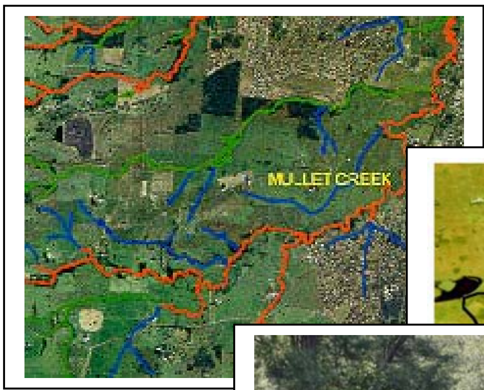
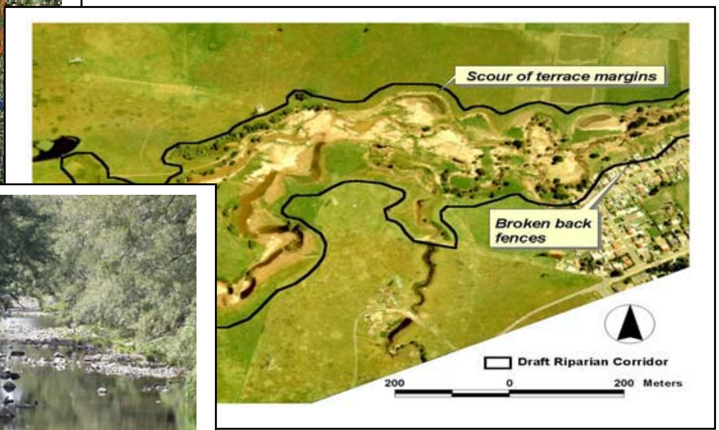
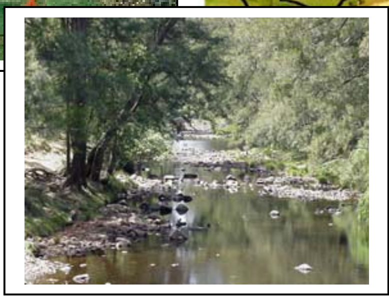
RIPARIAN CORRIDOR MANAGEMENT STUDY



Objective setting



Mapping



Implementation

COVERING ALL OF THE

WOLLONGONG LOCAL GOVERNMENT AREA

AND

CALDERWOOD VALLEY IN THE SHELLHARBOUR LOCAL GOVERNMENT AREA

Prepared for Wollongong City Council
by the Department of Infrastructure, Planning and Natural Resources
March 2004

ACKNOWLEDGMENTS

The Department of Infrastructure, Planning and Natural Resources (previously known as the Department of Land and Water Conservation) on behalf of Wollongong City Council prepared the Riparian Corridor Management Study. The study team consisted of Glenn Adamson, Martin Bergs, John Bucinskas, John de Groot, Janne Grose, Chris Page, Ivars Reinfelds, Matthew Russell, Merrin Tozer and Mark Watson. This team also ensured integration of a broad range of technical expertise was embedded into this body of work. The input received from various staff members, other agencies, Council and the community has added to the robustness of the Study.

FOREWORD

There is a growing awareness and value placed upon the natural processes and functions of the watershed catchments within which we all live, work and play.

Within catchments a variety of landowners, stakeholders and user groups seek continuity and viability in their pursuits. Most of these pursuits and aspirations lead to pressures, conflict, as well as exposure to natural processes, hazards and risks if not properly planned and managed. The popular saying, *"failing to plan is planning to fail",* rings true when looking at many existing riparian corridor problems.

The findings of various reports recently prepared by the NSW Healthy Rivers Commission point to an emphasis upon riparian management as a central issue to bed and bank stability, water quality, biodiversity and environmental corridor functioning to ensure long term health of our catchments. The Commission of Inquiry into the Long Term Planning and Management of the Illawarra Escarpment of 1999 also recognised the inherent value of riparian corridors. More recently, the Catchment Blueprint prepared by the Southern Catchment Management Board in 2002 reinforces the importance of riparian corridor management as a key natural resource issue of the Illawarra. Even more contemporary are the findings and recommendations of the Commission of Inquiry into Certain Land at Sandon Point. The Commission's findings send a clear message to the legitimacy of planning for riparian functions within landuse and development decisions.

Riparian corridor management has multi faceted components within landscapes. It is envisaged that this study will set an overarching direction in relation to how government agencies should make decisions. The study will also improve the awareness of the broader community and landowners as to the relative importance of riparian corridors in their neighbourhoods and on their property.

Long term sustainable riparian corridor management outcomes are, above anything else, a shared responsibility of government, community and industry.

This Riparian Corridor Management Study presents an opportunity for stakeholders to understand riparian corridor management issues at a catchment level. More importantly the study provides a process to establish priorities and achieve positive outcomes being sought for riparian management. Healthy and functioning catchments lend themselves to healthy urban settlements and rural pursuits.

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

The Riparian Corridor Management Study (ie the Study) has been prepared in response to the 1999 Commission of Inquiry into the *"Long Term Planning and Management of the Illawarra Escarpment"*. The Study area includes all of the Wollongong Local Government Area and Calderwood Valley, which spans both the Wollongong and the Shellharbour Local Government Areas.

Three categories of riparian environmental objectives were developed for the streams in the study area that reflect their relative environmental significance and these categories, in order of importance, are:

Cat. 1. *Environmental Corridor* – provide biodiversity linkages ideally between one key destination to another, (the coast and the escarpment, or large nodes of vegetation).

Cat. 2. *Terrestrial and Aquatic Habitat* – provides basic habitat and preserves the natural features of a watercourse (not necessarily linking key destinations).

Cat. 3. *Bank Stability and Water Quality* – has limited (if any) habitat value but contributes to the overall basic health of a catchment

For each of the above categories, the recommended minimum width of the riparian zone varies in order to achieve the functioning identified by the objective being sought. All of the streams in the study area were allocated a category (ie objective) and presented on maps shown in Appendix A.

Further detailed delineation and mapping of the actual key riparian corridor boundaries was undertaken for three catchments:

- *Mullet Creek,* a "greenfield site" earmarked for potential urban development;
- *Towradgi Creek,* an urbanised catchment; and
- *Calderwood Valley* (Duck and Marshall Mount Creeks) a rural area that is partly in both the Wollongong and the Shellharbour Local Government Areas.

The mapping was undertaken using a Geographic Information System with high resolution aerial photography and Digital Elevation Models and reflects the natural resources of the streams and the influence of a combination of known flooding and the geomorphology of the streams. Historical photos also assisted this process. The mapped detailed extent of riparian corridors are shown in Appendix B. Ideally this level of detailed mapping should be undertaken for all of the catchments as it provides certainty for stakeholders on what land needs to be managed in a way that reflects its inherent environmental or catchment functioning and what land is available for other purposes such as development. Detailed corridor mapping also resolves any anomalies that may arise from the broader scale objective mapping.

General principles were developed to manage riparian land and to ensure environmental significance was not compromised. Three natural resource management zones that should be identified at an early planning stage and integrated into decisions and future management are the:

(a) *Core Riparian Zone* which is ideally fully vegetated with local provenance vegetation,
(b) *Vegetated Buffer* which is not necessarily as heavily vegetated and protects the core riparian zone from edge effects such as weed invasion, and
(c) *Asset Protection Zone* also known as a fire protection zone which has reduced vegetation to help protect adjacent assets from bushfires (eg housing).

The relationship between these key features is shown on representative cross sections in Appendix C and with careful planning, the zones can complement each other and eliminate potential conflict between competing requirements.

The Study has made five recommendations that, if adopted, will provide recognition of the significance of riparian land and provide a logical framework to allow riparian land to be protected and properly managed. Those recommendations are:

(i) Establish environmental objectives for riparian land
(ii) Map the environmental objectives of all streams
(iii) Map riparian corridors prior to rezoning/redevelopment
(iv) Establish management zones and guidelines for riparian land
(v) Incorporate the envisaged riparian outcomes into the floodplain management planning process

By adopting the procedures developed in this Study, riparian management can readily be incorporated into planning instruments such as Local Environmental Plans and Development Control Plans and Developer Contribution Plans. This would provide a degree of upfront certainty and a legislative base for the protection, implementation and management of riparian land outcomes.

Floodplain risk management and riparian corridor management are interlinked and any action undertaken impacts on both. Therefore proposals for changes to the riparian corridor should consider the potential for impacts on flood risk in relation to the NSW Flood Prone Land Policy. Council therefore, in developing its floodplain risk management studies and plans should consider proposed changes in the riparian corridor is assessing and managing flood risk. The major implications of this riparian corridor management study with regard to flood risk management is that:

- it is critical that an integrated approach to floodplain risk and riparian corridor management is pursued if the objectives of both policies are to be realised; and
- implementation of riparian management strategies should be undertaken in such a manner so as not to make flooding worse to existing flood liable development.

The Study also provides a strategic framework within which investments in environmental improvement works can draw priorities from. The degree or extent of restoration or rehabilitation works can also gain from this study.

Above all, the Study provides a vision for the long term sustainable healthy functioning of our waterways and catchments.

2. INTRODUCTION

The Riparian Corridor Management Study (ie the Study) develops a three tier process that:

1. Develops three levels of environmental objectives for riparian land based on the relative importance of the watercourse and assigns a value (ie Category 1, 2 or 3) for all streams within a catchment in a map form.
2. Develops a mapping technique to delineate the actual riparian boundaries for major watercourses.
3. Delineates idealised cross-sections and plan views of the implemented riparian outcomes.

The mapping process can input directly into the preparation of Local Environmental Plans in particular to ensure the environmental significance of riparian land is recognised (through appropriate zoning) and preserved through the planning process.

The process is simple, cost effective and provides certainty on what land can be developed for urban use and what land must be managed as an environmental asset for present and future generations. It is important to recognise that existing use rights prevail under legislation. Nonetheless, awareness of the values of local waterways should be reflected in management practices.

(A glossary of terms is provided on page 36 to assist the reader to understand some of the more technical terminology contained in this report).

2.1 Background

The Study has been prepared in response to the 1999 Commission of Inquiry (COI) into the "*Long Term Planning and Management of the Illawarra Escarpment*" which recommended that, amongst other studies, "*a plan identifying riparian and desirable green corridors*" be prepared.

The Study applies to riparian lands in the Wollongong Local Government Area (LGA) and Calderwood Valley that straddles the Shellharbour LGA (see Figure 1) and is one of eight complementary studies that together will form the "*Wollongong Local Government Area Landuse Constraint Study*". The studies will provide significant input into an *Illawarra Escarpment Management Plan* which is to be prepared by Wollongong City Council.

The COI acknowledged that the then Department of Land and Water Conservation, given its technical capacity, should be the key coordinator for the Riparian Corridor Management Study. In preparing the Study consideration has been given to the COI report, current natural resource legislation, policy directions, scientific literature and other relevant reports.

2.2 Commission of Inquiry

The Commission of Inquiry (1999) was established to investigate and find solutions to issues relating to the management of the Illawarra Escarpment and adjoining foothills.

Specific Terms of Reference for the COI required the Commissioner to determine where "core escarpment lands" occur, what criteria established them and to consider appropriate management recommendations for these lands. The Commissioner was also required to review existing land use planning and development controls for the "core escarpment lands" as well as those lands considered to be important to the maintenance of the core areas.

The COI found the Illawarra Escarpment and adjoining foothills need to be planned, conserved, protected and managed as a single entity. The COI highlighted the need for both Local and State Government to be more effectively involved in future planning and management and that ad hoc development led to significant incremental losses in environmental quality.

The Inquiry also considered the information base to be inadequate on which to make informed decisions regarding the impacts on streams and terrestrial habitat within the local government ***area*** (LGA). This situation has now improved with the completion of detailed vegetation mapping by the National Parks and Wildlife Service for the Wollongong LGA (NPWS, 2002), and the availability of high resolution orthorectified aerial photography of the entire LGA by Wollongong City Council.

2.2.1 Recommendations of Commission of Inquiry

In relation to riparian land, the COI found "*there is a need to identify and strengthen the protection of riparian corridors having regard to their significant contribution to the long term health of the catchment*".

The COI made three recommendations with respect to riparian land:

- 1(d) a plan identifying riparian land and desirable green corridors be prepared.
- 5(g) Council's compensatory excavation policy be discontinued and a minimum setback of 40 metres from the top of the creek bank should apply to all developments, particularly those in the southern part of the catchment.
- 6(e) the criteria for identifying land to form 'core escarpment lands' should include generally undisturbed riparian areas to at least 40 m from top of creek bank.

In relation to Recommendation 5(g), the COI recognised that:

- it is not possible to provide a 40 metre set back from either side of the top bank of watercourse in all parts of the LGA (especially in existing urban areas), and
- wherever possible this setback requirement should apply in developed areas to minimise further encroachment on riparian corridors and prevent further deterioration of existing environmental conditions.

The Commissioner also agreed there is a need to:

- identify riparian corridors;
- determine set back requirements;
- examine their environmental conditions and establish whether an increase of set back requirement is warranted; and
- investigate management approaches

2.3 Study Details

2.3.1 Study Area

The study area includes all of the Wollongong Local Government Area (see Figure 1). The Calderwood Valley, which spans both the Wollongong and the Shellharbour Local Government Areas, is also part of the study area.

It should be noted that a generic riparian objective was set (ie Category 1 – Environmental Corridor) for those lands generally on the plateau and in the water catchment areas of the Sydney Catchment Authority.

2.3.2 Study objectives

The objectives of the Riparian Corridor Management Study are to:

Develop a cost effective process to:

- Readily assign environmental objectives to watercourses and map them using GIS;
- Accurately map the actual riparian boundary for key watercourses; and
- Feed directly into the planning process (eg REP, LEP, DCP, s.94 Contribution Plan).

In order to achieve this, the Study:

- Identifies environmental objectives for riparian lands;
- Assesses the natural features and physical processes of the study area;
- Reviews constraints and opportunities in achieving environmental objectives; and
- Provides recommendations on riparian corridor management

2.3.3 Study output

The Study <u>delivers</u> on landscape planning and <u>informs</u> on other processes.

