pressure and a further 39% that has only experienced limited clearing (Figure 4.4). With just over 400 000 ha of remnant vegetation, open forest is the dominant cover class, with closed forest and sparse woodland occupying 10-15% each (Pointon 1998). The remaining 55% is extensively to completely cleared (Pointon 1998).



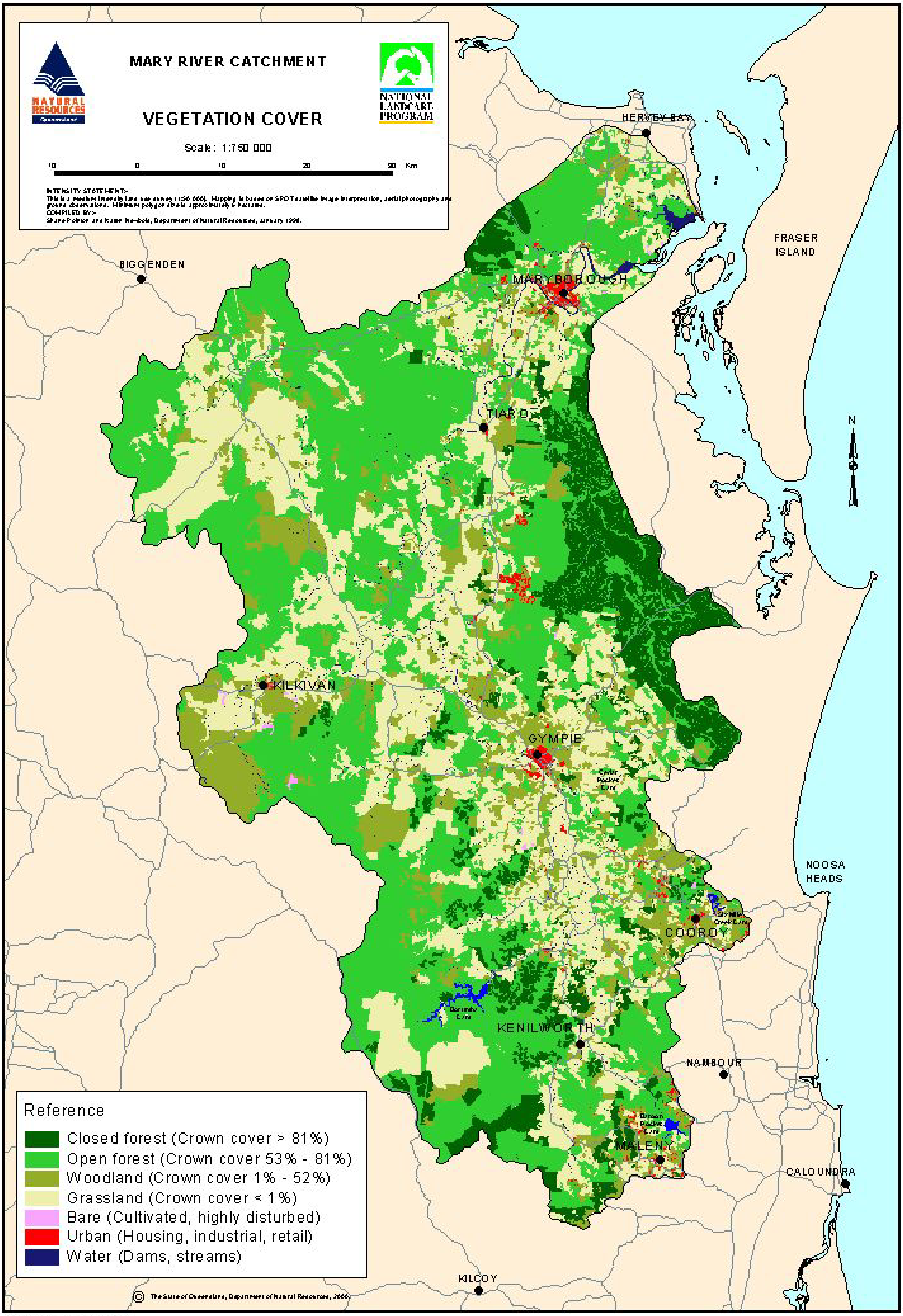
Source: Pointon 1998

Figure 4.3 Land-use Map of the Mary River Catchment
(Source: Pointon 1998)

Plantations account for approximately 71 000 ha in State forests in the catchment. Exotic pine plantations were first established in the east of the catchment in the 1940s. Bevege and Simpson (1981, cited in Lamb 1986) found that native vegetation clearance in areas of poorly drained humic gleys led to the death of young roots due to increased salinity associated with rising water tables. The impact of elevated dryland salinity on the naturally sub-acid Coondoo and Tinana Creeks in the locality has not been investigated. Clearing of forests on steep slip prone areas (see discussion above) reduces groundwater uptake and the binding capacity of tree roots greatly increasing the potential for mass movement (Willmott and Stevens 1984). Landslides occur throughout the catchment; large clusters occur in the Dagun, Cedar Pocket and Beenham Valley localities. A slip directly above the Cedar Pocket Dam site contributed significant amounts of sediment to the waterway. However, no substantial study has been undertaken to determine the relative contribution of sediment to streams from hillslopes, as compared to bank and bed erosion.

Ciesiolka et al. (1995) has demonstrated the hazards associated with poor land management practices on steep shaley pineapple growing land in the middle catchment. Their study showed that soil erosion in experimental plots increased four times when the row length was increased from 12 to 22 m on slopes of 38% due to increased rilling. During the wet 1998/99 experimental period, this equated to a soil loss of 178 tonnes per ha. The potential for these sediments to be entrained and enter creeks and rivers will depend on their proximity to the waterway and the ability of riparian vegetation to filter runoff.

A detailed survey of the river downstream of Gympie for its recreation potential in the early 1990s resulted in the Mary River Study Task Force (1992) describing a range of constraints to the peaceful enjoyment of the river.



Source: Pointon 1998

Figure 4.4 Vegetation Cover of the Mary River Catchment
(Source: Pointon 1998)

Their report stated:

> "*… it has to be said that it has serious scars, from erosion, most of the arterial creeks have serious siltation problems. In many places there is life choking silt and sand build ups. ... It has become invaded by an ever increasing number of water pumps, overhead powerlines and barbed wire fences, all of which certainly detract from the appearance of a serene waterway. Add to this dumped car bodies, household garbage and other debris and we have to say that there is a potentially cancerous situation.*" (1992, p.29)

4.7 Water Infrastructure Development and Utilisation

The catchment supplies water for local agriculture, urban and industrial water users as well as providing urban water supply to the Sunshine Coast. In 1994, urban water use accounted for 61% of total water use in the Sunshine Coast Wide Bay region supplied by the Mary and a number of other smaller impoundments (Department of Primary Industries, 1994). This supply is derived from major dams on the Obi Obi, Yabba and Six Mile Creeks, seven smaller storages throughout the catchment (Table 4.2).

Currently 45,000 ML/Annum is allocated for irrigation water and 56,100 ML/Annum for urban Water supplies. Current projections suggest there is an unmet demand of 27206 ML/Annum for irrigation supplies (Herd, 1999). By the year 2010, Council's (mainly coastal) envisage that the current allocations will need to increase by 53,600 ML, despite recent demand management strategies that have seen the percentage reduction in per capita consumption averaging around 25% across all Shires, except for the unmetered Maryborough scheme (MRCCC 1998).

Current environmental flow strategies being utilised by managers of storages are largely ad hoc and not based on current management theory and practice. In 1998, the various strategies adopted throughout the catchment included:

- 20th Percentile flows were passed on at Borumba Dam;
- there were no specific releases at the Maryborough Barrage, however, it generally overflows 300 out of 365 days which equates to 2.5 Million ML/yr;
- at Lake Baroon 2000 ML per year was released, largely to service downstream irrigators;

- at Lake MacDonald 1 ML per day was released (since increased to 4 ML/day), largely consisting of wastewater from the treatment plant; and
- No specific action or strategies exist for the Weirs in Tinana Creek and Cedar Pocket (MRCCC, 1998).

TABLE 4.2
Impoundments in the Mary River Catchment

Storage Name	Capacity (ML)	Stream
Tinana Barrage	**4,770**	Tinana Creek
Mary River Barrage	**11,700**	Mary River
Teddington Weir	**3,100**	Tinana Creek
Tellegella Weir	**460**	Tinana Creek
Goomeri Weir	**22**	Kimombi Creek
Cedar Pocket Dam	**730**	Deep Creek East
Imbil Weir	**46**	Yabba Creek
Borumba Dam	**45,900**	Yabba Creek
Lake Macdonald Dam	**8,000**	Six Mile Creek
Baroon Pocket Dam	**61,000**	Obi Obi Creek
Maleny Weir	**57**	Obi Obi Creek
TOTAL STORAGE	**135,785**	

(Source: Pointon 1998)

While little work has been undertaken regarding the impacts of these storages in terms of environmental flows, sediment retardation and other physical impacts, Water Studies Pty Ltd (1998) has described the degradation of a three kilometre reach below the Lake Macdonald Dam wall on the Six Mile Creek. In this stream segment, ecological processes are extremely disrupted and at the time of their survey, was bordering on becoming eutrophic as a result of the absence of flushing flows. Unlike much of the well-shaded reaches below, this section of creek supported abundant macrophytes, which combined with low flows could trigger dramatic falls in dissolved oxygen (Water Studies Pty Ltd 1998).

High nutrient levels in this impoundment may have driven Australia's first and largest outbreak of the invasive aquatic weed *Cabomba caroliniana* in a potable water storage (Anderson and Garraty, 1994). Siltation, water hyacinth and other floating aquatic weeds have also been recorded as problems above Maryborough Barrage (Mary River Study Task Force, 1992). The barrage is the only major structure with a fish ladder but there is a strong opinion amongst organisations that use the river, that a number of fish species cannot use it (Mary River Study Task Force, 1992). Cameron McNamara (1984) found that slumping of stream banks in a narrow fringe defined by the tidal range occurred following the construction of the tidal barrage at Maryborough. They proposed that slumping may have been initiated by tidal amplification following barrage construction. These banks were then found to be at greater risk of secondary slumping during periods of rapid recession of floodwaters (Cameron McNamara 1984).

While groundwater contributes to irrigation water supplies, a study in 1964 determined that prospects were not favourable for the location of supplies of groundwater of sufficient quantities for widespread irrigation (Hunter Valley Research Foundation, 1972). Accordingly, the Mary Valley has not been proclaimed as a groundwater control district and therefore there are no restrictions on the number or location of bores. Wide Bay Creek was thought to be suitable for limited development, while the groundwater reserves around Tiaro were of poor quality due to excessive salinity (Hunter Valley Research Foundation, 1972). Little data exists on the long-term quantity and quality of sub-artesian water resources, or the impacts of abstraction.

4.8 Physical Condition of the River Channel

The majority of the main channel of the Mary has been rated as having an unstable to moderately unstable stream-bed, while the majority of the tributary streams are considered to be very stable (Johnson, 1997). Channelisation, bed deepening, sand and gravel extraction, entrapment of sediment and mining were factors leading to this rating recorded in the State of the Rivers survey. Aggradation in the form of point bars and longitudinal bars was recorded at 63% of the sites surveyed. Channel habitat diversity was rated as very low for 72% of the reaches surveyed (Johnson, 1997). A degree of caution needs to be exercised in the interpretation of the results of this survey.

Ground truthing of the Six Mile Creek, Tinana Creek and Gutchy Creek sub-catchments has revealed a degree of error in mapped output. This is possibly due either to deficiencies in the methodology and data manipulation, inexperienced data collectors or the paucity of data collection points. It appears that the results consistently under value intact streams and those that retain a relatively undisturbed condition.

Analysis of 1992 aerial surveys revealed that riverbanks that have been cleared of all vegetation are far more likely to suffer severe degradation than timbered areas. Of the 179 reaches where streambank erosion was mapped, there was a high frequency of unstable 2-10 m high banks recorded in areas where grass was the dominant vegetation (Doak, 1995). Outside bends of the river were particularly prone to active erosion, with stability in these locations generally associated with well-timbered riparian zones (Doak 1995).

The rapid growth of the Sunshine Coast and Hervey Bay urban areas has resulted in a significant increase in the extraction of sand and gravel resources from the Mary River, particularly coarse sand for use in concrete. In a fifteen year period between 1980 and 1995, the production of aggregate from both the tidal and non-tidal sections of the river increased four-fold to over 200 000 m^3 (Department of Primary Industries (DPI) 1995). An extraction rate of 100 000 m^3 above Moy Pocket in 1995 was considered to be linked to bed and bank degradation, with average and maximum rates of sand transport past this point estimated at 6 000 m^3 and 27 000 m^3 respectively (DPI 1995).

Outside of site-specific assessment for infrastructure projects, there is a lack of fluvial geomorphological investigations in the Mary. Senior Officer Water Steve Kelly (DNR pers. comm. survey results 1999) has undertaken thalweg and cross sectional surveys in key reaches and compared them to similar work undertaken in the 1950s and 1970s. Preliminary results suggest bed lowering around Kenilworth in the last forty years may be between 2 m and 4 m, with an approximate 0.5 m drop in the Gympie area between the 1970s and early 1990s. Traverses by canoe following the February 1999 floods identified extensive occurrence of head cuts and hung tributaries in the upper Mary River above Moy Pocket (Damon Telfer, DNR, pers comm. conversation and photos, 1999).

4.9 Water Quality

The Queensland Local Government Department (1985) found that rapid subdivision around Noosa's primary water supply storage, Lake Macdonald, had led to elevated nutrient level. Sampling of the Lake Macdonald catchment during two rainfall events over 13 days in 1995 showed that a runoff volume of 23,600 ML inflow, contributed 2.7 tonnes of total phosphorous and 21 tonnes of nitrogen to the storage (Water Studies Pty Ltd 1996). Approximately one-half of the total phosphorous and one-third of the total nitrogen load settled to the bottom of the lake. Fortunately, high water colour levels and low pH levels hinder the development of algae in Lake Macdonald. However in 1990 runoff from urban, rural residential and agricultural land uses led to the first algal bloom of *Anabaena* soon after the completion of the Sunshine Coast's major water supply storage, Lake Baroon on the Obi Obi Creek (Lake Baroon Catchment Care Inc. and Maroochy Caloundra Water Board LBCC-MCWB 1997). Results of a detailed catchment monitoring program showed that nitrogen levels exceeded ANZECC (1992) guideline values in all sites on average 50% of the time, and guideline values for total phosporous were exceeded 76% of the time (LBCC-MCWB 1996). Elevated levels of nutrients, particularly nitrogen and phosphorous, have continued to cause Cyanobacteria (Blue-green algae) blooms in both Lake Baroon and Borumba Dam on Yabba Creek. Interestingly Borumba Dam has a catchment that is dominated by grazed State Forest. Elevated phosphorous and nitrogen levels have been recorded for a range of sub-catchments where grazing and rural residential uses are the major land uses, including Glastonbury, Eel, Calico, Kandanga, Coles and East Deep Creeks, as well as the Mary River itself. Diffuse (stormwater) and point source (Sewerage Treatment Plants) urban pollution also adds nutrients to the waterways within the catchment, the largest direct outfall being the Gympie Sewerage Treatment Plant. Hervey Bay now reuses its effluent on cane land and Maryborough is constructing a similar re-use scheme.

In September 1991, after 15 months of below average rainfall due to a weak El Nino episode, elevated salt concentration in creeks and dams in the catchment were recorded. Water in Sandy Creek and Pie Creek was brackish with salinity levels sufficient to cause crop loss if used for irrigation (Buhle 1991). Sampling during this period, Pusey et al. (1993) recorded consistently brackish levels of dissolved salts in Glastonbury Creek near its confluence with the Mary with a peak reading of 1850 uS/cm and the adjoining Widgee Creek also tended to have elevated conductivities.

Disregarding these two streams, Pusey et al. (1993) found that salinity gradually increased with increasing catchment area. Increased saline potential in a number of the creeks in the mid to lower western catchment is in part due to the marine sediments in the underlying geology (Pusey et al. 1993, Thompson 1996). During dry conditions in 1996, elevated salinity levels were again recorded in the western streams of the central catchment particularly the upper Glastonbury (2380uS/cm), Calico (1694uS/Cm) and Pie Creek (1256 uS/cm) (Stockwell 1996).

Pusey et al. (1993) found that the position of water quality sites within the catchment strongly influenced water quality parameters. There was a strong correlation between increases in turbidity and distance downstream. Turbidity is, however, significantly increased during peak rainfall events. In 1992, two flood events (approx: 1:40 ARI) resulted in increased sediment flowing into Hervey Bay that smothered and killed approximately 1000 km^2 of sea grass, consequently causing significant dugong mortalities in the following nine months (McGregor 1999). Water quality sampling in 1994 revealed the majority of streams within the Mary catchment had high turbidity levels as a result of high sediment loads in the water column (Pointon 1998). In May 1996, turbidity levels were measured for a flow of approximately 47,000 ML at Gympie over a 24 hour period (Stockwell 1996). The level of suspended sediment during this period equated to 10,340 tonnes, which carried approximately 2.02 tonnes of reactive phosphorous and 10.2 tonnes of nitrate. The volume equated to streambank erosion 3 m high and 1 m deep for 1.7 km on both sides of the river.

Pusey et al. (1993) found that headwater streams tended to be cooler (during summer) and more acidic than down-river sites. Seasonal rather than spatial patterns were evident in differences in dissolved oxygen with all sites being particularly low in February. However, during this sampling period, main-river sites were particularly oxygen depleted. In Wide Bay and Obi Obi Creeks and the Mary River at Dagun, iron levels were also elevated (>0.3 mg/l). Levels of manganese were high in Munna, Obi Obi and Yabba Creeks and the Mary River at Dagun, but this may relate to geology rather than anthropogenic influences (Pointon 1998).

The historic and continuing mining activity within the catchment may be responsible for recorded traces of heavy metals (particularly arsenic, chromium and nickel) in sampling of the central catchment. Levels were the highest at the site closest to the largest mining activity just above the confluence of Deep Creek and the Mary at Gympie (arsenic 345 ug/l, chromium 20ug/l, nickel 28 ug/l) (Stockwell 1996). Elevated heavy metals have also been recorded by Kilkivan Landcare Group (Pers. Comm, copy of results, 1998) downstream of the Shamrock mine, however, Environment Protection Agency surveys in June 1999 (Pers.comm. Walters, Dept Mines and Energy, letter 2/2000) failed to identify any downstream water quality impacts of the mining operation. Potential acid sulphate soils, which can release large amounts of sulphuric acid when drained with resultant increases in aluminium and other metals, have been identified in the Lower Mary and pose a threat to the estuarine system (Pointon 1998).