Within the framework of the recommendations developed by the COI, the outputs of this Study are essential in better guiding and coordinating the many cumulative actions and decisions of government, landowners, community and industry groups to facilitate sound management, planning and conservation of riparian lands. The Study provides:

1. a set of generic conservation and management objectives for riparian land that are applicable to all streams within the study area;

2. a classification of all streams in the study area according to the generic conservation and management objectives;

3. certainty for the protection of riparian areas if adopted into land use rezoning proposals;

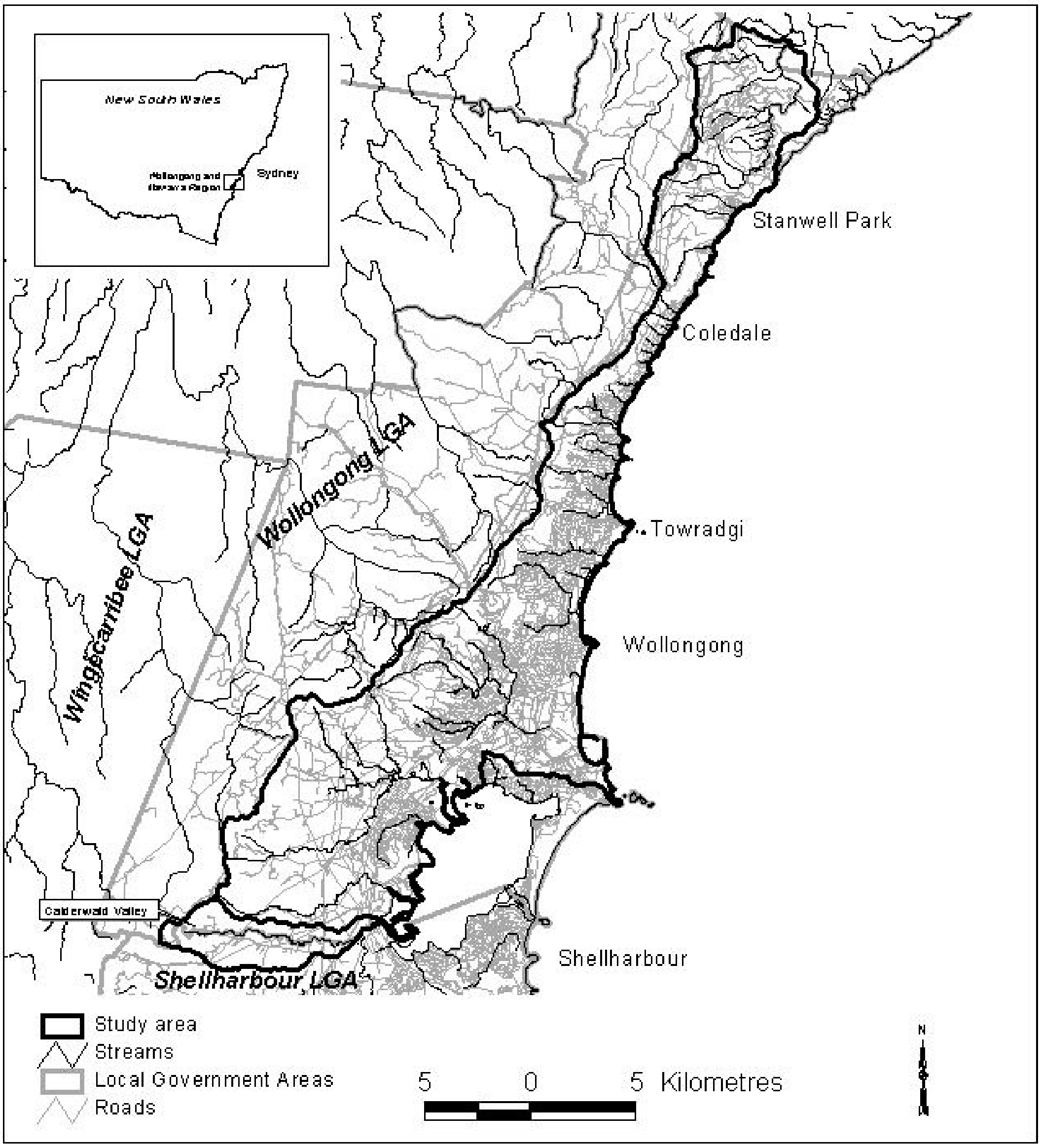


Figure 1: Map showing the study area – Wollongong Local Government Area and Calderwood Valley in the Shellharbour Local Government Area (from Department of Infrastructure, Planning and Natural Resources)

4. detailed mapping of specific riparian corridor boundaries for Mullet Creek and Calderwood Valley catchments, that forms the basis for riparian corridor zoning boundaries for relatively undeveloped ‘greenfield’ catchments;

5. detailed mapping of riparian corridor boundaries in Towradgi Creek catchment, that forms the basis for riparian corridor zoning boundaries for a heavily urbanised catchment;

6. additional information to assist in a more streamlined rezoning and development approval process for consent authorities, approval bodies and proponents;

7. guidance to Council and the Southern Rivers Catchment Management Authority (and other entities)in prioritising environmental enhancement activities;

8. guidance to Council and proponents/consultants with regard to integrating riparian corridor management into floodplain management planning process; and

9. guidance as to the design and location of new public and private infrastructure.

2.4 Riparian Land

2.4.1 Definition of riparian land

Riparian lands form the transition between terrestrial and aquatic environments. Often complexities arise when it comes to defining the width of riparian land. This is because of the diversity of environments that are riparian, the transitional nature of the boundary between these non-riparian environments and the objectives trying to be attained. Resolution of these complexities requires a multi-disciplinary approach.

Many definitions of riparian land are available.

From a geomorphological perspective Tubman & Price (1999) defined riparian land as land which adjoins or directly influences a body of water, including:

- land immediately alongside small creeks and rivers including the river banks itself;
- gullies and depressions that sometimes run with surface water;
- areas surrounding lakes; and
- wetlands on river floodplains which interact with the river in times of flood.

From an environmental perspective Ilhardt, Very & Palik (2000) defined riparian areas as:

- three dimensional ecotones of interactions that include terrestrial and aquatic ecosystems extending into the groundwater, above the canopy and across the floodplain.

From a vegetation perspective, Lovett & Price (1999) identify riparian land as:

- any land which adjoins, directly influences, or is influenced by a body of water.

(This Study draws upon the Strahler method for stream order identification – refer to the Glossary).

2.4.2 Importance of riparian land

The importance of riparian land is well established in scientific literature and is increasingly being recognised in Government legislation, policy and planning instruments. Riparian land is generally the most fertile and productive part of the landscape in terms of primary production and ecosystems and often supports a higher diversity of native flora and fauna species than non riparian land (Tubman and Price, 1999). Riparian land provides a number of important environmental and other values which can include:

- a diversity of habitat for terrestrial, riparian and aquatic species;
- a food source for a diversity of aquatic and terrestrial fauna (such as organic material, fruiting and flowering plants);
- promotion of the movement and recolonisation of individual species and plant and animal populations;
- shading and temperature regulation;
- conveyance of flood flows;
- settlement of high debris loads;
- reduction of bank and channel erosion through root systems binding the soil;
- water quality maintenance through the trapping of sediment, nutrients and other contaminants;
- an interface between development and waterways;
- visual amenity; and
- a sense of place with green belts or riparian bushland naturally dividing localities and suburbs.

Riparian land management decisions impact on flooding, infrastructure provision, fire hazard reduction and recreational opportunities. While recognition of the importance of riparian land continues to emerge, it is considered that the collection and analysis of environmental data required for planning decisions at a catchment level has lagged behind the advancement of this understanding. However, the following general information is known:

2.4.3 Scales of restoration

The spatial extent of restoration is rarely set from the perspective of target species or communities, instead being driven more often by human perceptions of important scales, or by issues of economic and social convenience. Although there appears to have been direct research into the importance of habitat-patch size in the stream restoration literature, evidence from studies examining habitat fragmentation suggests this is an important issue to consider. [Bond & Lake 2003].

2.4.4 Riparian habitat for wildlife

Riparian lands differ from adjacent areas in several ways. They often have more fertile soils, higher moisture levels and different plant species. For these reasons, riparian land provides the habitat features needed by a diverse range of wildlife species. For some species this habitat is critical. The components of habitat that are important include food, water, shelter from predators and from harsh physical conditions, and safe sites for nesting, roosting. [Price, and Lovett, 2002].

2.4.5 Value of ground foraging mammals

Small mammals can have profound effects on water harvesting and moisture retention in surface soil. Small mammal foraging scratchings also trap plant litter and seeds, forming nutrient-rich germination sites that enhance species diversity and can influence ecosystem processes from the microhabitat to the landscape scale [Martin, 2003].

2.4.6 Food sources for aquatic plants and animals

Leaves and fine twigs falling into the water provide the basic food source for a complex web of life that, in turn, supports larger animals such as fish. Many animals spend different parts of their lifecycle on the land and in the water. This means there is a close connection between in-stream health and the health of adjacent land-based ecosystems. [Price, P and Lovett, S. 2002]

2.5 Floodplain Risk Management (and Stormwater)

Floodplain risk management (including stormwater quantity and quality) and riparian corridor management are interlinked and any action taken impacts on both:

- it is critical that an integrated approach to floodplain risk and riparian corridor management is pursued if the objectives of both policies are to be realised;
- implementation of riparian management strategies should be undertaken in such a manner so as not to make flooding worse to existing flood liable development; and
- structures to treat water quality and/or quantity should not compromise core riparian zones.

This is dealt with in greater detail in section 6 of this Study.

2.6 Natural Resource Outcomes

There is a vast range of natural resource outcomes that need to be considered and integrated into decision making. Some of these objectives, with desirable outcomes are described in Table 1. Awareness of the outcomes given in Table 1 by decision makers and land managers is an important step toward achieving integrated outcomes.

Overarching Objective	Outcome
Biodiversity	• Halt loss and make provisions to conserve biodiversity • Maximise continuity of vegetation with multiple corridors connecting the escarpment to the coast • All existing native vegetation assemblages retained • Habitat diversity to cater for flora and fauna identified in bioregional study • Sufficient width of vegetation to provide diverse range of habitats and allow for edge effects and bushfire management without diminishing quality • Provide/retain larger vegetated nodes to allow for refuge during adverse environmental conditions (eg drought, fire)
Water Quality	• ANZECC quality for normal ecological processes • Sufficient riparian vegetation to act as a buffer for nutrient uptake and soil erosion control • Off-line storm water treatment to control pollutants before entering the natural watercourse • Control of soil erosion at source before it enters the watercourse • Off-line on site detention (OSD) structures and improved hydrologic regimes be sought in the design of the works to improve quantity management • Water quality structures should not compromise core riparian zones
Geomorphic Function	• Ensure riverine management works consider and complement fluvial geomorphic processes • Allow for natural stream processes to occur where possible. (eg provide room for natural lateral migration of the channel where assets are not at direct risk) • Do not channelise streams and destroy natural features • Maintenance and enhancement of hydraulic, geomorphic and habitat diversity (eg pools and riffles, chains-of-ponds, riparian vegetation etc) • Integration of associated natural assets (eg floodplains, wetlands, chute channels, river terrace remnants) • Minimise risk to development by provision of appropriate zoning and adequate setbacks • Vegetation of sufficient extent and density to provide for the stability of bed, banks and benches • Mimic as far as possible natural flow regimes post development • Continuous stream corridor meandering within the catchment • Strategically review compensatory excavation policies including cumulative impact assessments on natural stream functions.

Table 1: Natural resource management outcomes to be pursued when impacting on riparian lands.

Overarching Objective	Outcomes
Human Use	• Control/formalise access points for humans and stock • Water quality to ANZECC guidelines for human contact • Provide opportunities for recreational activities that do not impinge on habitat quality • Locate infrastructure and services so as not to compromise riparian functioning and integrity
Floodplain Risk Management	• Floodplain risk management studies and plans need to consider both existing and proposed long term development and changes to the catchment, floodplain and riparian corridors to assess the associated impacts and consider these in the management of flood risk. • Any proposed flood risk management measures need to be considered in terms of social, environmental and economic issues including the integration of riparian and ecological enhancement opportunities wherever possible. • Proposed changes to the riparian corridor need to consider any potential impact upon flood risk and ensure there is no adverse impact to the flood liability of existing development. • Encourage flood compatible use of the floodplains (particularly high hazard areas) that are outside the areas reserved for riparian vegetation through strategic environmental planning instruments. • Ensure that natural stream functions are not compromised by flood risk management measures such as "channelisation" of watercourses to support new development. • Support a stream rehabilitation and ecological enhancement philosophy wherever possible in the development of flood risk management measures.

Table 1: (continued) Natural resource management outcomes to be pursued when impacting on riparian lands.

2.7 Riparian Widths

2.7.1 Comparison of Riparian Widths

The management recommendations for Washington USA riparian habitats developed by the Washington Department of Fish and Wildlife (Knutson and Naef, 1997) represents one of the most comprehensive reviews available of riparian corridor dimensions required to maintain a range of ecological processes. Over 1500 references dealing with riparian corridors and buffer zones were reviewed in the process of developing these recommendations. While some of the riparian buffer requirements for wildlife are specific to North American species, suggested widths for processes such as temperature regulation, generation of large woody debris, sediment and pollution filtration transcend national boundaries. Table 2 provides a summary of the buffer widths from the top of bank required on each side of the stream channel for maintenance of a range of riparian zone functions.

Riparian Habitat Function	Range of reported widths in metres	Average of reported widths in metres
Temperature control	11 – 46	27
Large woody debris	30 – 61	45
Sediment filtration	8 – 91	42
Pollution filtration	4 – 183	24
Erosion control	30 – 38	34
Microclimate maintenance	61 – 160	126
Wildlife habitat	8 – 300	188

Table 2 Range and average widths from top of bank required to maintain a range of riparian zone functions (source Knutson and Naef, 1997)

Table 3 is a comparison of suggested riparian widths from a range of sources from the US and Australia. The data for North America was compiled by Ward et al, 2002 and the following should be noted:

2.7.2 Key Points for US Data Include:

- The riparian widths for northern America are subject to snow and ice, and large mammals (bear and deer) amongst the wildlife.

- The widths adopted by Washington State are designed first to retain riparian function to maintain instream habitat for fish and aquatic wildlife and secondly to provide sufficient riparian habitat for terrestrial species.
- The adopted widths are measured from the top of each bank. Where the 100 year floodplain exceeds these widths, the riparian width extends to the outer edge of the 100 year floodplain.
- Larger widths may be required where priority species occur.
- Add 30 m to the outer edge on the windward side of riparian areas with high blowdown potential.
- Extend widths at least to the outer edge of unstable slopes along waters in soils of high mass wasting potential.

2.7.3 Key Points for Australian Data Include:

- The DIPNR minimum riparian width consists of a core riparian zone (either 20 m or 40 m depending on objective), measured from the top of each bank, plus a 10 m vegetated buffer zone. Larger widths may be required depending on local geomorphology or ecology.
- A (bushfire) asset protection zone is not included in these widths.
- The wildlife corridor of 150 m is from a discussion paper only, prepared for Wollondilly Shire Council.
- What is noteworthy from Table 2 is that this Study has adopted possibly the absolute minimum width to cater for the effective functioning required to achieve the objectives.

Function	Study	Details	Width (m)	Average	DIPNR RCMS
Riparian Habitat Area	Washington State (2001)	Based on nearly 1500 reviews	46 – 76 or 100 yr floodplain	61	50
	Wollondilly Shire Council (1998)	Maintenance of ecological values	50 - 100	75	
	DIPNR (2003)	Environmental corridor Category 1 stream	40 plus 10 vegetated buffer		
Wildlife Protection	Rabeni (1991)	Fish, amphibians, birds	8 – 61		
	Cross (1985)	Small mammals	9 - 18	62	50
	Brown et al (1990)	Provision of food, water, cover	91 – 183		
	Wollondilly Shire Council (1998)	Wildlife corridor	100 - 200	150	
	DIPNR (2003)	Environmental corridor Category 1 stream	40 plus 10 vegetated buffer		
	Riding & Carter (1992)	Minimum for most birds & mammals	80 - 100	90	
Fish, Marine Vegetation and Aquatic Habitats	NSW Fisheries (1998)	Precautionary approach to protection of fish habitats	50 - 100	75	
	Riding & Carter (1992)	Protection of stream environment from forest operations	30		
Water Quality	Ahola (1990)	General improvements	49		
	Pinay & Decamp (1988)	As above	1 – 2	33	10
	Correll & Weller (1989)	Nitrate control	18		
	DIPNR (2003)	Nutrient control Category 3 stream	10 no buffer		
	NSW Native Vegetation Reform Implementation Group (Wentworth Group) (2003)	Major rivers Creeks Streams	50 – 100 20 – 50 10 - 20	75 35 15	

Table 3: Recommended riparian widths from a range of sources in the US and Australia

Function	Study	Details	Width (m)	Average	DIPNR RCMS
Sediment control	Peterjohn & Correll (1984)	Nutrient control	18		
	Riding & Carter (1992)	Protection from sediment & fertiliser (from Victorian DEC 1990)	30		
	Riding & Carter 1992	Sedimentation control (from Victorian SR & WSC 1982)	20		
	DIPNR (2003)	Category 3 stream	10		10
Bank Stabilization	Ontario Ministry Agriculture (1998)	Agricultural ditch bank stabilization	3		
	DIPNR (2003)	Category 3 stream	10		10
Urban stream buffer	Schueler (1995)	Survey of 36 buffer programs	6 – 61	33	30
	DUAP (1999)	Vegetated buffer from urban development	100 existing bushland 40 elsewhere	40	
	Illawarra Commission of Inquiry (1999)	Vegetated buffer from urban development	40		
	Wollongong City Council (2000)	DCP No 99/7 vegetated buffer from urban development	40		
	DIPNR	Terrestrial habitat Category 2 stream	20 plus 10 vegetated buffer		
Native Vegetation Conservation	Benson & Howell (1993)	Conservation of native riparian vegetation	50		

Table 3 (cont.): Recommended riparian widths from a range of sources in the US and Australia

3. OBJECTIVE MAPPING OF STREAMS

3.1 Introduction

Initial discussion within the Department's multi disciplinary working group resulted in a multitude of categories of riparian land being identified. However this was consolidated into 3 categories as it was felt that:

- too many categories would be time consuming and costly to define in the field and map;
- there was not a lot of difference in overall widths and desired outcomes between a large number of the categories; and
- the widths adopted are minimum widths for initial guidance. During the actual mapping process these widths vary considerably due to other factors such as stream geomorphology, wetlands, flooding characteristics and the location of remnant native vegetation.

There has been no specific investigation of the aquatic ecology of the streams although it has been assumed that the management recommendations made for stream categories 1 and 2 are sufficient to protect aquatic ecology. More detailed assessment of the ecology of category 3 streams should be undertaken (at the LES stage or environmental impact assessment stage) to verify if proposed setbacks are sufficient.

The three categories of environmental objectives the working group agreed to were adopted for the following reasons:

Category 1 – Environmental Corridor. The overarching objective is to maintain riparian connectivity between one key destination to another for the movement of aquatic and terrestrial fauna and flora. In the Illawarra it was felt to be particularly important to maintain connectivity between the coast and the escarpment (the escarpment and beyond provides north-south linkages). Other key destinations that could be linked include a wetland of regional or State significance or a remnant stand of high conservation value vegetation for example.

This category was originally called a "Wildlife Corridor" however it soon became apparent that extensive scientific research would be required to identify the specific wildlife and determine appropriate minimum widths (this has been done in Washington where they have considerably more resources). As a compromise, a minimum width of 40 m from the top of bank was adopted for riparian land in this category with an additional 10 m width of vegetation to buffer and protect this core from edge effects.. (This is also consistent with a recommendation from the COI). It should be recognised that this is a minimum width that the authors of this Study could justify to achieve this function and further scientific research may recommend greater widths to cater for specific wildlife and habitat requirements. For example, shy bird species may require up to a 400 m wide corridor if a riparian corridor was to cater for such an outcome.

Category 2 – Terrestrial and Aquatic Habitat. The overarching objective is to emulate as much as possible a lesser node of naturally functioning stream reach with connectivity for the movement of aquatic and terrestrial fauna. While accepting the width of the riparian corridor will not fully satisfy the requirements of a wildlife corridor, the width must still be sufficient to provide habitat and refuge for native fauna. Robustness and viability of this lesser node of riparian habitat is critical. Rigorous scientific data is not available to determine this width, however, the available literature both local and overseas suggests that a minimum width of 20 m to 30 m is required. This study has considered a 20 m width of vegetation with an additional 10 m width of vegetation to buffer and protect this core from edge effects.

Category 3 – Bank Stability and Water Quality. As implied, the overarching objectives are to prevent soil erosion and enhance water quality. This category generally covers minor watercourses (eg 1st order streams according to the Strahler method) and/or where there are limits to long term values due to heavy impact, degradation or compromise from, for example, encroachment of urban development, historic channelisation or piping of sections.

These relatively minor watercourses may also lack the high degree of potential for habitat restoration or provide any level of connectivity between key biodiversity nodes. Natural stream functioning, however, is not to be discounted as an outcome. This study has considered a 10 m width of vegetation wherever possible.

3.2 Environmental Objectives for Riparian Land

The three broad categories of riparian land identified above, reflect the relative importance of the watercourse. The environmental objectives developed for each category together with the recommended minimum riparian widths are as follows:

Category 1 - Environmental Corridor [see Note (i)]

Maximise the protection of terrestrial and aquatic habitat to:

- provide a continuous corridor width for the movement of flora and fauna;
- provide extensive habitat (and connectivity between habitat nodes) for terrestrial and aquatic fauna;
- maintain the viability of native riparian vegetation;
- manage edge effects at the riparian/urban interface;
- provide bank stability, and
- protect water quality.

This is achieved by:

(i) providing a continuous riparian corridor that also provides linkages to stands of remnant vegetation where applicable;
(ii) providing a "core riparian zone" (CRZ) with a minimum width of 40 m from the top of the bank;
(iii) providing an vegetated buffer of 10 m minimum width to protect the CRZ from edge effects;
(iv) providing sufficient (additional) riparian corridor width based on geomorphological and environmental considerations;
(v) providing a suitable environmental protection zoning to the riparian land that recognises its environmental significance;

(vi) restoring/rehabilitating the riparian zone by returning as far as practicable the vegetation, geomorphic structure, hydrology and water quality of the original (pre European) condition of the stream;
(vii) ensuring vegetation in the CRZ is at a density that would occur naturally;
(viii) locating services (power, water, sewerage, and water quality treatment ponds) outside of the CRZ and vegetated buffer. (Encroachment into the non core riparian area may be possible if unavoidable and the impact on riparian functions is minimal and integrity maintained);
(ix) providing a suitable interface between the riparian area and urban development (roads, cycleways, playing fields, open space) to minimise edge effects and provide a (bushfire) asset protection zone (APZ);
(x) minimising the number of road crossings;
(xi) maintain riparian connectivity by using piered crossings in preference to pipes or culverts;
(xii) minimise the impact of walkways, cycleways and general access points by using ecologically informed design principles;
(xiii) locating flood compatible activities (playing fields) outside of the CRZ. (Encroachment into the riparian area may be possible if unavoidable and the impact on riparian functions is minimal and integrity maintained), and
(xiv) treating stormwater runoff outside of the CRZ (and buffer) before discharge into the natural watercourse.

Note (i): Also note the importance of corridor connections between adjoining watercourses or within key nodes of vegetation.

Category 2 - Terrestrial and Aquatic Habitat

Maintain/restore as much as possible the natural functions of a stream to:

- maintain the viability of native riparian vegetation;
- provide suitable habitat for terrestrial and aquatic fauna;
- provide bank stability, and
- protect water quality.

This is achieved by:

(i) providing a “core riparian zone” (CRZ) with a minimum width of 20 m from the top of the bank;
(ii) providing a vegetated buffer of 10 m minimum width to protect the CRZ from edge effects;
(iii) providing, wherever possible, sufficient (additional) riparian corridor width based on geomorphological and environmental considerations;
(iv) restoring/rehabilitating the riparian zone by returning as far as practicable the vegetation, geomorphic structure, hydrology and water quality of the original (pre European) condition of the stream;
(v) ensuring vegetation in the CRZ is at a density that would occur naturally;
(vi) providing, whenever possible, appropriate zoning that recognises the environmental significance of the riparian land;
(vii) minimising the number of road crossings;

(viii) ensure road crossings are designed to maintain riparian connectivity;
(ix) providing a suitable interface between the riparian area and urban development (roads, cycleways, playing fields, open space) to minimise edge affects and provide a (bushfire) APZ;
(x) minimising the extent of open parkland adjacent to a stream;
(xi) locating services (power, water, and sewerage water quality treatment ponds) outside of the CRZ and vegetated buffer. Encroachment into the riparian area may be possible if unavoidable and the impact on riparian functions is minimised, and
(xii) treating stormwater runoff outside the CRZ (and buffer) before discharge into the natural watercourse.

Category 3 -Bank Stability and Water Quality

Minimise sedimentation and nutrient transfer to:

- provide bank stability;
- protect water quality, and
- protect native vegetation.

This is achieved by:

(i) emulating wherever possible a naturally functioning stream with a minimum riparian width of 10 m from the top of the bank.
(ii) where possible provide opportunity for vegetated habitat refuges (terrestrial and aquatic).
(iii) using pipes or other engineering devices as a last resort.
(iv) treating stormwater runoff before discharge into the riparian zone or the watercourse wherever possible.

3.3 Mapping of Objectives

The COI found that ad hoc decisions were being made in relation to management of the escarpment, foothills and the riparian corridors that connect them to the coastal plain and ocean. In relation to riparian management, one step in overcoming ad hoc decisions is to put in place a strategic context or long term vision for how certain waterways (and reaches of waterways) are valued. The process aims to secure future functions for waterways based on their values.

Given the environmental objectives developed for riparian lands in the preceding section, three riparian categories were identified:

Category 1 - an environmental corridor
Category 2 - terrestrial and aquatic habitat
Category 3 - bed and bank stability/water quality

The streams were identified using digital data supplied by the Land Information Centre. Field verification delivered a high correlation with the desk-top assessment utilising local knowledge of staff. While the large size of the LGA and resources available did not enable complete field verification it is anticipated that future updating will be minor as anomalies are discovered and values and constraints change.

Most of the streams throughout the study area were tagged and assigned a category (1, 2 0r 3) reflecting their relative importance as riparian zones within respective catchments. When assigning these values, consideration was given to existing opportunities and constraints and to establishing key environmental corridors and linkages from the ocean to the escarpment (as well as north-south linkages along the escarpment and foothills). The maps showing these values are given in Appendix A.

It is important to note that riparian objective mapping has been limited to the watercourses flowing east off the escarpment. The plateau area, while just as important and a vital part of the north-south wildlife link, is mostly National Park/water catchment area and subject to considerable development controls and environmental protection so has not been included in this study. One should assume, however, that all watercourses in this area warrant Category 1 – Environmental Corridor objectives.

The integrity of watercourses (especially in urban areas) have been significantly compromised due to many reasons (piping, diversion, channelisation, minimal setback by development, etc). Due to the hydraulic, geomorphic, biodiversity implications of these impacts, the NSW State Rivers and Estuaries Policy directs that such activities are now to be halted wherever possible.

In many urban areas, watercourses may be in channels/pipes but are still nonetheless given consideration in the objective setting exercise. In most cases, continuously hard lined or piped watercourses are recognised as Category 3 as it is still critical that management decisions in and around these watercourses result in bed and bank stability and improvement in water quality. The management of highly impacted watercourses, consistent with Category 3 objectives, can still contribute to overall catchment health.

Minimum Environmental Objectives for Riparian Land	**Category 1** Environmental Corridor	**Category 2** Terrestrial & Aquatic Habitat	**Category 3** Bank Stability & Water Quality
Delineate riparian zone on a map and zone appropriately for environmental protection	yes	yes	if resources are available
Provide a minimum core riparian zone width	40 m from top of bank	20 m from top of bank	usually 10 m from top of bank
Provide additional width to counter edge effects on the urban interface	10 m	10 m	generally not required
Provide continuity for movement of terrestrial and aquatic habitat	yes (including piered crossings)	yes (with appropriate crossing design)	where appropriate
Rehabilitate/reestablish local provenance native vegetation	yes	yes	where appropriate
Locate services outside the CRZ wherever possible	yes	yes	merit consideration
Locate playing fields and recreational activities outside the CRZ	yes	yes	merit consideration
Treat stormwater runoff before discharge into riparian zone or the watercourse	yes (outside CRZ and buffer)	yes (outside CRZ and buffer)	yes

Table 4: Summary of riparian management objectives

4. DETAILED RIPARIAN CORRIDOR MAPPING

4.1 Introduction

One of the primary recommendations of the COI was to prepare a plan identifying desirable riparian or green corridors. This chapter describes the rationale and methods by which detailed mapping of desirable riparian corridors was undertaken for three contrasting catchments (ie urban, greenfield and rural) within the study area. The purpose was to test the methodology for translating the key environmental corridors (as shown in Appendix A) into actual riparian "footprints" on the ground -–that is, moving from a riparian objective to an actual defined corridor that could be included in detailed maps associated with planning instruments such as REPs, LEPs and DCPs.