4.10 Instream Biological Condition and Conservation

In undisturbed catchments, fish species richness generally increases from headwaters to the lower reaches. Pusey et al. (1993), however, found that this was not the case in the Mary catchment. A survey of ten sites throughout the catchment identified 19 species, with the high order tributaries having consistently higher mean species richness than the main stem of the river. They identified a significant relationship between the complexity of cover (riparian overhang, snags and undercut banks) and the diversity of species. Species richness was highest where cover complexity was highest regardless of position in the catchment. Eighty six percent of the total catch was comprised of only six species (*Hypseleotris spp. (*Gudgeons)*, Pseudomugil signifer* (Blue-eye), *Anguilla reinhardtii* (Long-finned eel)*, Retropinna semoni* (Australian smelt)*, Craterocephalus marjoriae* (Marjorie's hardyhead), *Melanotaenia duboulayi* (Duboulay's rainbowfish)). Interestingly, they found that sewerage effluent released from the township of Gympie did not appear to have a serious affect on fish assemblage with the immediate downstream site more abundant than that above the outlet (Pusey et al. 1993). Agricultural land use practices and gravel extraction were considered to be more likely to cause low species richness, low densities and instability of fish assemblage structure. The very low densities of exotic fish identified (except for *Xiphophorus helleri* (Swordtail)) was attributed to the unpredictable nature of the Mary River discharge regime which may give competitive advantage to native species in unregulated sections of the river.

Mackay et al. (1999) rigorously sampled macrophytes, fish and habitat parameters in 29 sites throughout the Mary, using largely quantitative assessment techniques. A total of 13 submerged macrophyte taxa comprising seven different families were identified in 25 of these sites. *Myriophyllum verrucosum*, *Vallisneria nana* and *Potamogeton crispus* were the most widespread species occurring in about one-third of sites sampled (Table 4.3). *Myriophyllum verrucosum* and *Vallisneria nana* contributed over half (53.8%) of total mean submerged macrophyte cover. In addition to the species listed, *Cabomba caroliniana, Elgeria densa* and *Potamogeton javanicus* have also been recorded in the catchment. The study identified four different macrophyte communities, the most restricted only occurring in Amamoor and Boolumba Creeks at elevations above 100 m. These communities were dominated by *M.verrucosum, Nitella* sp. And *M.variifolium* (rare in south–east Queensland) as co-occuring species. While their data indicates that most species tolerate a broad range of habitat conditions (Table 4.4) macrophytes were absent from Kilcoy and Tinana Creeks. This may be due to the fact that both creeks have a very low alkalinity and in Tinana Creek high turbidity may lead to light limitations (Mackay et al. 1999).

The Mary River Turtle (*Elusor macrurus*) and Mary River Cod (*Maccullochella peelii mariensis*) are listed under the Federal Endangered Species legislation. The Queensland Lungfish (*Ceratobus spp*.) is listed under the Queensland Nature Conservation Act due to its scientific interest. The Mary River Turtle has been recorded in the main stem of the Mary River from Tiaro (AMTD 68) to Kenilworth (AMTD 245) and in Tinana and Yabba Creeks (Tucker 2000). Compared to fish species, the turtle has a reasonably small home range with the maximum upstream and downstream extent varying in the vicinity of 0.5 to 6 km. On average, radio tracked females moved between 150-200 m with a home range area of 2-51 ha (Flakus and Wright 2000). The species show a preference for free flowing water in and around riffle zones to a maximum depth of 5-6 metres (Flakus and Wright 2000). Their diet changes between life stages with juveniles feeding largely on riffle zone macroinvertebrates (74%) with macrophytes (81%) forming the dominant part of the adult diet (Flakus 2000). Importantly, many of the species consumed by the turtle are pollution sensitive species (eg. *Ephemeroptera* (mayflies), *Trichoptera* (caddis flies), *Vallisneria* spp.). While terrestrial plant material comprises only 2% of the adult turtles diet, the fruit of the cluster fig (*Ficus racemosa*) is known to be sort after by the turtle.

The Mary River Cod is one of Australia's most endangered fish with populations largely restricted to a few tributaries of the catchment (Simpson and Jackson, 1996). Habitat fragmentation and impoundment of streams has isolated remnant populations, which now occur in an estimated 30% of their former known range. After extensive habitat mapping and investigation Pickersgill (1998) has tabulated the priority protection and rehabilitation reaches within the Mary to assist in the recovery of the endangered Mary River Cod (Table 4.5). Radio tracking has revealed the strong connection between cod and large woody debris. Habitat use by cod was highly specific, with more than 93% of all observations occurring within 2 m of submerged timber (Simpson 1999).

TABL.E 4.3

Native Submerged Macrophytes of the Mary River Catchment

Taxon	Common Name	Frequency of occurrence (%)	Mean site cover (%)	% of total cover
CHARACEAE				
Nitella sp.	Stonewort	9	0.76 ± 0.30	3.2
Chara sp.	Stonewort	6	0.67 ± 0.35	2.8
HYDROCHARITACEAE				
Hydrilla verticillata L.f. Royle	Hydrilla	11	1.02 ± 0.42	4.3
Vallisneria nana (R. Br.)	Eelgrass	31	6.84 ± 1.27	28.6
NAJADACEAE				
Najas tenuifolia R. Br.	Waternymph	4	0.12 ± 0.07	0.5
POTAMOGETONACEAE				
Potamogeton crispus L.	Curly Pondweed	30	2.25 ± 0.49	9.4
P. ochreatus Raoul	Blunt Pondweed	1	0.01 ± 0.01	0.03
P. perfoliatus L.	Clasped Pondweed	7	1.95 ± 0.90	8.1
P. tricarinatus F. Muell. & A. Benn. Ex A. Benn.		5	0.58 ± 0.28	2.4
CALLITRICHACEAE				
Callitriche stagnalis Scop.	Starwort	4	0.47 ± 0.27	2.0
CERATOPHYLLACEAE				
Ceratophyllum demersum L.	Hornwort	3	0.15 ± 0.10	0.6
HALORAGACEAE				
Myriophyllum variifolium J. Hooker	Variable Water-Milfoil	13	3.07 ± 0.89	12.8
M. verrucosum Lindley	Red Water-Milfoil	34	6.03 ± 1.16	25.2

(Source Mackay et al. 1999)

TABLE 4.4

Habitat Conditions under which Common Submerged Macrophyte Species were collected in the Mary River Catchment,

Species	Water Velocity (ms^{-1})	Depth (cm)	TKN (mgL^{-1})	TP (mgL^{-1})
M. variifolium	0-0.25	12-88	<0.1-0.3	<0.002-0.130
M. verrucosum	0-0.80	7-76	<0.1-0.6	<0.002-0.130
Nitella sp.	0-0.11	22-76	<0.1-0.5	<0.002-0.13
V. nana	0-0.80	10-82	<0.1-0.6	0.003-0.12
H. verticillata	0-0.46	10-82	<0.1-0.6	0.003-0.012
P. crispus	0-0.64	9-88	<0.1-0.6	0.003-0.120
P. perfoliatus	0-0.60	9-69	0.2-0.5	0.004-0.027

(Source Mackay et al. 1999)

Simpson (1999) found that complex log-piles and individual logs larger than 300 mm diameter were preferred by cod over other habitat types. Undercut banks also frequently provided cover for cod, but usually only when submerged timber was also present. Sunken logs are also thought to be used for nest sites. Ranging from high gradient upland streams to slow flowing waterways in the lowlands, large, shaded pools form the preferred home range for the cod (Simpson and Jackson, 1996). The current distribution of the cod in areas of varied physico-chemical water quality conditions suggests that they do not have highly specific requirements in this regard. Water storage impoundments are thought to restrict the migratory and dispersal movements, and reduce the amount of accessible stream habitat. In addition, changes in flow regime and water temperature associated with river regulation may adversely affect populations downstream from storages (Smith and Jackson 1996). Over fishing also posed a threat to the recovery of the species until a prohibition was placed on this activity throughout the catchment. However, extensive land clearing leading to erosion and in-filling of pools and removal of riparian vegetation resulting in a reduction of shade cover and large woody debris inputs in watercourses are considered to be the major causes of the decline in distribution and abundance of cod (Simpson and Jackson, 1996).

Radio tracking of lungfish in the Mary has revealed a strong habitat preference for large macrophyte beds in 1.5 to 2.1 m of water during daylight hours. At night the fish move into riffle areas and shallow pools to graze on invertebrates (Peter Kind, PhD student Uni. Of Qld Pers. Comm. Conversation 1/2000). The species appears to be robust in terms of water quality requirements, with a significant population occurring in the macrophyte beds immediately below the Gympie Sewerage Treatment Plant outfall (Kind op cit.).

Their preference for sheltering in macrophyte beds may be a response to the significant riparian deforestation in the Mary. In the Burnett catchment they are more regularly found in the shade of the riparian zone cover, which is more plentiful in that river (Kind op cit.).

TABLE 4.5

Areas for Mary River Cod Habitat Rehabilitation and Protection

Areas	Locations
1. Cod habitat needing protection **(eg. Cod population in good habitat)**	1. **Six Mile Creek** from Lake McDonald to Mary River Junction . 2. **Tinana Creek** from mouth of Goomboorian creek (Anderleigh Rd) to Teddington Weir 3. **Coondoo Creek** from Windsors Rd to junction with Tinana Creek. 4. **Obi Obi Gorge** from Lake Baroon to Skene's Creek (or Baxter Creek). 5. **Amamoor Creek** from McGills Creek to Amamoor.
2. Cod habitat needs rehabilitation **(eg. Cod population in poor habitat)**	1. **Mary River** from 2 km above Cambroon Bridge, Kenilworth to Mary River Barrage, Tiaro. 2. **Widgee Creek** –End of Powers Rd to the Rock hole, Brooyar State Forest. 3. **Station Creek** from McCarthy's to Widgee Creek junction. 4. **Glastonbury Creek** from Pratt's Rd to Mary River junction. 5. **Munna Creek** between Sandy Creek and Miva Creek? 6. **Wide Bay Creek**. 7. **Kandanga Creek** from Harts to Mary River junction. 8. **Obi Obi Creek** above Lake Baroon. 9. **Six Mile Creek** above Lake Macdonald to Mountain Rd Xing. 10. **Lake Borumba** and **Yabba Creek** down to Imbil. 11. **Tinana Creek** above mouth of Goomboorian Creek.
3. Areas linking remnant cod locations **(eg. No recent records of cod but tracking research is showing the importance of fish passage.)**	1. **Obi Obi Creek-** Skene's Creek (or Baxter Creek) to the Mary R. junction. 2. **Yabba Creek** from below Imbil weir to Mary River junction. 3. **Widgee Creek** –Rock hole at Brooyar State Forest to Mary River junction. 4. **Munna Creek** from Miva Creek to Mary River junction. 5. **Amamoor Creek** from Amamoor town to Mary River junction. 6. 6. **Tinana Creek** below Teddington Weir to the Mary River and back up to Tiaro.