Towradgi Creek was selected as a case study as it shows mapping in a heavily urbanised catchment. Encroachment of urban development into riparian zones since the early 1900s has placed a major constraint on the ability of current planning authorities to protect riparian corridors and to provide for a naturally functioning riparian zone. This constraint is recognised and the methodology adopted to delineate riparian corridor boundaries in already urbanised areas was modified to reflect such constraints.

Towradgi Creek has been the subject of a recent Floodplain Risk Management Study that has identified areas of flood hazard and developed flood risk management strategies. This case study also provides suggestions of how environmental improvements for riparian corridors, such as enhancement of native vegetation, could be integrated with floodplain management studies in urban catchments so as to not increase existing flood risks for residents.

It is recommended further hydraulic modelling of Towradgi Creek (and other catchments) be undertaken by Council to obtain a sensitivity analysis of the impacts of revegetating the riparian area and identify constraints and opportunities for proposed improvements. This may either be part of the floodplain management planning process or part of riparian corridor assessment for new development.

Mullet Creek catchment is a major tributary of Lake Illawarra and is currently a largely rural 'green fields' catchment with significant future urban development expectations. It is considered that future urban development may have a capacity for around 15,000 residential lots (Illawarra Urban Development Program). Mullet Creek catchment was selected for a riparian corridor mapping case study because it provides an excellent example of a largely rural catchment subject to significant urban development demands over the next decade. Also, a landuse structure planning process and Floodplain Management Plan are currently being prepared for this catchment. In addition to the release of land for employment purposes in West Kembla Grange, these activities will lead to major rezoning of land use and is an excellent opportunity to integrate the identified riparian objectives.

Duck Creek is south of Mullet Creek and will be impacted upon by the potential development of West Dapto. Duck creek catchment is a transitional one in, planning terms, between potential urban development and continued rural use.

Marshall Mount Creek (Calderwood Valley) straddles the Shellharbour and Wollongong LGAs. It is currently largely rural and provides a contrast to the other catchments mapped. In this catchment the riparian footprint highlights the environmental significance of the land, however, existing use right prevail while the land remains rural.

4.2 Rationale Behind Riparian Corridor Mapping

The COI recognised that past planning of development on floodplains and riparian corridors was inadequate. This has contributed to degradation of the natural environment and has also created significant flood problems in the study area.

In the Illawarra, streams are well known to be particularly dynamic and subject to frequent floods with high debris and sediment loads (Nanson and Hean, 1985; Reinfelds and Nanson, 2001). Between major floods, streams and riparian zones experience rapid and dense vegetation growth of both native and exotic species that can affect the behaviour of future flood events. Across the developed areas of the Wollongong LGA, many floodplains and creeks have been modified by infilling, channel realignment and piping of watercourses to cater for development. As a result, natural geomorphic boundaries between floodplains and terraces have become obscured. Former pre-development topographic relationships between geomorphic floodplains and terraces, however, can be clearly discerned on historical aerial photography.

In Towradgi Creek catchment, for example, geomorphic floodplains and terraces in the mid-catchment zone can be clearly observed on aerial photography from 1938. The boundary along the terrace tops could have potentially been used to delineate a riparian corridor (Figure 2). When this riparian corridor is overlain onto current 2001 aerial photography, it is clear that some properties in this area were developed on geomorphic floodplains. It is also interesting to note that in 1938, in contrast to the current situation, there were few dwellings built within the clearly defined geomorphic floodplain (Figure 2). This suggests that in 1938, residents of Wollongong were aware of hazardous flood zones but this early awareness seems to have been lost in the subsequent decades of rapid urbanisation. Better informed decisions can now be made s a result of this Study.

The well defined floodplains and terraces across the mid-catchment zone of the Illawarra region had evolved to their current dimensions for several reasons – (i) to convey floodwaters, (ii) accommodate large organic debris loads, and (iii) to accumulate sediment delivered from upstream by major flood events. Detailed mapping of geomorphic riparian corridor boundaries and appropriate zoning offers a contemporary alternative to the traditional 'blanket zoning' approach by planning authorities generally across NSW whereby delineation of limits to urban development is undertaken by proponents and their consultants at the development application stage. Riparian corridor boundaries mapped within a GIS environment have the potential for inclusion as a zoning category in Local Environment Plans (or to have riparian corridors clearly defined in worded clauses). Clearly mapped riparian corridors, together with mapped boundaries of associated environmental features and natural hazards, would greatly facilitate their protection, conservation and enhancement of natural functions and process. Clearly mapped riparian corridors would also form a clear demarcation or footprint between land required for effective catchment function and other uses, particularly urban development. The South Coast Regional Planning Strategy under preparation by DIPNR will also deal with improving the inclusion of riparian lands via objectives, strategic processes and regulation and is applicable to all the coastal local government areas.

4.3 Methodology

A computer based Geographic Information System (GIS), Arcview 3.3, was used to undertake the mapping. Using this system, multiple layers of information such as aerial photos, digital elevation models (DEM), stream locations, property boundaries, existing development etc. were used in combination to develop mapping products.

4.3.1 Data sources

Riparian corridors for Mullet Creek, Towradgi Creek, Duck Creek and Marshall Mount Creek (Calderwood Valley) catchments were delineated in Arcview GIS using a variety of vector, image and grid based data sources. These data sources provided information on the geomorphology, historic flood events, vegetation, wetlands, and existing development constraints. The data sources include:

- 1:25,000 scale streams as available from Land and Property Information (LPI). This was provided in digital form suitable for use in the computer mapping system;
- cadastral (or property) boundaries as available from Land and Property Information (LPI);
- a 5 m cell size Digital Elevation Model (DEM which is a computer generated interpolation of 2 m contour mapping) available from Land and Property Information (LPI);
- a 25 m cell size DEM (a computer generated interpolation of 10 m contour mapping) available from LPI;
- a slope grid at 3.0° intervals generated from the 5 m and 25 m cell size DEMs;
- flood extent and hazard mapping provided by Wollongong City Council;
- orthorectified aerial photography from 2001 (0.60 m on-ground pixel size) provided by Wollongong City Council. (Orthorectified aerial photography has any lens distortion removed and is used in computer mapping systems);
- rectified historical aerial photography from 1938 and 1984 with on-ground pixel sizes ranging from 0.40 m – 1.50 m; and
- NSW NPWS (2002) native vegetation maps of the Wollongong escarpment and coastal plain.

4.3.2 Methods

Drawing on the riparian objective classification (outlined in sections 2 and 3), draft riparian corridor boundaries were delineated utilising the data sources described above. An initial polygon of a 50 metre buffer around all 2nd order and larger streams (Strahler method 1:25,000 scale LPI drainage layer) was generated in Arcview 3.2 using standard procedures. A 50 metre buffer from the stream centreline was initially chosen as this is considered commensurate with the COI recommended minimum 40 metre buffer from both banks of streams plus the width of stream. Hence, adopting a value of 50 metres from the centreline of streams depicted as single threads provides a reasonable approximation to the COI recommended minimum of 40 m from both banks. Nonetheless, it is at the individual site level where the application of the spatial requirements to achieve environmental objectives is best defined.

Figure 2. Towradgi Creek in mid-catchment around the Princes Highway and South Coast Railway. Note the clearly defined floodplain and terrace on the 1938 aerial photograph and the lack of development within the geomorphic floodplain relative to 2001.

The vertices of this initial polygon were then adjusted using 'heads up digitising' (on-screen digitising) at a scale of 1:2,500 to 1:5,000 to follow either singly or in combination:

- geomorphic boundaries separating floodplains from terraces using DEM derived slope maps;

- geomorphic boundaries separating flatter hillsides and ridge lines from steep slopes descending to floodplains or streams;
- geomorphic hazard zones such as sediment fans at the base of the escarpment or eroding/incising high banks;
- woody vegetation or wetlands within or in close proximity to geomorphic floodplains;
- property boundaries of developments encroaching into the transition zone between geomorphic floodplains and terraces;
- flood extent mapping of high hazard floodways (Towradgi Creek), 1% design event (Mullet Creek) and 1984 flood event (Mullet Creek); and
- a 50 metre buffer either from the centre thread of the stream or from both banks of the stream as depicted on the LPI 1:25,000 drainage layer.

The 2001 orthorectified aerial photography with 0.60 m pixel size can be enlarged to approximately 1:2,500 scale without excessive on-screen blurriness. At this level of detail, it became apparent that the 1:25,000 scale LPI stream data needed to be adjusted so that the stream vector data matched the 'true' position of the stream on the orthorectified photography. Positional adjustments were undertaken in Arcview through on-screen interpretation of aerial photography.

Local factors dictated which of the above considerations, either singly or in combination, that the riparian corridor delineation followed at any particular point. The riparian corridor boundary should be interpreted at 1:10,000 scale meaning that the on-ground position of the boundary is ± 5.0 metres. Again, it is at the individual site scale where the detailed application of the exact spatial extent of riparian objectives is best determined.

4.3.3 Field Investigation

Field investigation was undertaken for much of Towradgi Creek catchment to verify the information identified from the aerial photography. The main arm of Towradgi Creek was identified as having the most realistic potential for conserving and enhancing riparian vegetation and providing, in the longer term, a green corridor linking the coast and the escarpment.

Field investigation was undertaken along much of the main arm of Mullet Creek to ground-truth the information identified on the aerial photographs and mapping of the stream geomorphology, ecological assets, remnant vegetation and flood hazard. This included: changes in stream location, existing erosion of the bed and banks, sedimentation, current physical constraints such as buildings, roads and other structures.

Limited field investigation was undertaken for Duck Creek and Marshall Mount Creek. This has limited impact on defining the riparian boundary, however, further field investigation is required before making firm land management decisions.

4.4 Riparian Corridor Maps

The riparian corridors were delineated and mapped for Towradgi Creek catchment, Mullet Creek catchment, Duck River catchment and Marshall Mount Creek Catchment (Calderwood Valley). The completed maps are shown in Appendix B.

4.4.1 Towradgi Creek Catchment

Towradgi Creek catchment is largely urbanised and has undergone substantial landform alteration when compared to Mullet Creek catchment. This necessitated a different approach to the 'natural landform' approach that largely dictated riparian corridor boundaries across the central zone of Mullet Creek catchment. In the case of Towradgi Creek catchment, and drawing upon the riparian zone objective classification outlined in sections 2 and 3, riparian corridor boundaries follow mostly cadastral boundaries and the high hazard floodway mapping developed for Wollongong City Council. While using the natural landform approach may have been preferable, the potential for misunderstanding and conflict with existing landowners due to urban landform modifications, fencelines and existing ancillary structure locations could have had a negative influence on the acceptance of this report. This is an aspect that Council should revisit at a later date and at a more detailed level of analysis to consider appropriate setbacks for new development. Obviously, existing use rights prevail.

Initial riparian corridor polygon development for Towradgi Creek catchment was the same as for Mullet Creek. The LPI 1:25,000 scale streams were adjusted to match the position of streams visible on the 2001 orthorectified imagery. A 50 m buffer was then applied to all second order and larger streams to form the initial riparian corridor polygon. The boundaries of this polygon were then adjusted at 1:2500 to 1:5000 scale to follow mostly property boundaries, the edge of developments where private property boundaries extend into the riparian zone, and the high hazard floodway mapping available for Towradgi Creek catchment. In some locations, natural landforms, remnant and regrowth riparian vegetation were used to determine the position of the riparian corridor boundary.

In hindsight, it would probably have been better to follow land form rather than cadastral boundaries. This would then identify the true value of the watercourse and the width of riparian vegetation required for a healthy, functioning riparian zone which future generations may wish to works towards achieving.

4.4.2 Mullet Creek Catchment

The upper Mullet Creek catchment is dominated by steep gradient, high energy 1st to 3rd order streams. These high gradient stream channels form the dominant source for sediment fans and bars delivered during high magnitude events to the rapid gradient transition zones at the base of the escarpment and some escarpment benches (eg. Reinfelds and Nanson, 2001). These locations are hazardous as they are subject to catastrophic reworking and deposition of poorly sorted boulder fans as exemplified in Figure 3.

Riparian zones of most upper catchment escarpment streams are well vegetated and are confined within well-defined gullies. The main technique for delineating riparian corridors in these streams was simply to apply the 50 m buffer to 2nd order and larger streams. It should be noted

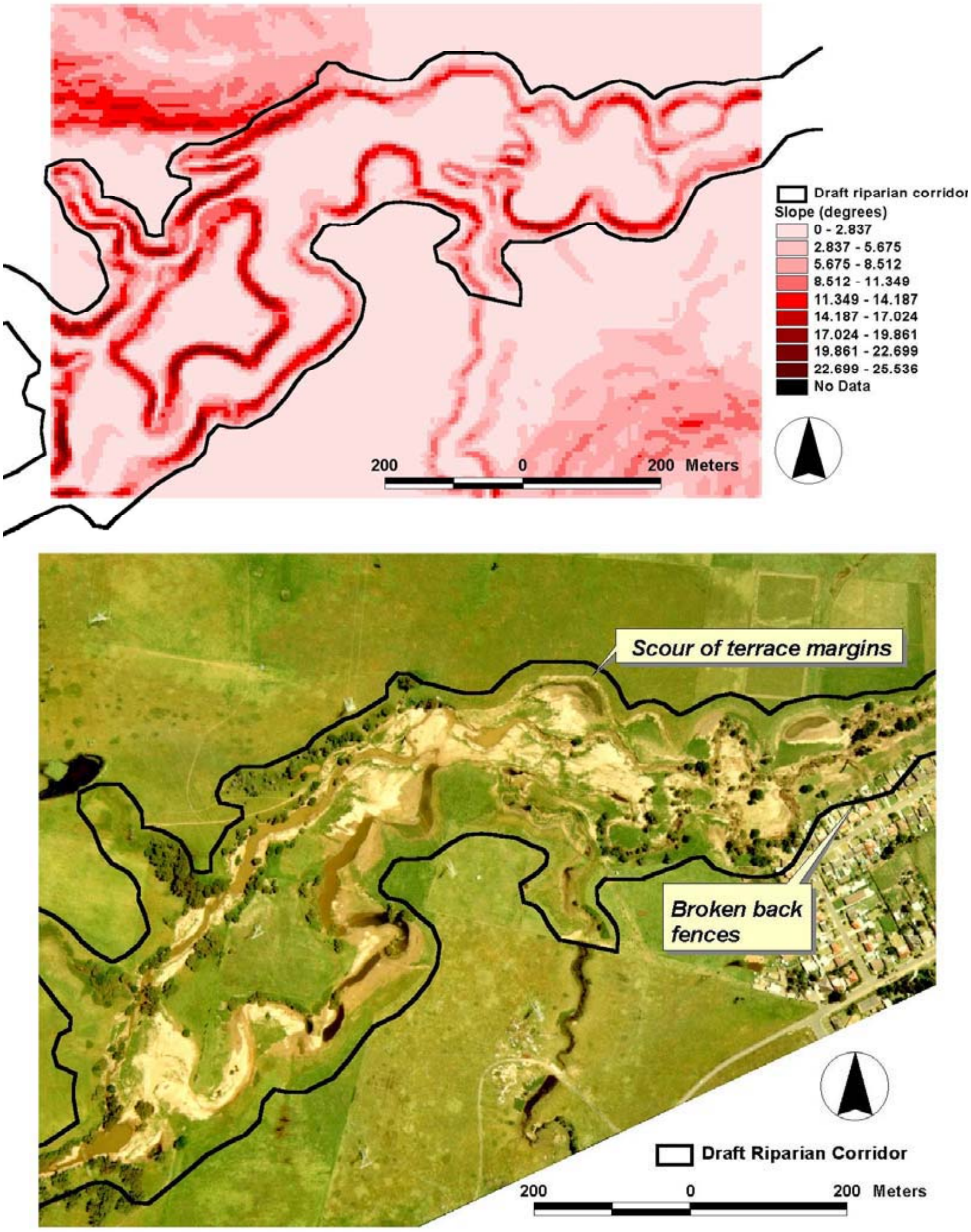


Figure 4: Mullet Creek in the vicinity of Ena Avenue. The top diagram is a slope map generated from a 5 m cell size Digital Elevation Model. Darker tones depict the slope separating the geomorphic floodplain from the terrace. The bottom aerial photograph was taken approximately one week after the West Dapto flood of February 1984. Note the extensive reworking of the geomorphic floodplain and scour of terrace margins. Flow is from left to right.

that due to the dense escarpment vegetation, there are uncertainties in the location of some mapped streams on the steep escarpment slopes.

Across the mid catchment zone of Mullet Creek, the most commonly followed feature was the boundary between the geomorphic floodplain and the terrace. The distinction between geomorphic floodplains and terraces was greatly facilitated through generation of a slope grid in 3° intervals from the 5 metre cell size LPI digital elevation model using standard procedures in Arcview Spatial Analyst. An example of terrace identification and riparian corridor delineation using a slope grid is provided for a section of Mullet Creek in the vicinity of Ena Avenue (Figure 4). Also shown is the same area after the February 1984 West Dapto flood that caused scour of terrace margins and damaged fences and structures in Ena Avenue that had encroached beyond this dynamic and geomorphologically active riparian area (the black line on Figure 4). It would obviously be good practice to avoid future subdivisions and housing development that encroaches into the active riparian area.

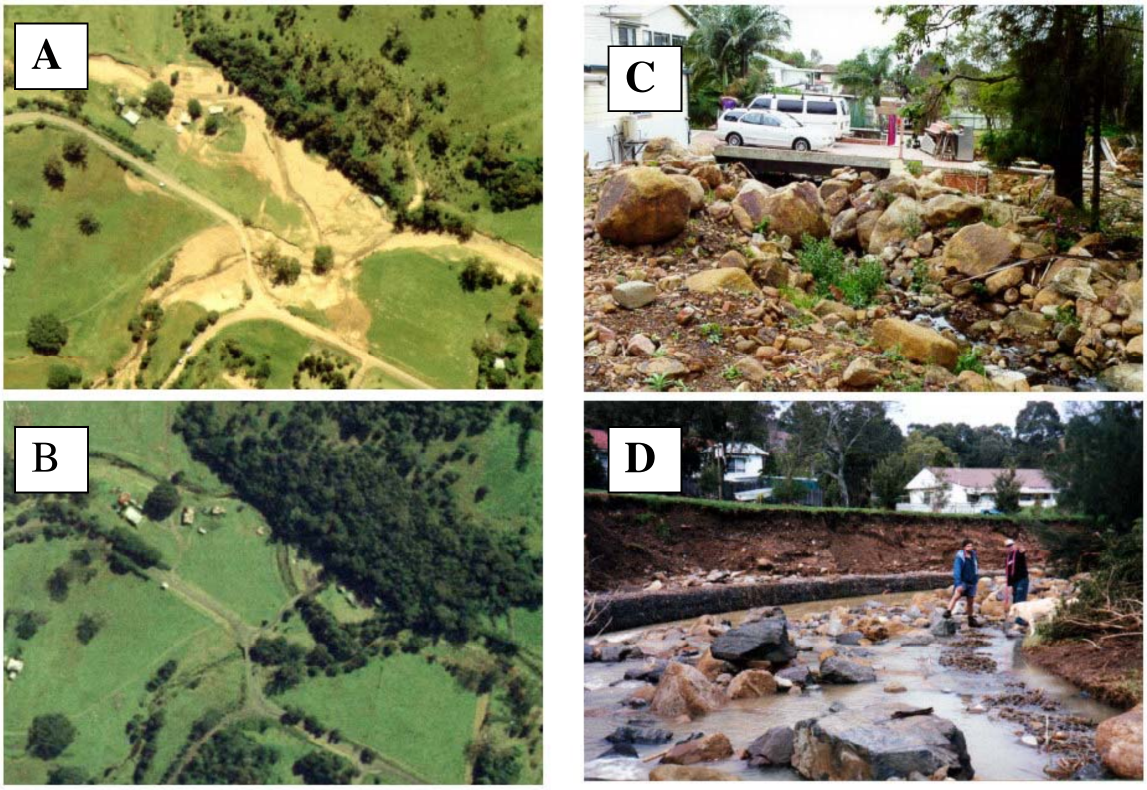


Figure 3: Mullet Creek at the base of the escarpment after the February 1984 flood event (A) and in 2001 (B). Note the massive sediment fan deposition in (A) and engineered channel in (B). (C) shows deposition of a 1-2 m deep boulder fan in Hewitts Creek and (D) shows a 1-1.5 m deep cobble and boulder point bar deposited in Byarong Creek as a result of the August 1998 event. The point bar in (D) was excavated out from the channel to maintain the design channel capacity but was re-deposited in the next large flood event of October 1999.

In the lower catchment of Mullet Creek, streams and floodwaters are not confined by well defined terraces. The geomorphic floodplain is up to 2 km wide and is substantially wider than the minimum riparian corridor dimensions recommended by the COI. In this area, the dimensions of the riparian corridor were determined largely by the 50 m stream buffer either side from the centre thread of the stream, or where both banks are delineated on the 1:25,000 scale drainage layer, 50 m from each bank. Given the extent of the floodplain in the lower catchment, regeneration of a 100 m wide band of riparian vegetation is unlikely to have a major impact on flood levels. However, the flood study modelling process should assess the flood implications of a vegetated riparian corridor. From this flood modelling process there may be a need to reassess management issues for the riparian corridor in certain locations. For example, the use of flood compatible species in certain areas that 'bend' under flood situations and assist conveyance of water volume so as not to increase the flood levels or hazard. Careful consideration of where there is a need to manage roughness implications of riparian vegetation upon flood conveyance will dramatically reduce maintenance burdens to Council. Therefore detailed consideration of this issue is recommended to ensure that riparian corridors are planned and established in the most sustainable manner and integrated with floodplain management.

4.4.3 Duck Creek

Duck Creek catchment lies to the south of Mullet Creek and is characterised by an elongate form and a narrower headwater valley than the amphitheatre shape of Mullet Creek catchment to the north. Similar to Mullet Creek, however, floodplains and terraces are well developed across the middle catchment of Duck Creek and are readily discerned from slope maps set at 3° increments derived from the LPI 5 m cell size DEM. As such, the floodplain-terrace geomorphology formed the dominant landform element guiding the riparian corridor delineation across the catchment. Similar to Mullet and Towradgi Creeks, the initial riparian corridor polygon was generated with a 50 m buffer applied to 2nd order and larger streams (1:25,000 scale Strahler method) and then adjusted on-screen using heads-up digitising in Arcview 3.2 and the data sources described previously.

4.4.4 Marshall Mount Creek (Calderwood Valley)

Marshall Mount Creek catchment lies to the south of Duck Creek and lies within both Wollongong and Shellharbour Local Government Areas. The headwaters of the catchment are characterised by an amphitheatre shaped bowl with a dense drainage pattern separated by narrow ridgelines. Stereoscopic assessment of aerial photography suggests that because of the rugged topography and dense vegetation, topographic maps at 1:25,000 scale incorrectly depict the location of some headwater drainage lines. The locations of these drainage lines were corrected prior to generation of a 50 m buffer for 2nd order and larger streams (1:25,000 scale Strahler method) to develop an initial polygon for further refinement of riparian corridor boundaries using the data sources and methods described previously.

Floodplain-terrace boundaries across the middle reaches of Marshall Mount creek are in some locations more subtle, or in the vicinity of the golf course, more altered than in Mullet and Duck Creek catchments. Hatch Pty Ltd was commissioned to develop a more detailed terrain model from photogrammetric techniques to try to more clearly discern alluvial landform boundaries. While the Hatch data did improve detail in some areas, slope maps from the resultant terrain model were fairly similar to those developed from the LPI 5 m cell size DEM.

The lower reaches of Marshall Mount Creek contains extensive floodplain wetlands along the northern margin of the riparian corridor. Chafer (1997) lists that these occupy approximately 11 Ha and that they have been inadequately surveyed. Limited field investigations suggest that the lower reach of Marshall Mount Creek may be currently incising but further field investigations are necessary to investigate this matter.

4.5 Summary of Riparian Mapping Methodology

Table 5 is a summary of the methodology used to map riparian boundaries in the different catchments. In Towradgi Creek, an urban catchment, existing development and high hazard floodways heavily influence the riparian boundary. In Mullet, Duck and Marshall Mount Creeks, which are predominantly rural catchments, the riparian boundary is largely determined by natural landforms.

Riparian Mapping Methodology	**Mullet Creek** (greenfield)			**Towradgi Creek** (urban)			**Duck Creek** (greenfield/urban)			**Marshall Mount Creek (Calderwood Valley)** (rural)		
	Mid catchment	Upper catchment	Lower catchment	Mid catchment	Upper catchment	Upper catchment	Mid catchment	Upper catchment	Upper catchment	Mid catchment	Upper catchment	Upper catchment
Mapped 50 m either side of the stream centreline	yes	yes confined stream	yes wide floodplain	yes	yes confined stream	yes wide floodplain	yes	yes confined stream	yes wide floodplain	yes	yes confined stream & floodplain	yes wide floodplain
Mapped boundary between geomorphic floodplain and terrace (often > than 50 m)	yes using digital elevation model			where appropriate using DEM (short remnant sections only)			yes using digital elevation model			yes using digital elevation model		
Adjusted to follow edge of development on private property	no			yes to exclude dwellings on private land			no			no		
Adjusted to include high hazard floodway	not available			yes where high hazard floodway greater than 50 m			not available			not available		
Adjusted to include remnant vegetation and regrowth riparian vegetation	yes			yes			yes			yes		

Table 5: Summary of riparian mapping methodology

5. MANAGEMENT OF RIPARIAN LAND

This section provides guidance and general principles to the many stakeholders involved in the management of riparian land. Of fundamental importance is recognition that:

- Riparian land aligns with inherent natural functions and processes and is not available for urban development
- Riparian land is a major environmental asset for the urban community
- Riparian land must be robust enough to recover when damaged by major events such as fire or flood

5.1 Natural Resource Management Zones

Without adequate awareness of attributes and planning, riparian land is often compromised and its environmental value lessened. To ensure improved consideration occurs, key environmental requirements need to be identified and provided for at the outset. Allowance needs to made for three key features:

- *Core riparian zone*
- *Vegetated buffer*
- *Asset protection zone*

The requirements for each of these zones are detailed in Table 6 and shown on the representative cross sections in Appendix C.

Natural Resource Management Zones	Detail	Minimum Width
Core riparian zone (CRZ)	A minimum width to be fully vegetated with local provenance native vegetation (including aquatic groundcovers, shrubs and other species). The minimum widths are determined by the stream category and are: *Category 1:* Environmental Corridor *Category 2:* Terrestrial and Aquatic Habitat *Category 3:* Bank Stability and Water Quality	*(from top of bank)* 40 m 20 m normally 10 m
Vegetated buffer	Required to protect the environmental integrity of the CRZ from edge effects such as: Weed invasion from adjacent lands Micro-climate changes within the CRZ Litter / Pollution Trampling	*(from edge of CRZ)* 10 m but widths vary dependent on site conditions and the stream category
Asset protection zone (APZ) *Also known as Fire Protection Zone, comprised of:* *Inner Protection Area (IPA) and Outer Protection Area (OPA)*	Required to protect assets from potential bushfire damage. The APZ is measured from the outer edge of the core riparian zone/vegetated buffer to the asset. Depending on vegetation type and % of cover in the vegetated buffer, it may be possible to extend part of the APZ into the vegetated buffer. Urban perimeter roads, flood conveyance areas and stormwater quality and quantity controls can form part of the APZ provided these objectives are not in conflict with or compromising of riparian outcomes.	Site dependent

Table 6: Natural resource management zones

5.2 General Principles of Riparian Management

These include:

- decision making should be undertaken within the context of objectives set for riparian land which recognise their environmental significance;
- adequate set back between riparian land and new development is to be provided;
- the bushfire buffer zone is to be located within the defined limits of the development site and not be located in the riparian zone;
- subdivisions (via perimeter roads) and new development should front onto riparian land and not back onto it;
- wherever possible services should be located on the outer edge of the riparian corridor;
- limit crossings of the riparian corridor to maximise connectivity;
- consider alternative means of crossings eg direct drill for pipelines, piered crossings for roadways;
- locate bike and walking tracks sensitively so they do not compromise the integrity of the riparian corridor;
- stream bank stability is to be promoted by retaining and establishing well vegetated riparian zones;
- if required, stream bank stabilisation works should be of a soft-engineered design with the regeneration and/or rehabilitation of appropriate local native riparian vegetation and ecological amenity;
- water quality treatment should occur prior to surface water runoff entering the riparian land. (Where possible sediment/litter runoff needs to be resolved at source.);
- water quantity and quality treatment controls (for example flood storage structures, constructed wetlands, gross pollutant traps) should not be located on a watercourse or within the core riparian zone and vegetated buffer; and
- access to the watercourse should be at strategic locations where the ecological integrity of existing riparian vegetation and stream bed and bank stability will not be compromised.