(Source: Pickersgill 1998)

Two crayfish with distributions restricted to the rainforest streams in the Conondale Ranges, are entered on the IUCN's red list of endangered fauna *(Euastacus hystricosus* – vulnerable and *Euastacus urospinosus* – endangered*)*. The first is commonly called a "lobster" and grows up to more than a foot long and weighs over 2kg, and was a popular food source for forest workers. A range of rare and threatened frog species have been recorded in the catchment including the Green–thighed frog *(Litoria brevipalmata* – rare) Cascade Tree frog (*Litoria pearsoniana – endangered*), Fleays Giant Barred-frog (*Mixophyes fleayi* – endangered), Giant Barred Frog (*Mixophyes □terates* – endangered), Southern Gastric-brooding frog (*Rheobactrachus silus* – endangered), and Southern Day frog (*Taudactylus diurnus*- endangered). Surveys to determine the distribution of these species are currently underway. The Department of Natural Resources has a data-base for habitat in State Forests (Figure 4.5).

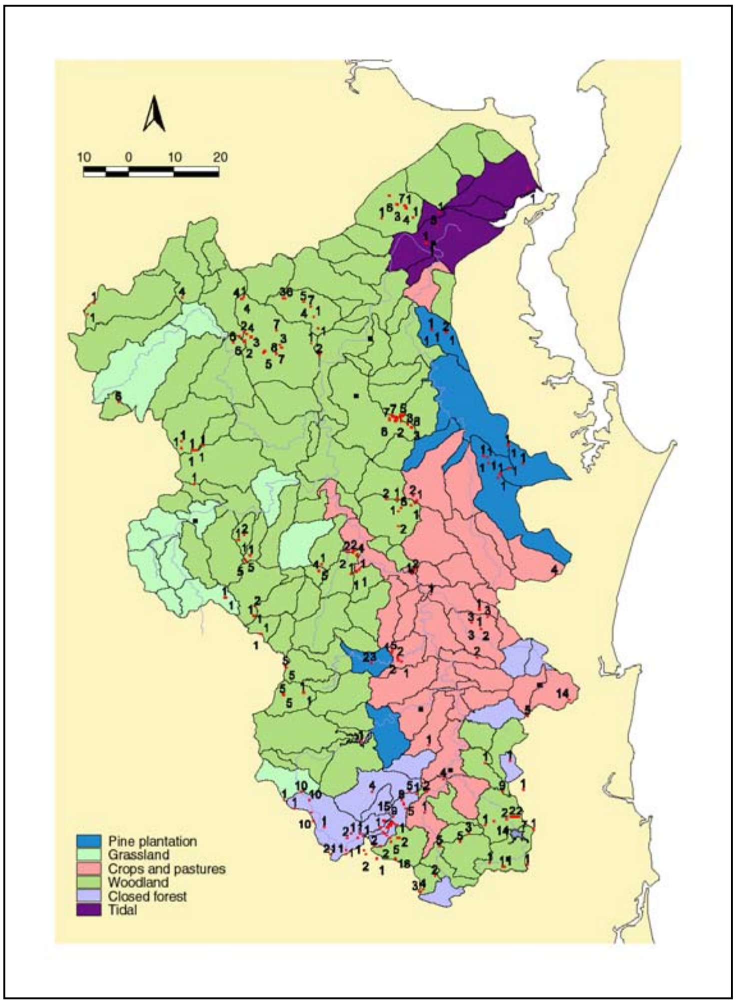


Figure 4.5 Known Distribution of Rare and Threatened Frogs
Each digit represents a species present in State Forest/NP in that locality
(Source: Marshall 1999).

4.11 Riparian Zone and Floodplain Wetlands

Intact riparian communities in the catchment can display a diverse floristic composition. In a study of one 3.5 ha riparian remnant community in the Gympie locality, Smith (1987) identified 66 major species in a notophyll vine forest community. However, the State of the Rivers report highlights the current rarity of such stands. Johnson (1997) revealed that the poor condition of the riparian zone related to a very poor riparian width and a high percentage of exotic species present. Vegetated riparian zones average 17 m across the catchment, ranging from 0.5 m in the main Mary River to over 50 m in a number of subcatchments. Erosion was recorded along 85% of the stream length with at least 13% of the banks being considered unstable.

O'Donnell (1996) surveyed 54 streambanks over a width of 25 metres and identified 119 species of terrestrial plants (excluding sedges and grasses), with the greatest species diversity occurring in the zone along the face of the streambank. Twenty–nine of these species, however, were woody and vine-type weeds. Vegetation structure type varied from predominantly dry sclerophyll river forest of *Eucalyptus, Callistemon, Melaleuca* and *Casuarina* in the north and west to mainly sub-tropical rainforest associations in the south and east (O'Donnell 1996). However, not all vegetation followed this climatic gradient with dry sclerophyll species colonising degraded rainforest areas and rainforest stabilising severe slips in the northern Maryborough area.

The most extensive survey of riparian condition was conducted by Pickersgill (1998), who has made a continuous recording (largely from canoe traverse) of riparian condition of over 300 kilometres of the Mary River and its tributaries. Riparian disturbance was ranked on a four point scale and the location of environmental weeds was noted. Her work identifies Cats Claw (*Macfadyena unguis-cati*), Madeira Vine (*Andera cordifolia*), Narrow leaf Privet (*Ligustrum sinense*), Broad leaf Privet (*Ligustrum lucidum*), Balloon Vine (*Cardiospermum grandiflorum*), Chinese Elm (*Celtis sinensis*) and Camphor Laurel (*Cinnammum camphora*) as weeds that are currently dominating native riparian vegetation in sections of the catchment.

Davies and Bunn (1999) work in the catchment has shown how light levels in undisturbed riparian zones with greater than 70% canopy cover restricts filamentous algae growth and invasive macrophytes in upland forested streams.

They found that disturbance that reduces riparian canopy cover below 60% causes the stream to shift from being a net consumer (P<R) to a net producer (P>R) of organic carbon. The dominant in-stream plant structure also shifts from microalgae, which is palatable to macroinvertebrates and fish, to the less palatable filamentous algae and macrophytes. They developed a predictive model that suggests that a major decline in stream health occurs with increased primary productivity when canopy cover is reduced to below 40-50%.

Remnant floodplain wetlands in the Mary are uncommon and are typically associated with paperbark (*Melaleuca quiquenervia*) woodland and forests. Catterall and Kingston (1993) predicted that all lowland *Melaleuca* forests in South East Queensland (outside of protected areas) would be cleared by the year 2004 and, according to Watt (1995), this vegetation association has suffered the greatest rate of loss of any in the region. Thomas (1997) conducted a botanical survey of three representative *Melaleuca* wetlands in the Six Mile Creek Catchment and identified the rare species *Symplocos harroldii* (listed Qld Nature Conservation Act 1992) and a number of other locally rare species. *Melaleuca* wetlands have also been identified as one of the most threatened vegetation communities on private lands in the Cooloola Shire in the centre of the catchment (Olsen, 1996).

4.12 Sociological Trends Influencing Restoration

The dedication with which local Landcare, Catchment Management and Councils have approached the restoration and management of waterways and riparian zones within the catchment has been widely acknowledged. Three Councils, two Landcare Groups, one Landcare Group Coordinator and the Mary River Catchment Coordinating Committee have all won State Landcare or Rivercare Awards for their efforts in restoring the catchment. Furthermore, the only two Councils in the State to receive "Waterwise" awards are also found within the boundaries of the Mary River Catchment.

Recent research has identified that the strength of Landcare groups in the catchment is at the local level, identifying priority issues and empowering local communities (Keith, 1999).

Focus group sessions revealed that the groups recognised the importance of the objectives of the MRCCC, but were largely autonomous in their selection of projects. While in ideal financial conditions approximately 30% of Landcare Group members surveyed would allocate resources to revegetation projects as their highest priority, only 20% would give a similar priority to riverbank stabilisation. Riverbank restoration was a low priority for respondents from groups centred off the main river (Barung, Gympie and Kilkivan) and a high priority for those on it (Kenilworth and Tiaro - Keith, 1999).

A survey in 1998 (Alliance Resource Economics, 1998) sought to identify how Integrated Catchment Management and Landcare activities had affected the management practices and attitudes of riparian landholders on the Mary River and its major tributaries. Encouragingly, respondents reported a 60% increase in riparian management practices in the last five years since the inception of the MRCCC, and foreshadowed that on average this would increase by a further 23% in the coming five years. The sample represented 19% of rural riparian landholders and revealed several interesting trends. The most significant trend is a striking linear relationship between increasing length of time on a property, increasing response rate and increasing relative level of implementation of riparian management practices (Figure 4.6).

When asked about their vision for the river, landholders ideally want to see significant improvement in environmental values, but their expectations of what would actually happen was significantly lower (Figure 4.7). Controlling access to stock and stock exclusion were the most popular practices in riparian areas, with weed control, tree planting and remnant protection also featuring highly in responses (Figure 4.8). A greater awareness of the issues is the strongest motivating force for better management, while family inheritance and making a profit were also important (Figure 4.9).

Riverbank stability and erosion was the highest ranked priority from a telephone survey of 115 riparian landholders in the lower Mary (Tiaro Landcare Group, 1998). Concerns about the raising of the barrage and weed problems were also highly rated by respondents who indicated that they were dissatisfied with strategies being implemented by government in this district. A high proportion of farmers (60-72%) involved in irrigated sugar, dairy and horticulture industries have also indicated that they have attempted to make improvements in their water use efficiency over the last five years (Wiggington and Raine, 1999).

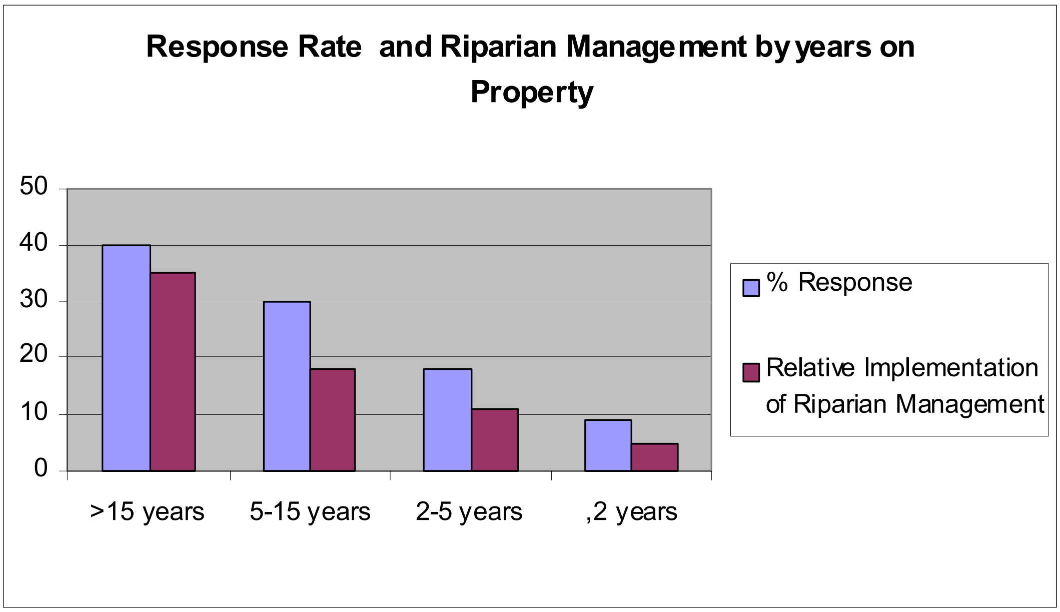


Figure 4.6
Graph depicting strong correlation between the length of time living on a property with the involvement in Riparian Landholder Attitude Survey and adoption of riparian management practices (from data in Alliance Resource Economics, 1998).

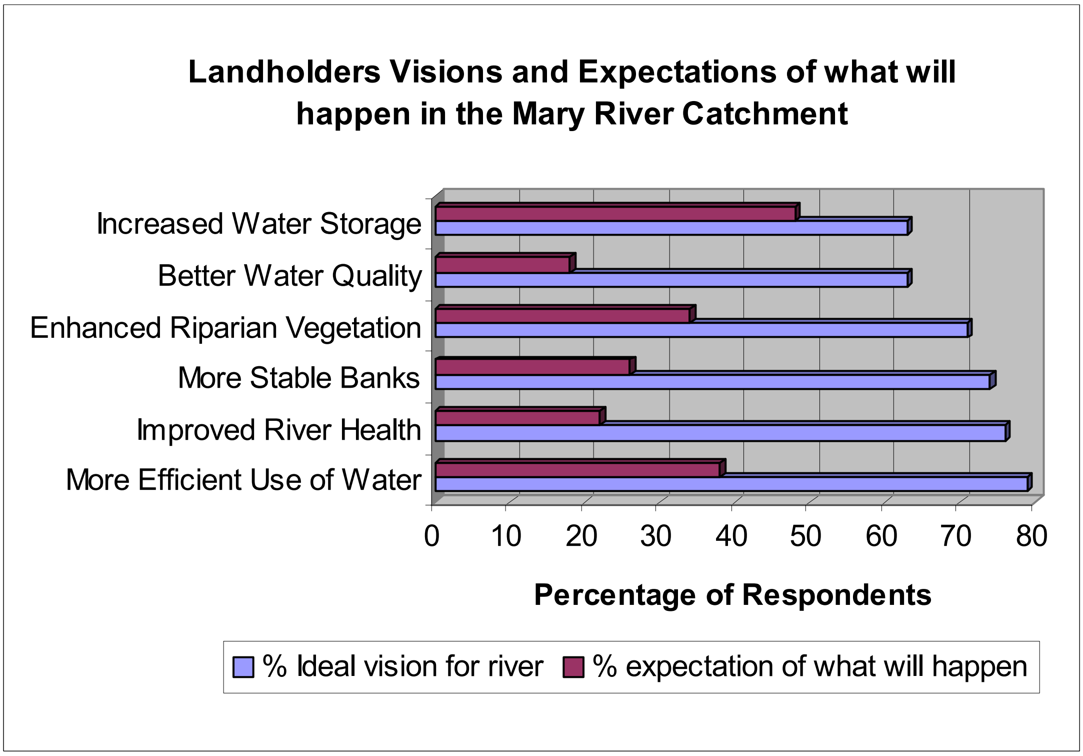


Figure 4.7

Mary River riparian landholders desired vision of the river and their expectations of what will happen (from data in Alliance Resource Economics, 1998).

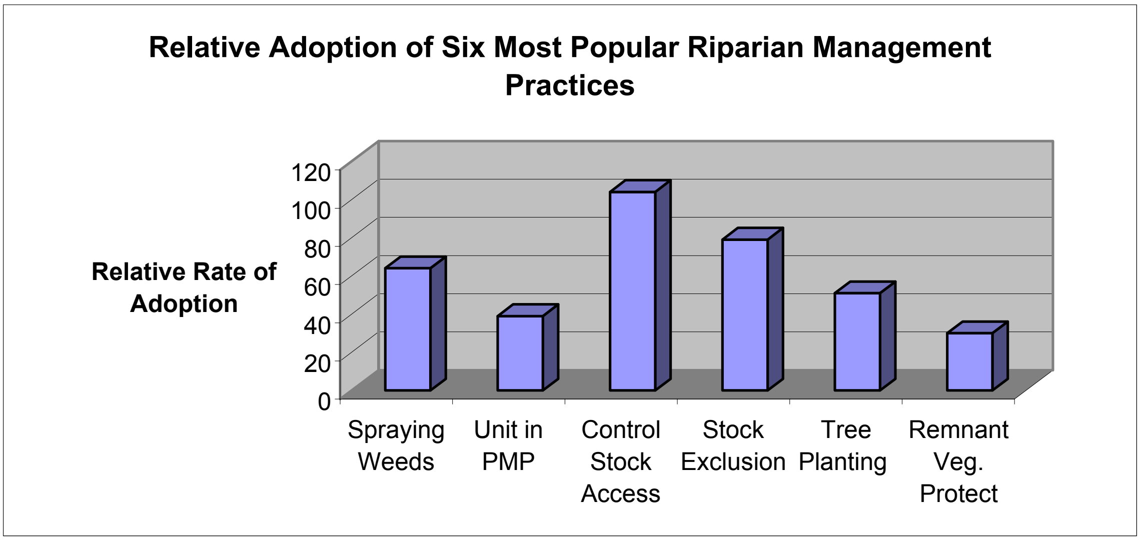


Figure 4.8
Six most common riparian management practices identified by riparian landholders in catchment and the relative rate of adoption of each (from data in Alliance Resource Economics, 1998).

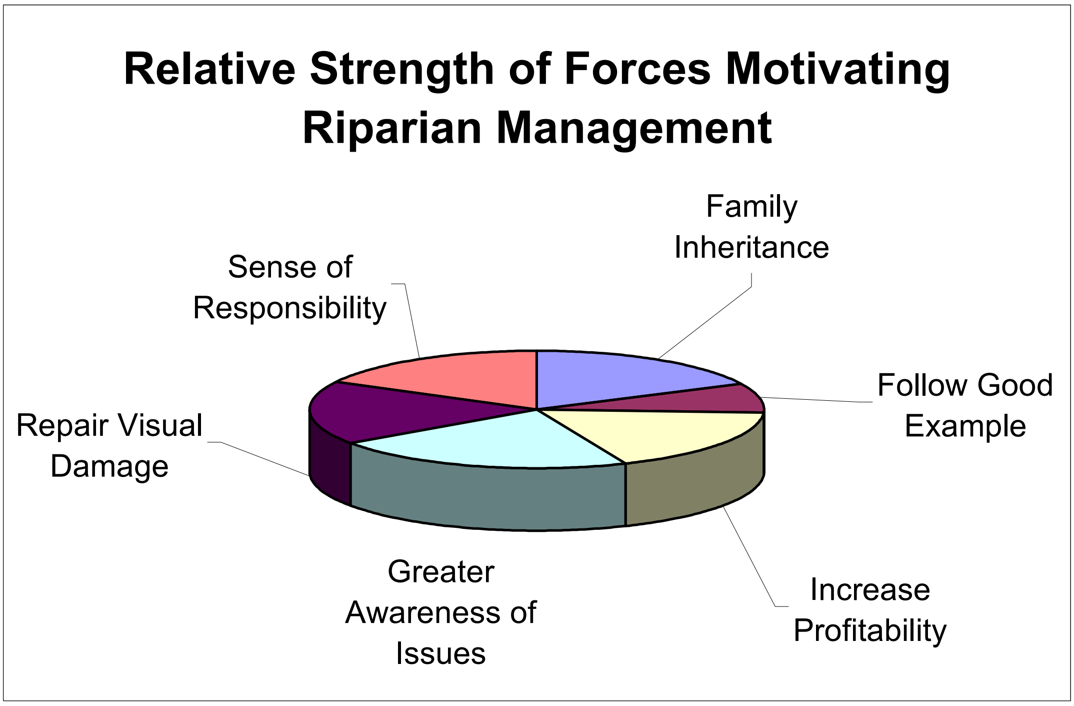


Figure 4.9
Relative strength of six most common forces motivating landholders to undertake riparian management practices in the Mary River Catchment (from data in Alliance Resource Economics, 1998).