5.3 Riparian Vegetation

This section focuses on the activities and resources required for the successful management of riparian vegetation. It is intended to indicate to the many stakeholders (government agencies, land developers, and landowners) what is involved in the management of riparian vegetation and how they can best focus their resources. The management issues are indicative in relation to achieving successful outcomes. The legal issue of existing use rights is clearly acknowledged and respected. However, land managers through their management issues and techniques are encouraged to be compatible in respecting the strategic riparian objectives (at the same time as continuing existing uses). Awareness and behavioural change are equally central to positive outcomes.

Types of Riparian Management	Areas where this type of management should be applied	What activities are required	Resources
Protection	Natural geomorphic processes dominate. Generally stable bed and banks within confined valley setting. Good quality and continuous riparian vegetation across whole width of corridor. Riparian vegetation is self-sustaining. Low level weed presence. Moderate to steep slope.	Riparian land secured by planning and other controls Monitor for weed infestation. Control/restrict stock access. No clearing of native vegetation. Source of seed and genetic stock for export to degraded areas. Weed control by hand and herbicide (eg. blackberries) as required	Ongoing use of existing planning and technical resources. Visual surveys every one to two years.
Natural and Assisted Regeneration	Natural geomorphic processes dominate. Generally stable bed and banks within confined valley setting. Significant patches of good quality riparian vegetation but discontinuous across and/or along the corridor. Moderate to high natural regeneration potential for riparian vegetation. Low to moderate level weed presence. Moderate to steep slope. Some cleared land within corridor.	Riparian land secured via planning and other controls. No additional clearing of native vegetation. Retain and regenerate vegetation at key locations (eg. confluences and 20m from top of bank). Prioritise works to improve connectivity and continuity of riparian vegetation. Where pasture is along edge of corridor use crash grazing rather than constant grazing. Deny stock access to regenerating areas. Weed control by hand and herbicide (eg. blackberries) as required.	Ongoing use of existing planning and technical resources within operational budgets. Visual surveys every one to two years.

Table 7 Riparian Vegetation Management (continued over)

Types of Riparian Management	Areas where this type of management should be applied	What activities are required	Resources
Revegetation	Some natural morphological features present (ie. pools, riffles, inset bars, and floodplain). Minor to moderate degradation and instability apparent. Little significant natural riparian vegetation. Little effective riparian vegetation cover along and/or across riparian corridor. Low regeneration potential. Moderate to high levels of weed infestation. Moderate to low slope.	Retain, regenerate and where necessary replant native vegetation at key locations (eg. confluence and compatible widths either side of top of bank). Mechanical weed control in infested areas. Seedlings sourced from local genetic stock. Continued grazing and crash grazing in revegetation areas.	Consultants for preparation of riparian management plan. Seed collection and plant propagation. Planting - stakes and tree guards. Mobile electric fencing for stock control. Watering sites not direct from watercourse.
Rehabilitation requiring earth works and revegetation	Natural morphology of stream degraded or destroyed. Instability or potential geomorphic instability apparent. Little or no native riparian vegetation. Weeds dominate. Low slope.	Minor to moderate earthworks to reshape banks, placement of soft engineering solutions or rock protection commensurate with hydraulic regime to assist re-establishment of natural stream features and functions. Dense planting as clumps, fenced off and weed control undertaken.	Consultants for preparation of riparian management plan. Minor to moderate earthworks. Placement of hard materials Seed collection and plant propagation. Planting - stakes and tree guards. Weed control and maintenance.
Reconstruction requiring earth and structural works and revegetation	Where riparian lands are confined within an area less than that required for natural geomorphic processes to occur. Asset protection required. Stable stream morphology desired. Flood flow heights, duration and conveyance are high priority issues.	Hydraulic geomorphic assessment required. Rehabilitation requirements integrated into floodplain management study. Stripping of non-native vegetation and reshaping of channel. Soil remediation. Sizing, sourcing and placement of scour protection. Revegetation (see above).	Consultants for preparation of riparian management plan. Extensive earthworks. Extensive placement of Hard materials required. Seed collection and plant propagation. Planting - stakes and tree guards. Weed control and maintenance.

Table 7 Riparian Vegetation Management (cont)

6. MANAGEMENT OF FLOODPLAIN RISK

Management of floodplain risk and management of riparian corridors are interlinked and any action undertaken impacts on both. Therefore proposals for changes to the riparian corridor should consider the potential for impacts on flood risk in relation to the NSW Flood Prone Land Policy. Council therefore, in developing its floodplain risk management studies and plans should consider proposed changes in the riparian corridor is assessing and managing flood risk. The major implications of this riparian corridor management study with regard to flood risk management is that:

- it is critical that an integrated approach to floodplain risk and riparian corridor management is pursued if the objectives of both policies are to be realised;
- implementation of riparian management strategies should be undertaken in such a manner so as not to make flooding worse to existing flood liable development; and
- structures to treat water quality and/or quantity should not compromise core riparian zones.

In New South Wales, floodplain management planning is a responsibility of Local Government consistent with the Government's Flood Prone Land Policy as set out in the "Floodplain Management Manual: the management of flood liable land (2001)". The flood manual provides guidelines by which local Councils can prepare Floodplain Risk Management Plans consistent with the objectives of the NSW Flood Prone Land Policy.

Following the process outlined in the Floodplain Management Manual (2001), Wollongong City Council has established eight Floodplain Management Committees to cover the floodplains in its LGA to manage existing, future and continuing flood risk. The FMC membership generally includes a wide cross-section of community and government agency representatives. Council obtains financial and technical assistance from the Government's Floodplain Management Program to prepare and implement floodplain risk management plans.

6.1 Flood History

Wollongong has an extensive record of historic floods from which to access relevant flood information for planning. Davidson [1981], Weeks [1982] and Reinfelds and Nanson [2001] have provided detailed reviews of historical flood records. The most recent floods include that of 17 August 1998 which impacted the northern suburbs of Wollongong 9Reinfelds & Nanson 2001) and the flood of 24 October 1999 which affected the Figtree area. Council has collected extensive flood data throughout the city from these events. This data is being considered in the preparation of floodplain risk management plans and background studies.

6.2 Blockage

One of the major observations following the August 1998 event was the significant impact of flood debris loads on culvert blockage. Blockage of waterway structures exacerbated flooding resulting in increased flood depths and diversion of floodwaters to unexpected flow paths increasing the danger to personal safety and flood damages resulting from this event. Council has since adopted a Culvert Blockage Policy to more accurately reflect the conditions experienced during the 1998 flood event. Details of this policy are available from Council. This issue highlighted an important inter-relationship between the management of riparian zones and flood risks in the catchments with large proportions of debris loads being sourced from inappropriately vegetated and treated riparian zones.

6.3 Flood Planning Levels

Flood studies and floodplain risk management studies, undertaken as part of the floodplain risk management process provide the basis for decisions in relation to the management of flood risk. These studies need to consider the potential development of the catchment, the dynamics of stream processes including riparian vegetation and associated changes in relation to flood behaviour in setting Flood Planning Levels. The sort of factors that may have an impact and should be considered and taken into account include:

- vegetation impacts (changes in hydraulic roughness);
- downstream tailwater conditions/greenhouse effect;
- debris loads and blockage of waterway openings;
- watercourse and flow diversions;
- dynamics of the stream geomorphology (erosion/sedimentation);
- accretion of floodplains;
- cumulative impacts of future development; and
- major infrastructure crossing floodplains.

A sensitivity analysis of the above factors undertaken whilst preparing Floodplain Management Plans will work to ensure appropriate floodplain risk management outcomes.

6.4 Flood Detention Basins

On-line basins have the potential to disrupt the life cycle of aquatic flora and fauna by providing an in-stream barrier to the movement of aquatic organisms. Wet type detention basins if they are located on-line have the potential to trap and propagate aquatic weeds, which can cause major management problems throughout the catchment.

Flood detention basins used to mitigate development are often designed and constructed as part of the Floodplain Risk Management process. These basins should be assessed considering the potential environmental, social and economic issues relevant to the locality as outlined in the Floodplain Risk Management Manual. Detailed environmental assessments should be undertaken in the planning and design of flood detention basins particularly where opportunities exist to incorporate into the design features to ensure the basin does not adversely effect the continuity of natural stream functions. “Stream category”, which is explained later in this report, can be a useful tool in assessing the acceptability and appropriateness of works on streams.

6.5 Implications of this study to Floodplain Management Planning Processes

Floodplain management and riparian corridor management is inherently interlinked in the Illawarra. Flood mitigation works undertaken in riparian corridors affect the ecological performance of the riparian corridor and vice versa. It is therefore important that floodplain risk management and riparian corridor management outcomes are consistent and compatible.

Riparian corridor management, along with many other aspects, can impact upon the existing long-term conditions in the floodplain and therefore flood behaviour and risk. Therefore any proposals for changes to the riparian corridor should consider the associated implications on flood levels and flood risk in terms of the primary objective of the NSW Government's Flood Prone Land Policy which is to:

> "reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods where possible."

These impacts are particularly critical in developed areas of the floodplain with existing flood risk management issues. Local riparian corridor management strategies will need to be developed in a manner that ensures that existing flood risk and liabilities are not exacerbated. This responsibility will rest with Council by ensuring that appropriate investigations and/or floodplain risk management studies and plans assess the impacts of riparian corridor management strategies on flood risk, along with other impacts of development of the catchment. In greenfield and new development areas, it will be necessary to consider the implications of this study in the estimation of Flood Planning Levels to ensure appropriate rehabilitation and management of geomorphic and ecological processes.

6.6 Channel modification

A frequently utilised flood mitigation measure is channelling of a watercourse. These works seek to increase the hydraulic capacity of the stream by widening, deepening, or realigning and clearing any "obstructions including vegetation" in the channel. This management option is actively discouraged as it has the potential to:

- increase flood problems downstream
- impact on channel stability both upstream and downstream
- destroy riverine habitat and ecological function
- increase maintenance costs

Modifications to channels can have significant impacts on the ecology and geomorphology of the riparian corridor. The associated environmental impacts need to be incorporated into consideration of any floodplain risk management measure.

If modification to a natural stream is essential, the work should be designed following best management guidelines for the rehabilitation and restoration of streams. Guidelines are available through organisations such as the Co-operative Research Centre for Catchment Hydrology, NSW Government (2000).

7. PROGRAM INTEGRATION AND IMPLEMENTATION

7.1 Who Can Utilise This Study?

The Riparian Corridor Management Study interacts directly with a variety of programs driven by government and the community which achieve on-ground riparian related outcomes. The relationship between the Study and the various programs is shown in Figure 5.

From Figure 5 it is apparent how wide ranging the application of this Study and its methodology and products can be. The Study crosses tiers of government in regard to policy setting, guideline preparation, assessment and modelling parameters, approvals, management/maintenance and investment of resources. At a catchment perspective, the Catchment Management Authority along with key stakeholders/interest groups and landowners can become more aware of how to best achieve protection and rehabilitation of objectives and targets for riparian, biodiversity, water quality and erosion control (via investment and incentives). At the local scale, individual landowners and industry/community groups (eg Landcare) can become more aware of the relative long-term values, functions and processes for riparian lands in their vicinity.

The suite of mechanisms or “tools” that are available to implement outcomes onto the ground are also wide ranging. The spectrum or “tool-box” to draw upon will depend largely upon the nature and scale of the decisions to be made. For example, where landuse change or development is proposed then the “tools” available largely within the Environmental Planning and Assessment legislation would be central to achieving the desired riparian outcomes. Desired riparian outcomes can also come from varied sources depending upon the tenure of land. For example, public authorities generally have Plans of Management (and resources) that account for how such public lands are to be managed and maintained into the future, whereas, private landowners may seek/require environmental grants and other available incentives to better protect/rehabilitate riparian areas. Private landowners may also seek technical advice and support on how to change in order that better management practices result to help achieve improved riparian management.

[This Study recognises that existing use rights prevails under legislation where non-compatible activities can legally continue despite possibly compromising the riparian outcome identified. However, awareness and behavioural change is always encouraged where incompatible land uses exist today. Often there are practical alternatives or management techniques that can be utilised to achieve improved riparian management at the same time as continuing with existing use rights.]