5.0 MARY RIVER REHABILITATION PLAN

This section outlines the Mary River Rehabilitation Plan, and will be an evolving component of the publication as more information comes to light and experiences guides our practices. This plan implements elements of the Catchment Management Strategy and provides more specific direction and targeted actions for waterway rehabilitation and can be considered to be an action planning component of the Strategy.

5.1 Step 1 - Developing the Vision for the Mary River and its Tributaries

At a workshop of the Mary River Catchment Coordinating Committee the elements of a 50 year vision and 10 year goals for the rehabilitation of the waterways of the catchment were identified. The following vision and goal statements provide the guiding principles for the prioritisation of the river rehabilitation plan and were developed through a broad consultation process.

LIFE TIME VISION

In our lifetime the community will be enjoying the natural bounty of sustainable agricultural, fishing and recreational activities flowing from a healthy river system. Native forests growing on stable streambanks will shade the length of the river and all its creeks, where pools, riffles and snags interplay, to create diverse habitat for a myriad of life forms.

Sustainability Indicators to Measure Achievement of Vision

- *Water quality will be as clean as has been recorded in living memory.*
- *Major linkages will exist to allow aquatic and riparian fauna to move freely between conservation reaches, especially our rare and threatened fish, turtle, frog and bird species.*
- *The flow of water and sediments through the rivers and creeks will sustain the physical and biological needs of the riverine system, as well as the agreed sustainable requirements of the community.*
- *The community will be able to see, understand and value the changes and be proud of their role in achieving them. Each new generation will have a lifetime commitment to managing and restoring the catchment for their whole lifetime.*

GOALS FOR ACHIEVEMENT BY 2010

1. *CONSERVATION OF FLAGSHIP SPECIES*

   Remnant populations of the no longer endangered Mary River Cod will be expanding in the Mary River, Tinana, Six Mile, Amamoor and Obi Obi Creeks where they will enjoy well conserved and rehabilitated habitat.

Sustainability Indicators to Measure Achievement of Goal

- *Ample shade exists from streambank vegetation in target reaches.*
- *Abundant fish cover exists from natural and introduced snags in target reaches.*
- *Flow regimes that maintain water quality and facilitate migration through channels which permit the free passage of fish.*

2. *ESTUARINE ECOSYSTEM PRODUCTION*

   Best catchment management practises will restore the RAMSAR listed estuarine wetlands of the Lower Mary and protect a diversity of resident and migratory birds, and the nursery and recruitment areas used by a diversity of fish and other fauna.

Sustainability Indicators to Measure Achievement of Goal

- *Environmental flows entering estuary that mimic 'natural' seasonal flow regimes.*
- *Blockages to estuarine fish migration have been removed.*
- *Reduced sediment and nutrient loads during flushing flows.*

3. *PROTECTION OF REACHES OF CONSERVATION SIGNIFICANCE*

   All reaches of local or regional conservation significance on public land will be protected. Most similar reaches in private custodianship will be will be voluntarily protected by agreement or commitment.

Sustainability Indicators to Measure Achievement of Goal

- *All public conservation reaches will be managed to maintain and enhance riverine ecosystems and their scientific, recreational and intrinsic values.*
- *Most landholders who manage similar good quality remnants will be involved in voluntary protection measures through the provision of financial and other incentives that recognise the public value of their efforts.*
- *Active weed control programs will be under way in all reaches of conservation significance.*

4. HEALTHIER WATERWAYS

Sparkling, rippling streams, teaming with life, will become a more common sight throughout the catchment.

Sustainability Indicators to Measure Achievement of Goal

- *The diversity and abundance of stream bugs indicating good stream health will be increased in most reaches.*
- *Water quality will be improved in most reaches.*

5. RIPARIAN LANDHOLDER CAPACITY TO TACKLE DEGRADED REACHES

Assistance, advice and incentives to riparian landholders will ensure that over 1000 kilometres of riparian zone is managed for rehabilitation purposes. Revegetation, regeneration and physical recovery will begin to repair degraded beds and banks.

Sustainability Indicators to Measure Achievement of Goal

- *All riparian landholders will understand why it is important to manage and protect streambanks.*
- *Sufficient resources to ensure community empowerment, extension, facilitation, education and incentive programs can achieve the target of this goal.*
- *Riparian fencing will be erected on areas most at risk from grazing pressure.*
- *Strategic revegetation initiatives will have occurred in high visibility locations and adjacent to remnant sections of good riparian vegetation.*

6. ENVIRONMENTAL MANAGEMENT OF WATER SUPPLY STORAGES

All storages will be operated to achieve appropriate environmental flows. Potable water supply storages will have reduced blue-green algae, weed, bank erosion and public health hazards to manageable levels.

Sustainability Indicators to Measure Achievement of Goal

- *Major new water infrastructure (if any) will have demonstrated its compliance with sustainability principles as part of a participatory water resource planning process and recommendations of plan will be implemented in existing storages.*
- *Water quality in all storages will meet standards for contact recreation all year round.*
- *Aquatic Weed invasions will be actively controlled in all storages.*
- *Councils and State Government will actively work with Catchment Care or Landcare Groups to improve catchment management above all potable water supply storages or intake points.*

7. *FACILITATING NATURAL RECOVERY OF CHANNEL FEATURES*

Bed degradation in the Mary River will have been returned to natural levels, with terracing commencing to narrow over-wide reaches, and point bar, pool and riffle features re-establishing through natural fluvial processes.

Sustainability Indicators to Measure Achievement of Goal

- *Any extraction of river resources will only occur if in accordance with plans which set benchmarks for sustainable management.*
- *Sufficient sediment is maintained within the system to facilitate natural recovery of downstream bed instability.*

8. *AN EMPOWERED, COMMITTED AND CARING COMMUNITY*

An enlightened, aware and involved community with a common vision for the Mary River Valley will share an understanding of river processes to enable them to extend their contributions to the planning and implementation of effective and inclusive river restoration and rehabilitation programs.

Sustainability Indicators to Measure Achievement of Goal

- *An empowered community will ensure decision makers adequately river restoration and rehabilitation.*
- *Community-government partnerships are driving education, extension, rehabilitation and conservation actions.*

5.2 Step 2 - Who Shares the Goals for River Rehabilitation?

Getting broad acceptance of an agreed vision and a commitment to its achievement is an iterative process, which will be ongoing. Some perceived impediments to achieving the goals of the draft plan were identified through a brainstorming session conducted with the MRCCC. The summarised list of impediments identified in the workshop is contained in Table 5.1. The results outline the barriers to the achievement of an agreed vision, and the challenges required to be addressed for successful implementation of the river rehabilitation plan. This session followed the visioning session and what is most interesting is that not one person identified a lack of technical, scientific or management knowledge as a potential obstacle in the achievement of the vision. In other words they felt they had the knowledge of how it should be done, and that the goals were realistic and achievable, the major concern was that they were doing so in a socio-political system that did not adequately value what it was they were trying to protect and restore.

5.3 Step 3 - How has the Stream Changed Since European Settlement

The initial results of this step in the process were derived from the review of previous work in the catchment summarised in Chapter 3. This review identified the need for more detailed historical, geomorphic analysis and ecological analysis. The historical component was beyond the scope of this study. The preliminary reach boundaries used for classifying reaches of similar style and the location of sample sites are depicted on Figure 5.1 and described in the reach-by-reach summaries (Appendix 1). These summary sheets provide a snapshot of current and reference condition of the catchment based on original work undertaken as part of this project and a range of published and unpublished data cited in Chapter 4.

TABLE 5.1

Barriers and Challenges to be Overcome to Achieve Goals

Changing the Current Cultural and Economic Paradigm	Financial Impediments
❑ The need to achieve whole of community ownership of the river. ❑ The need to educate the entire community in order for the broad adoption of a philosophy that acknowledges that actions of the individual will affect the whole system and therefore pro-active initiatives will do the same. ❑ Biggest challenge will be convincing landowners that the riparian strip belongs to the stream and their activities should be in harmony with this – manage the strip for the river. ❑ Lack of appreciation of the importance and uniqueness of our native vegetation. ❑ The greatest barrier is the unfounded belief that we can have unending economic growth and at the same time maintain sustainability of our natural resources. ❑ Overcoming cultural conditioning and people's attitude. ❑ Acceptance that the responsibility for sustainable action starts with us.	❑ Lack of appreciation of the magnitude of the problem hence lack of resources. ❑ Difficulty in obtaining financial incentives. ❑ Lack of prosperity in rural sector to implement this. ❑ $ - Where landholders can't afford it. ❑ $ cost for fencing. ❑ $ cost for weed control. ❑ $'s to do the work required on riparian areas. ❑ Cost of retreating wastewater.