7.2 The Plan Making Process: A Key Implementation Tool

Part 3 of the Environmental Planning and Assessment (EPA) Act (1979) is a key tool in implementing the riparian corridor outcomes identified in the Study. This part of the EPA Act provides for the making of statutory plans that identify key objectives and determines how, where and what type of development can occur. A State Environmental Planning Policy (SEPP) can generally do this at a much larger scale than a Regional Environmental Plan (REP), both of which are tools available to the State Government. Figure 6 shows an application of the riparian mapping process in practice via a REP (albeit in draft form). The Figure shows how the riparian corridor mapping of Mullet Creek has been incorporated into the draft REP for the West Kembla Grange Employment Lands. The green hatched areas show the lands intended to be zoned and

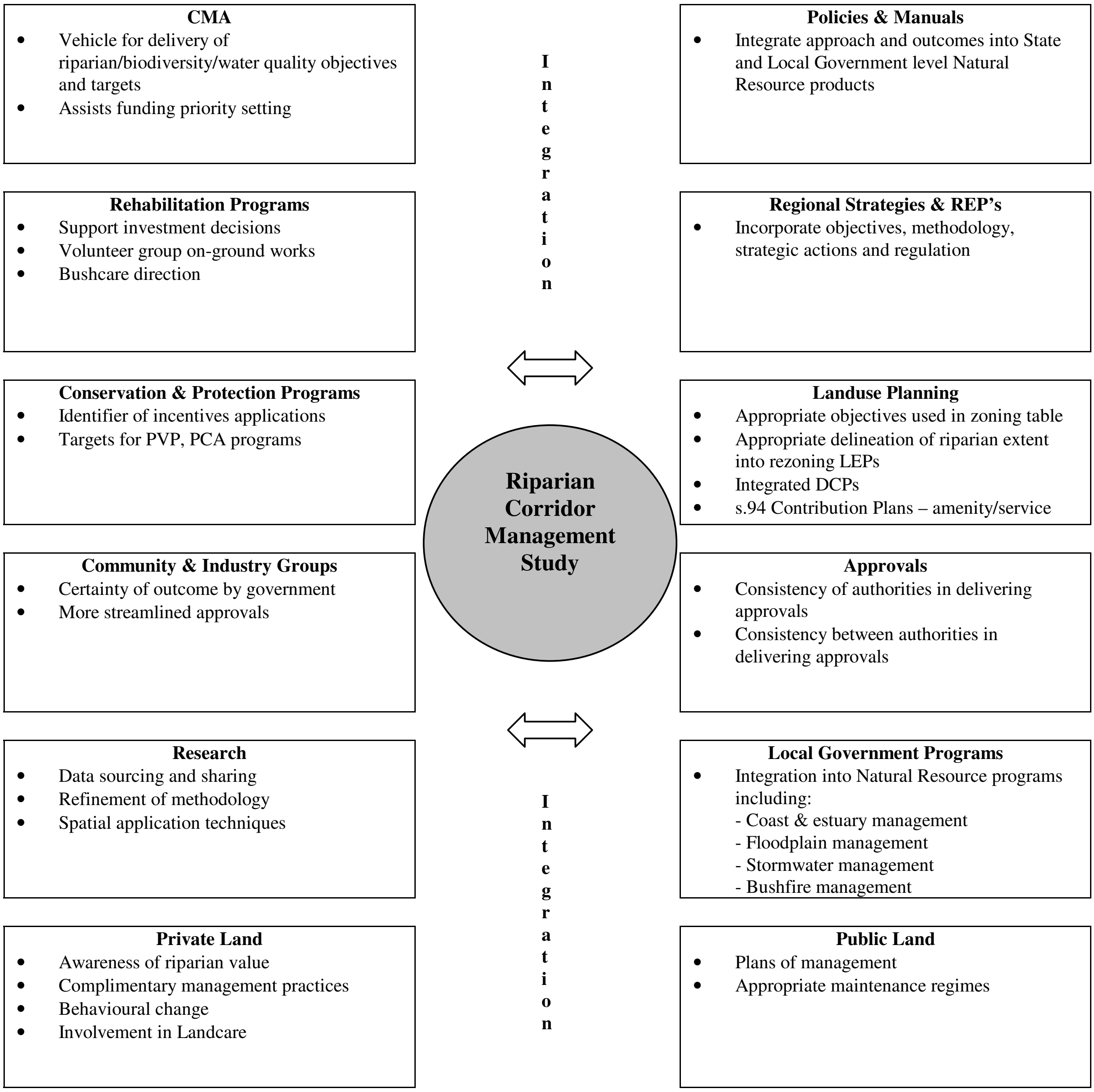


Figure 5: Relationship of the Riparian Corridor Management Study to other programs

protected as key riparian corridors (ie Category 1 – Environmental Corridor). Note the varying width of the riparian corridors which reflects the site-specific natural features rather than a single fixed width. Also, the overall Environmental Corridor has been embellished due to the integration of the adjacent remnant vegetation (of high conservation significance) and the known extent of the floodplain.

At the Local Government level, the local environmental plan (LEP) is probably the most important planning tool to best implement the detailed riparian outcomes set out in this Study. For example, the LEP can look to the zoning table to provide a zone that contains key objectives to achieve the Study outcomes and permits/prohibits appropriate development. Alternately, the LEP can contain special provisions that inform the type of development or the type of consideration to be made to ensure the value of the riparian lands results.

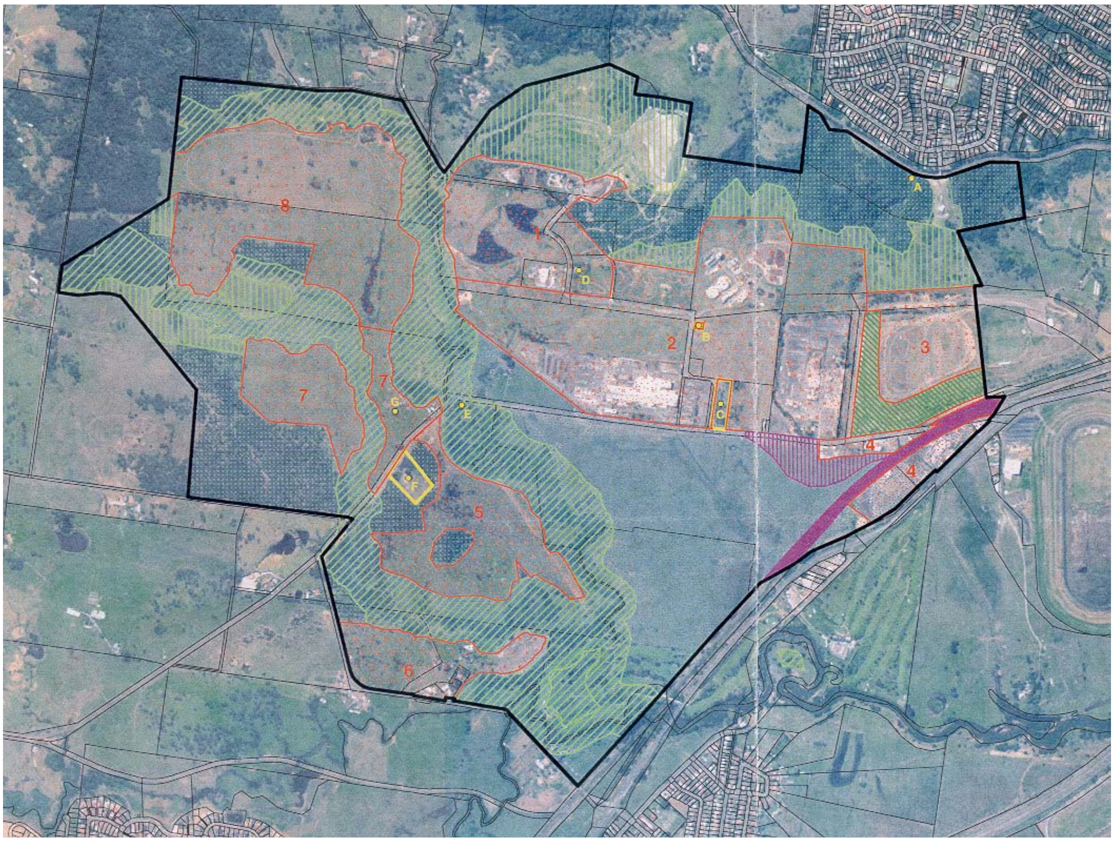


Figure 6: A preliminary version of the draft REP for West Kembla Grange showing proposed riparian corridors.

A site specific LEP (ie rezoning), where relevant, can delineate the actual footprint of the riparian land and zone it accordingly to protect the inherent functions and values. LEPs could also include worded clauses or Foreshore Building Lines to determine the extent of the riparian footprint or extent of development (and thus ensure the riparian outcome). Development control plans (DCP) and contributions plans (s.94) can add support in implementing riparian outcomes by containing valuable prescriptive and performance detail, integration of related issues (eg considerations on flooding, stormwater, bushfire, service easement locations, etc) and in regard to delivery of the environmental public amenity and service performed by riparian corridors (eg rehabilitation of riparian vegetation to deliver water quality outcomes). Appendix C encapsulates a visual representation of future riparian outcomes for land at West Dapto earmarked for urban development (ie Mullet Creek catchment area). The type of detail contained in the Appendix C can be conveyed in the LEP, DCP and s.94 processes.

While riparian outcomes are only one of possibly many layers of information that guide the making of plans, Figure 7 outlines the broader context for how riparian management can be readily incorporated into the planning framework. Understanding upfront how riparian lands fit spatially into decision making processes, one can also begin to integrate/overlay the outcomes with other aspects (eg Aboriginal heritage, fish habitat, natural bushland/open space networks, asset protection zones, etc.

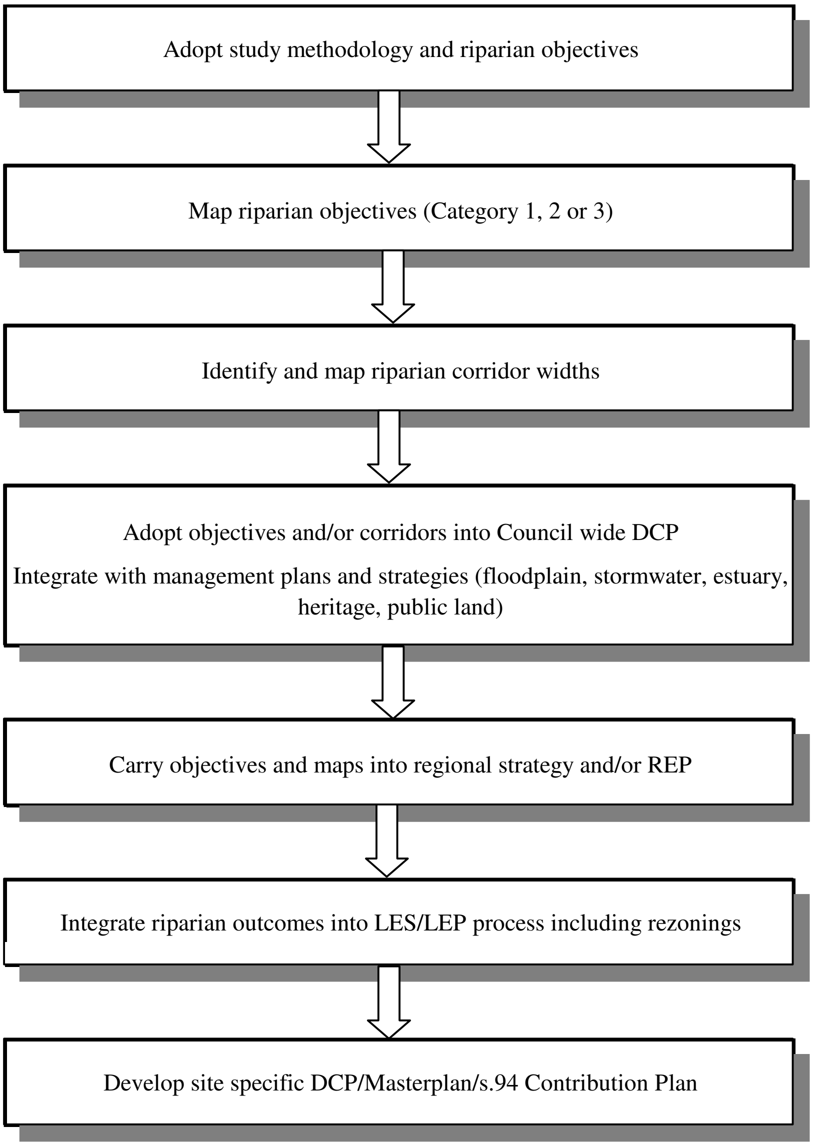


Figure 7: Planning processes in relation to implementing riparian outcomes

The incorporation of riparian objectives and delineated corridors into future plan making processes should become standard practice for Local and State governments as a result of this Study. This would support the broader environmental objectives and targets encapsulated into the Cabinet-endorsed Catchment Blueprints at the same time as enabling a more streamlined approval process to ensue for all stakeholders.

8. FUTURE DIRECTIONS FOR RIPARIAN OUTCOMES

This Study has resulted in a cost-effective methodology and mapped products that gives clarity on certainty for a multitude of end users ranging from Government through to individual landholders (plus improving awareness across the whole community). Figure 5 in the previous Section clearly set out the broad range of areas where this Study can add-value.

8.1 Recommendations

In summary, the key recommendations for riparian land management developed by this Study are:

(a) Establish Objectives for Riparian Land

Action:
- Develop environmental management objectives for riparian land that reflect the function and importance of the watercourses within a catchment context.

Outcome:
- Provides clear guidance to all stakeholders, planners and land managers/developers as to the riparian outcomes (ie functions and processes) that are achievable by consistent decision making. Riparian management is a shared responsibility.

(b) Map the Environmental Objectives of all Streams

Action:
- Clearly map the environmental category of each watercourse within a catchment that indicates the level of protection recommended for the watercourse and incorporate the map into the (advisory and statutory) planning and decision making processes.

Outcome:
- Provides upfront identification of the longer term value of a waterway and the functioning of the associated riparian lands.
- Indicates minimum core riparian widths and management areas to achieve the identified functioning so that decision makers and land managers can work towards protecting the land and implementing the outcome.

(c) Delineate and Map riparian corridor Boundaries Prior to Rezoning or Development

Action:
- As part of preparing a development proposal or a rezoning, map the actual boundaries of the riparian zone (relevant to the objective established).

Outcome:
- Ensures the relevant functioning and protection of riparian land.
- Provides certainty as to which land is available for development and how the appropriate design elements can be incorporated.
- Reduces exposure of future development to hazard and risk (eg flooding, erosion).

(d) Incorporate Riparian Management into Natural Resource Management Processes

Action:
- Integrate the riparian objectives and setbacks into other management processes such as stormwater (quality and quantity), estuary, biodiversity and bushfire studies and plans.
- Consider adequately the hydraulic implications of fully vegetated riparian zones as part of floodplain management studies and plans and develop strategies accordingly.

Outcome:
- Ensures integrated outcomes and multiple objectives are achieved.
- Provides clarity on the spatial implications and management requirements.
- Reduces potential conflict between riparian management and other natural resource processes.
- Ensures reduced hazard and risk by considering integrated outcomes.

(e) Use the Riparian Mapping to Develop Environmental Planning Instruments and Policy

Action:
- Use the objective setting to identify and map a strategic riparian framework for decision making and incorporate into development control plan (DCP) and/or regional planning strategy.
- Use the corridor mapping to delineate riparian land in the development of a local environmental plan (LEP) and/or regional planning instrument.
- Assign appropriate aims, objectives and environmental protection zone to riparian land in a LEP.

Outcome:
- Strategically recognises the importance of riparian land as an environmental asset requiring protection.
- Delivers upfront certainty to land managers, land developers and decision makers.
- Respects existing use rights.