5.4 Step 4 - Identifying Streams Main Assets and Problems.

An asset for the purpose of this study is any aspect of the stream that is in good enough condition to meet the goals of the plan. Assets (Figure 5.2), including linked off-stream conservation assets (Figure 5.3 this map available for viewing only at resource Centre not in this publication), along with the problems and constraints that threaten them (Figure 5.4), are spatially identified in mapped format. Each reach summary sheet summarises the major assets, condition and problems (Appendix 1). Reaches sampled exclusively by other programs are not generally included in Appendix 1, as the unpublished data is provided to this project on a confidential basis.

5.5 Steps 5,6,7 - Setting Priorities, Developing Strategies & Detailing Objectives

The foregoing analysis has facilitated the prioritisation of reaches generally along the lines proposed by Rutherfurd et al. (1999 – Table 4.2). Some modifications to the suggested categories have been made to take into account Brierley's model (1999) and due to the fact that our understanding of the geomorphic processes as a result of this analysis has not in all cases allowed us to confidently assert the recovery potential and trajectory of all reaches. Prioritisation is generally on a reach-by-reach basis. Reaches are delineated on long profiles of the river and creeks and photographed (Appendix 1). Considering the significant length of the Mary River that is highly degraded, "Remnants" of better quality remnant sections are separately prioritised in some of these reaches, to focus rehabilitation effort from enthusiastic community groups in the locality. These Remnants may represent a reasonable target condition for the remainder of the surrounding reach. A list of generic strategies has been developed in Table 5.2 for application across a range of priority categories. The level of rehabilitation proposed (ie. whether the strategies are aiming at restoration, reclamation, rehabilitation or stabilisation) and the desired target condition – reference stream is outlined in Table 5.3. Reaches are grouped in priority categories, problems are briefly stated in priority order and strategies and objectives enumerated in Table 5.4. These priorities are mapped in Figure 5.5.

5.6 Conclusions

The extensive review of literature and broad data collection undertaken have provided a solid base upon which to formulate the river rehabilitation plan, and will provide a baseline against which future activities and outcomes can be evaluated. The principles and elements of the Rehabilitation Manual for Australian Streams (Rutherfurd, Jerie and Marsh 1999) have provided a successful framework upon which to develop a catchment-wide river rehabilitation plan. The plan encourages prioritisation of effort on a reach-by-reach basis and provides a strategic direction for future implementation projects. If this direction is followed the future focus will be on areas that have existing or potential biological value and a reasonable potential to recover from disturbance through rehabilitation effort. The goals, strategies, objectives and overall settings of this plan suggest a significant change in the way rehabilitation is undertaken in the catchment. A participative process has also encouraged a group of partners into a proposed consortium to implement the plan (Figure 5.6).

TABLE 5.2
List of Strategies Used in Rehabilitation Plan

Code #	Strategy	Related Actions	By Whom	Relevant Guidelines
	VEGETATION			
VA Riparian Management	Maintain adequate riparian buffers and erect riparian fencing and exclude or actively manage stock access to stream, include provision for off-stream watering and shade, and hardened access points.	1. Implement Plan through Rivercare Grants Scheme.	Landholders MRCCC Landcare	Stock Management Section WCMM. Industry Codes
VB Conserve Remnants	Provide incentive, advice and encouragement for riparian landholders to retain and manage all existing native vegetation within riparian buffers, actively conserve key areas.	1. Implement Plan through Rivercare Grants Scheme. 2. Development permits to restrict clearing within riparian areas. 3. Provide Nature Conservation Rate Rebates, VCA's, and Advice.	MRCCC NR&M Councils MRCCC Councils	Mary Rivercare Grants Brochure Fauna & Flora Section WCMM
VC Revegetation	Implement revegetation initiatives, focussing on building linkages with remnants of conservation significance, or in good condition, and increasing vegetation on floodplains and hillslopes to slow the flow of water and reduce the power of flood events.	1. Implement Plan through Rivercare Grants Scheme.	Landholders MRCCC Landcare	Fauna and Flora Section WCMM
VD *Weed Management	Control aggressive environmental weeds, commencing with those threatening reaches of regional or local conservation significance, then good remnant areas, etc.	1. Implement Plan through Rivercare Grants Scheme. 2. Implement SEQ Environmental Weed Strategy.	Landholders Councils	Weed & Pest Section of WCMM
VE *Assisted Regeneration	Facilitate regeneration and other low cost vegetation establishment techniques (eg. direct seeding, strategic seed tree planting, cuttings etc) by exclusion of stock, control of weeds and management of access by heavy equipment in riparian zones and channels.	1. Implement Plan through Rivercare Grants Scheme.	Landholders	Above Sections of WCMM
	FISH AND FLOW			
FA Fishways	Construct fishways with rock ramps or LWD at road crossings, weirs and other hydraulic jumps, starting at strategic blockages between known cod habitats	1. Advocate to NR&M and DPI Fisheries the need for fishways on all passage blocking structures.	MRCCC NR&M DPI	
FB Environmental Flows	Return critical elements of natural flow regime, by modifying flow releases, or modifying channel to produce desired flows.	1. Implement the Water Resources Plan and assess all applications for new allocation against it or appropriate analysis.	NR&M	WRP Works

FC Resnagging	Implement strategic LWD resnagging projects to increase fish habitat and geomorphic diversity and stabilising banks and beds where possible.	1. Implement Plan through Rivercare Grants Scheme.	MRCCC	LWRRDC Excerpt in WCMM
FD Restocking	Restock Mary River Cod fingerlings in suitable reaches of regional or local conservation significance and other good remnants and rehabilitated areas.	1. Implement Mary River Cod Recovery Plan.	DPI Fishery Lake Mac. Hatchery	
FE Remove Impediments	Remove unsustainable, unviable structures in waterways that inhibit fish passage and impact on natural flow regime, or construct fish ladders on productive structures.	1. Raise issue in WRP and ROP planning process.	MRCCC	
FF Fish Passage	Review guidelines for minor weir approvals and develop code for assessment of applications that ensures fish passage requirements are met for all new approvals.	1. Negotiate with NR&M and DPI Fisheries to implement strategy.	MRCCC NR&M DPI Fishery	
FG Cod Habitat	Encourage the retention of habitat potentially suitable for Mary River Cod.	1. Implement Cod Recovery Plan.	Recovery Team WWF MRCCC	Waterways Section WCMM
	WATER QUALITY			
WA Wastewater Treatment	Progressively upgrade all pollution treatment plants to include tertiary treatment and water reuse to ensure all point source pollution sources meet EPA guidelines.	Encourage Councils through the ICM process to implement Catchment Strategy &EPA recommendations.	MRCCC EPA Councils	EPP Water
WB Stormwater Management	Adopt urban stormwater management systems including reuse options from detention ponds, to reduce diffuse source urban pollution.	As above	As above	EPP Water
WC Wetland Rehabilitation	Restore and construct wetlands to intercept runoff and remove pollutants prior to entering streams, stock wetlands with native macrophytes to assist in process.	1. As above for urban locations. 2. Implement Plan through Rivercare Grants Scheme.	As above Landholders	
WD Road Crossing	Redesign fords and culverts on forest stream roads to reduce blockage of flow and animal migration and reduce sediment entering streams directly from roads.		EPA Forests Councils	
WE Water Quality Grants	Provide incentives to primary producers to upgrade equipment to ensure all waste waters are reused in a sustainable manner to minimise nutrients entering streams.	1. Implement Plan through Rivercare Grants Scheme.	MRCCC Landholders	
WF Unregulated Flows	Review licence conditions and riparian water rights in unregulated tributaries to reduce dissolved oxygen and salinity problems that may result from abstraction.	1. Discuss issue with NR&M with a view to developing appropriate standard conditions.	MRCCC NR&M	

WG Sediment Control	Require all infrastructure construction authorities to ensure appropriate sediment and erosion control regimes are incorporated into contracts for stream crossings.	1. Raise issue with NR&M and in Mayors Forum for implementation of proposals.	MRCCC NR&M Councils	
WH Riparian Code of Practice	Review Native Forest & Plantation Management code and Agricultural Codes of Practice to ensure they meet best practice with respect to riparian buffer widths and forestry track construction and harvesting in steep unstable areas, and audit practices to ensure compliance.	1. Negotiate with EPA, NR&M, DPI and Industry Bodies to enhance riparian measures within codes or practice.	MRCCC	
	PHYSICAL STABILITY			
PA Channel Recovery	Allow over-wide reaches to narrow through retaining point bar and mid-channel deposits and allowing natural regeneration of pioneer species to trap sediments.	1. Work with NR&M and Extractive Industry to develop and distribute relevant fact sheets.	MRCCC NR&M	RQM Guidelines DNR Web Site.
PB Extraction Management	Progressively reduce sand and gravel extraction permits to a sustainable limit, in areas with active bed lowering a sustainable limit may equate to no extraction.	1. Liaise with NR&M and Extractive Industry regarding the development and implementation of the Mary River Sand and Gravel Extraction Plan and State Riverine Quarry Material Guidelines.	MRCCC NR&M	
PC LWD Placement	Utilise LWD replacement to stabilise beds, low to moderate bank erosion, create scour pools, encourage channel realignment away from erosion prone banks and to increase local geomorphic complexity.	1. Implement Plan through Rivercare Grants Scheme.	MRCCC Landholders Landcare	LWRRDC Excerpt in WCMM
PD Riffle Construction	Reconstruct riffles when pool riffle sequence is degraded to increase local geomorphic complexity.	1. Implement Plan through Rivercare Grants Scheme.	MRCCC Landholders Landcare	Case Studies in WCMM
PE Bank Stabilisation	Where protection of failing banks is considered important to save high value habitat, vegetation or infrastructure and LWD or other natural materials are considered unsuitable, use rock toe stabilisation and revegetation methods with subsurface drainage where required.	1. Implement Plan through Rivercare Grants Scheme.	MRCCC Landholders Landcare	
PF Channel realignment	Where channel realignment training is required and the stream is too large for LWD techniques use best practice techniques eg. appropriate rock, timber pile groynes or mesh embayments.	1. Implement Plan through Rivercare Grants Scheme.	MRCCC Landholders Landcare	
PG Rock Ramps	To stop head cuts retreating up tributaries construct rock ramps or bed chute and drop structures if necessary to control bed slope grade.	1. Implement Plan through Rivercare Grants Scheme.	As above	
PH Channel	Where channel narrowing is desired as part of strategies PC, PD, PE, and PF, width needs to be decreased by only 5-10 m at a time. Further narrowing	1. Implement Plan through Rivercare Grants Scheme.	As above	

Narrowing	should only be attempted once the reclaimed area has undergone sedimentation and vegetation is taking hold.			
PI Boat Wash Reduction	Reduce impacts of boat wash on stream banks, especially areas where dispersive soils increase hazard.	1. Negotiate with Department of Transport regarding appropriate controls on Boating activity to	MRCCC Tiaro Landcare	
PJ LWD Retention	Encourage through education and statutory controls the retention of all LWD in the river system and retain all LWD within riparian zones to increase the habitat and stability within stream channels.	1. Liaise with NR&M and Councils regarding appropriate controls on LWD removal from streams and Riparian zones.	MRCCC NR&M Councils	
	GENERAL			
G1 Rivercare	Develop detailed reach-by-reach Rivercare Plans for priority reaches in conjunction with riparian landholders and local Landcare and Catchment Care Groups.	1. Maintain ongoing funding for existing Rivercare Program	NR&M	
G2 Water Planning	Minimise inter-basin transfers of water by taking long-term approach of facilitating good Local Government Planning that acknowledges the goals of this plan.	1. Participate actively in Water Resource Planning process.	MRCCC NR&M	
G3 Water use Efficiency	Minimise demands for, and defer construction of, new major instream impoundments by introducing urban and rural water re-use and water use efficiency, and encouraging sustainable water harvesting and off-stream storage.		MRCCC Councils	AWA Kit Waterwise Brochures
G4 Monitoring & Evaluation	Monitor and evaluate all restoration and rehabilitation strategies using similar methods undertaken in the conduct of this study on key sites to detect change.		MRCCC CRC Waterwatch	
G5 Capacity Building	Continually enhance the capacity of the community to be involved in river rehabilitation through education, extension, and motivating people to adopt a culture of care for our waterways and catchment.	1. Implement relevant sections of the Catchment Management Strategy.	MRCCC Landcare Education Dept.	
G6 Partnerships	Enhance collaborative partnerships for river rehabilitation through Mayors Forum, Researchers Forum Congress etc	1. Implement relevant sections of the Catchment Management Strategy.	MRCCC Landcare Councils	
G7	Encourage good farming practice , particularly on floodplains and steep slopes, which reduces the rate of soil loss to below that of natural soil forming processes.	1. Liaise with industry to ensure Codes of Practice minimise the amount of soil borne nutrients and contaminants entering waterways.	MRCCC Industry	Codes of Practice
G8	Prepare a Salinity and Water Quality Action Plan for Catchment	1. Liaise with Burnett Catchment to form regional NAPSWQ group.	MRCCC	NAPSWQ Guidelines

Note: WCMM is the acronym for MRCCC's Watercourse Management Manual

TABLE 5.3
FEASIBLE RECOVERY PATH AND TARGET REFERENCE CONDITION

REACH	RESTORE PRESERVE Almost Intact	RECLAIM Minor Disturbance	REHABILITATE Crossed One Critical Threshold	STABILISE Crossed Many Critical Thresholds	REFERENCE REACH Target Condition
PRIORITY 1 – PROTECTED REACHES IN GOOD CONDITION THROUGHOUT					
Booloumba 1	■				**Booloumba 1**
Gheerulla 1	■				**Gheerulla 1**
Belli & Cedar 1	■				**Belli & Cedar 1**
Kandanga 1	■				**Kandanga 1**
"Lagoons" Wetlands	■				**"Lagoons"**
PRIORITY 2 – UNPROTECTED REACHES OF REGIONAL CONSERVATION SIGNIFICANCE.					
Geraghty's 1		■			**Booloumba 1**
Kilcoy 1		■			**Booloumba 1**
Scrubby 1		■			**Booloumba 1**
Amamoor 1		■			**Booloumba 1**
Obi Obi 3 (not dam)		■			**Booloumba 1**
Belli & Cedar 2		■			**SF Sections**
		■			**SF Sections**
Six Mile Creek 2,3,4		■			**SF Sections**
Tinan 2		■			**SF Sections**
Mary 14		■			**Lower Baffle Ck**
PRIORITY 3 - REACHES OF LOCAL CONSERVATION VALUE					
Mary 1			■		**Geraghty's 1**
Mary 3			■		**Kilcoy 1**
Elam 1			■		**Booloumba 1**
Lit Yab 1,2			■		**Booloumba 1**
Gheer 2			■		**Belli & Cedar 2**
Tinan 1			■		**Tinan 2**
Gutchy 1,2,3			■		**unidentified**
PRIORITY 4 - DETERIORATING STRATEGIC REACHES					
Obi 1,2			■		**Elam 1**
Yabba 1			■		**Amamoor 1**
Yabba 2				■	**#1**
Amamoor 2				■	**Amamoor 1**
Six 1			■		**Six Mile Creek 2**
Deep 1			■		**Tinan 1**
Mary 12				■	**#1**
All degrading 1st & 2nd Order streams				■	
PRIORITY 5 – LINKING REACHES REACHES AND SIGNIFICANT REMNANT SECTIONS					
Mary 2			■		**End of Mary1**
Obi 4			■		**Lit Yab 1,2**
Yabba 3,4			■		**Lit Yab 1,2**
Kand 3			■		**End of Amam 2**
Amam 3			■		**End of Amam 2**
Six 5			■		**Six 2 SF Section**
'Remnant' in Mary 5			■		**Mary 3**
'Remnant' in Mary 7			■		**Mary 3**
'Remnant' in Mary 9			■		**#2**
'Remnant' in Mary 10			■		**#2**
'Remnant' in Mary 11			■		**#3**

Table 5.3 continued.

REACH	RESTORE Almost Intact	RECLAIM Minor Disturbance	REHABILITATE Crossed One Critical Threshold	STABILISE Crossed Many Critical Thresholds	REFERENCE REACH
PRIORITY 6 - REACHES WITH MODERATE RECOVERY POTENTIAL					
Mary 5					**Remnant in M5**
Mary 8					**#2**
Mary 13					**#2**
Kand 2					**Kand 3**
Deep 2					**Deep 1**
Tinan 4					**#2**
PRIORITY 7 REACHES WITH LITTLE CHANCE OF NATURAL RECOVERY					
Mary 4					**#3**
Mary 6					**#3**
Mary 7					**Remnantin M7**
Mary 9					**#3**
Mary 10					**Remnant in M10**
					Remnant in M11
Deep 3					**#2**
Tinan 3					**# Tinan 1**
Offstream Wetlands					**"Lagoons"**

Notes:
1. Black shaded area represents the desired type of restoration aimed at for each reach.
2. Refer to Chapter 2 and Figure 2.1 for precise meaning of rehabilitation types.
3. SF Sections refers to intact segments of the reach bounded by State Forest (both sides if possible)
4. # 1 Target condition for ponded areas is well vegetated riparian zone, rare occurrence of blue green algae outbreak, and no additional stream bank erosion on impoundment margins, minimal infestation of aquatic weeds.
5. # 2 Target condition for these degraded river and creeks where not over-wide may be gained from a reach of similar stream order in the Logan/Albert system, but shall generally included well vegetated (3 tiered native plants) riparian zones to a distance at least equivalent to the height of the bank, bank from the top of the bank, bed and bank will be stable and meander migration rates approaching Australian average, water quality should be within ANZECC guidelines and SIGNAL scores exceeding 5 on all occasions, with in-stream habitat of moderate geomorphic and biological complexity.
6. # 3 Target condition for degraded rivers and creeks that are over-wide are similar to #2 except the target cross section of the channel will be stepped with new in-channel benches formed and vegetated. The target width of the stream between these benches should be no more than 150% of predisturbance width estimated from old channel cut-offs, remnant channels etc.

TABLE 5.4 River Rehabilitation Plan

Reach Prioritisation, Strategies and Objectives

(click here for Table 5.4)

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Glossary of Terms

MRCCC	Mary River Catchment Coordinating Committee
DNR *now* **NR & M**	Department of Natural Resources
NR & M	Natural Resources & Mines
RQM	Riverine Quarry Material
DPI	Department of Primary Industries
EPA	Environmental Protection Agency
EPP	Environmental Protection Policy
WWF	World Wide Fund for Nature
WCMM	Mary River Catchment Watercourse Management Manual
LWRRDC	Land & Water Resource Research & Development Corporation
CRC	Cooperative Research Centre
AWA	Australian Water Association
NAPSWQ	National Action Plan for Salinity and Water Quality

Figure 5.1 Map - Location of Geomorphic Reach Types and Sample Sites

(click here for map)

Figure 5.2 Map - Assets of the Mary River and Tributaries

(click here for map)

Figure 5.3 Map - Endangered and Threatened Ecosystems in the Mary River

(Map not available)

Figure 5.4 Map - Problems and Constraints of the Mary River

(click here for map)

Figure 5.5 Map - Reach Priorities for the Mary River Catchment

(click here for map)

APPENDICES

Appendix 1 Reach Summary Sheets

(click here for appendix 1)

Appendix 2 Literature Review – River Processes and Rehabilitation

(click here for appendix 2)