(f) Establish Management Guidelines for Riparian Land

Action:
- Establish guidelines to integrate outcomes for the distinct management areas: core riparian zone, vegetated buffer and asset protection zone.
- Integrate the public service and amenity derived from riparian outcomes into developer agreements/developer contribution plans.
- Establish guidelines/policy for management issues including tenure and maintenance regimes (including Plans of Management for public lands).

Outcome:
- Integrates the three natural resource management zones and eliminates conflict between the requirements for each zone.
- Provides certainty of implementation and responsibility into the future.

8.2 Recent Steps Towards Integrated Outcomes

Since the draft Study was released in May 2003, a number of positive steps have been made towards the integration of the methodology and products into other strategic documents.

The objective setting and stream categorisation methodolgy has received recognition in the State Government's revised edition of, "Managing Urban Stormwater: Soils and Construction" administered jointly by the Department of Housing and Landcom (Landcom 2003). Along the similar lines, the new Department of Environment and Conservation (DEC) is integrating the spatial implications and riparian management areas of this Study into a revised suite of Managing Urban Stormwater documents relating to subdivision design, location of stormwater related infrastructure and techniques, and rehabilitation and restoration guidelines on behalf of the NSW Government.

The methodology and application of this Study has been successfully extended into the structure planning processes for the future urban growth of north-west and south-west Sydney. Over 18,000ha of largely rural land has been assessed for its long-term riparian functioning within a future urban context and the results integrated into landuse planning scenarios. The verification between the desk-top assessment of stream category and actual field inspection has resulted in extremely high correlation reinforcing the cost-effectiveness of the methodology as a fairly rapid means of establishing a strategic riparian framework for decision making.

Preliminary discussions at the local level with the Rural Fire Service has resulted in consensus that there is a need for a (bushfire) asset protection zone (APZ) in relation to vegetated riparian corridors. Given the extensive vegetated width to allow for a functioning Environmental Corridor (including CRZ and vegetated buffer), there has been general agreement, that any APZ can be largely accommodated in a new urban area by the cumulative width involved in the front setback to dwellings, the perimeter road (and its verges) fronting onto the bushland, and space for ancillary urban uses (eg pedestrian/cycleway, service easements, stormwater quality infrastructure location, urban parkland, etc). This type of subdivision design solution is already supported by the RFS in regard to managing bushfire hazard and risk.

Local Councils have embraced the strategic nature of the objective setting maps with action being proposed and taken towards inclusion of the maps and methodology into Council-wide DCPs and integration into other relevant policies and guidelines (eg biodiversity strategy preparation).

A key interest group, the Urban Development Institute of Australia, stated that the "*UDIA considers the Draft Riparian Objectives (DIPNR 2003) to be an excellent basis for formulating categories of riparian corridors*" (UDIA 2003). There is, however, a recognised need by the UDIA and DIPNR to revise State government policy considerations commensurate with the stream categories and the outcomes – particularly in regard to urbanised and urbanising catchments.

The Office of the Commissioners of Inquiry for Environment and Planning in its findings and recommendations into the Landuse Planning for certain land at Sandon Point, Wollongong City also peer reviewed the draft Study and found the report "*provides sound guidance for addressing long term riparian corridor management requirements in terms of ecologically sustainable development*" (COI 2003). The Commission also found that in determining the width of a key waterway assigned as Category 1 – Environmental Corridor, taking all the evidence into consideration, that the riparian corridor design for the subject creek should be determined generally according to the principles set out in the draft Study (ie a CRZ of 40m either side of the watercourse; a 10m vegetated buffer to counter edge effects; that water pollution control ponds and/or wetlands should not be constructed in the CRZ or vegetated buffer, and that the APZ is to be determined outside of the CRZ and vegetated buffer).

8.3 Future Directions

Some key steps that warrant further deliberation and action arising for this Study include:

8.3.1 Strategic policy level:

Review riparian related policy considerations commensurate with the stream categories and the outcomes – particularly in regard to urbanised and urbanising catchments.

Corporate governance should embrace this Study for its capacity to deliver ecologically sustainable development solutions and encourage an ethos of decision making consistent with the Study.

8.3.2 Strategic planning level:

Corporate planning recognise that when updating relevant/overlapping policies and guidelines that this Study and its methodology and principles are integrated

Develop landuse zones, aims, objectives and other special provisions to reflect the values and functions of riparian outcomes.

Incorporate strategic riparian frameworks into all planning and development processes – including statutory instruments and other plans of management (including for public land, natural resource management (eg floodplain management assessment)), study briefs for consultancies, even maintenance guidelines, etc.

8.3.3 Local level implementation:

Development of local-scale integrated management plans that identify various local actions and decisions to support the cumulative delivery of long term riparian outcomes. Take for example the Towradgi Creek catchment (or just the Environmental Corridor area), this could have a plan prepared for it whereby the various committees and arms of Council (and relevant agencies) set out the type of actions and decisions that can be taken to assist in improving the riparian corridor functioning into the long term.

For example, the upgrade of a culvert that is required to improve flood conveyance could be replaced by a bridge that also improves riparian connectivity. The re-run of computer flood modelling should be done to ascertain the implications of investing in revegetation of reaches of the creek and estuary or the implications of changing maintenance regimes from mowing and slashing certain grassed public areas to revegetating them with appropriate native species. Refocus Bushcare work. There may also be strategic opportunities where ageing housing stock is under pressure for redevelopment and the location and current development is also a constraint to the corridor functioning (eg rethinking urban design controls such as FSR, front and rear building lines, open weave fencing, etc to accommodate new development that improves the corridor functioning even by a small factor). Softer engineering solutions can be implemented where creek rehabilitation works are required is another example.

There is a multitude of small decisions continuing to occur in any single catchment over many years. It is imperative that there is some way to ensure the many small decisions work towards a larger vision. An integrated management plan prepared at the local level for strategic catchments can play a role in delivering consistent decisions towards long term outcomes. A series of integrated plans could be developed over the medium term for key/strategic catchments initially.

9. CONCLUSION

The Riparian Corridor Management Study is the culmination of a multi-disciplinary technical working group providing what has become recognised as a cost-effective and strategic way to identify and implement long term riparian outcomes. This body of work is essentially a planning tool to guide understanding and decisions. The broad range of users who can utilise and benefit from this work only adds to the Study's effectiveness. There is a plethora of detailed technical and management related work that will build upon this direction-setting work.

The Study has been made more robust from, firstly, review and comment not just within government but also from public submissions ranging from community views to technical advice. The time available to apply this body of work to other landscapes and catchments outside of the Illawarra has also highlighted the robustness and transportable nature of the Study's methodology and usefulness.

The Study methodology has been derived from sound environmental principles and scientific research. This allows a very high degree of objectivity to be built into the development of the strategic and detailed maps. The mapping products have been kept simple so that the interpretation, planning and implementation of the outcomes are made easy.

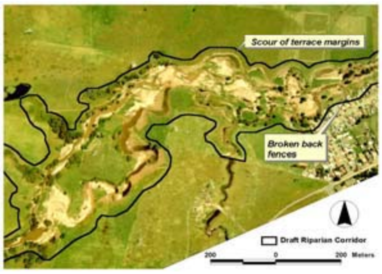
The information contained in the Study <u>delivers</u> on landuse planning and <u>informs</u> other programs. The information is readily transferable to the various types of planners, land managers, land developers and the general community. This Study improves certainty and clarity, and as such, expectations can be better understood and potential for conflict reduced.

Most importantly, the information is available for everyone to work collectively and consistently towards the identified outcomes. Embracing the visions and outcomes established in this Study requires ongoing leadership by all decision makers – elected or otherwise. Appropriate action by contemporary decision makers allows this generation to pass onto future generations riparian lands that are regarded more commonly as environmental and community assets rather than liabilities. There will be complex issues and tough decisions along the way, but at the end of the day, it is a shared responsibility to deliver healthy catchments within which we all live, work and play.

The five key elements derived from this Study are summarised below:

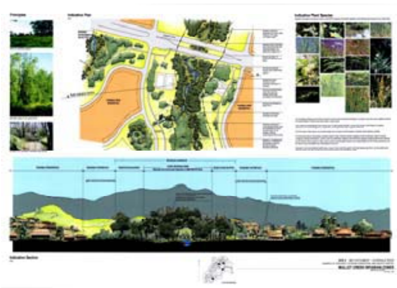
Understand the functions, processes and benefits of riparian lands and establish clear and simple objectives to maintain or restore.

Assign long term objectives to all riparian lands by mapping a Stream Category to reflect the values, functions and spatial implications.



Undertake more detailed assessment to map key riparian corridor boundaries.

Implement the objectives and protect key corridors by using the most appropriate mechanisms (eg statutory planning instruments).



Work towards clear outcomes and an understanding that all the complex issues can come together quite simply.

10. GLOSSARY OF TERMS

AEP – annual exceedance probability – the chance of a flood of a given size or larger occurring in any one year, usually expressed as a percentage.

Assisted regeneration – uses natural regeneration but also includes site replanting with locally indigenous seed or plants from a similar plant community occurring on the site, or controlled management of disturbance

Cadastral Map – a map showing legal survey boundaries, portion and plan numbers, parish and county names and boundaries. The cadastral pattern is that arrangement of survey boundaries that defines all separate parcels of land, usually for the purpose of describing and recording ownership and tenure

COI – Commission of Inquiry into the long term planning and management of the Illawarra escarpment.

CRZ – Core Riparian Zone

DCP – Development Control Plan

DEM- Digital Elevation Model

DLWC - NSW Department of Land and Water Conservation (now known as Department of Infrastructure, Planning and Natural Resources)

DIPNR – NSW Department of Infrastructure, Planning and Natural Resources

Edge Effects – particularly apply to narrow riparian corridors and include altered microclimate, weed invasion and altered interaction amongst species. The effects can be reduced on the core riparian zone by increasing the width of the vegetated riparian corridor.

Exotic – in regard to vegetation, this term refers to species coming from another area, not occurring naturally in that area

Floodplain – area of land that is subject to inundation by floods up to and including the probable maximum flood event. Floodplain is synonymous with flood prone land and flood liable land. Note it is not just land below the flood planning level or 1 in 100 year Average Recurrence Level (ARI) of 1% Annual Exceedance Probability (AEP) flood event.

Fluvial geomorphology- is the study of landforms shaped by flowing waters

LEP – Local Environmental Plan

LGA – Local Government Area

LPI - Land and Property Information Centre

Locally indigenous – with a long history of occurrence in a defined local area

Natural regeneration - relies on natural germination and resprouting of plants and focuses on weed removal, management of disturbance and the maintenance of natural processes.

NPWS - NSW National Parks and Wildlife Service

Remnant vegetation – means any patch of native vegetation around which most or all of the native vegetation has been removed

Revegetation – involves the planting or establishment of plants on a site.

Riparian vegetation – means any vegetation (native or exotic species) which is located on riparian land

Strahler's method – see stream order

Stream order - is a measure of the position of a stream in the hierarchy of tributaries and ranks the relative sizes of streams within a drainage basin (Gordon *et al*. 1994). There are a number of stream ordering methods that have been developed and include those by Horton (1932), Strahler (1952), Shreve (1967) and Scheidegger (1965). Of these, Strahler's method is widely accepted and commonly used by biologists (Gordon *et al*. 1994).

Using Strahler's method, first order streams are defined as the small intermittent and/or perennial exterior streams which have no tributaries. Second order streams form where two first order streams join together; third order streams form where two streams of order 2 join, and so on. Based on Strahler's method only one stream segment is designated the highest order number, rather than the whole parent stream.

Streams with order numbers 1-3 are low order streams and are often referred to as upland or headwater streams. Streams with order numbers 4-6 are mid order streams, while streams with order numbers greater than 6 are referred to as high order or lowland streams.

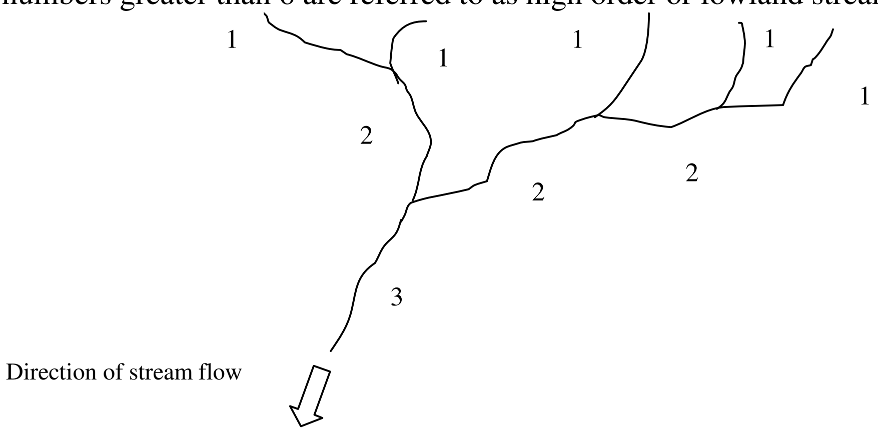


Figure 6 Stream Order – Strahler method

Watercourse – means:

(a) any watercourse, whether perennial or intermittent and whether comprising a natural channel or a natural channel artificially improved and

(b) any tributary, branch or other watercourse into or from which a watercourse referred to in (a) flows

11. REFERENCES

Abernethy, B. and Rutherford, I.D. (1999). Guidelines for Stabilising Streambanks with Riparian Vegetation. Technical Report 99/10. Cooperative Research Centre for Catchment Hydrology.

Anderson Ecological Surveys (1999). Field Determination of Riparian vegetation and watercourse characteristics to support the BMCC model for determining a watercourse buffer hierarchy in the Blue Mountains. Prepared for Blue Mountains City Council.

Askey- Doran, M., Pettit, N., Robins, L. and McDonald (1999). The Role of vegetation in riparian management. In Land and Water Resources Research and Development Corporation (1999a). Riparian Land Management Technical Guidelines. Volume One: Part A: Principles of Sound Management Part B: Review of Legislation Relating to Riparian Management.

Bennett, A. F., Brown, G., Lumsden, L., Hespe, D., Krasna, S. and Silins, J (1998). Fragments for the Future. Wildlife in the Victorian Riverina (the Northern Plains). Department of Natural Resources and Environment.

Bennett, A. F. (1999). Linkages in the Landscape. The Role of Corridors and Connectivity in Wildlife Conservation. The World Conservation Union.

Blue Mountains City Council (1999)Watercourse buffers. A model for determining a hierarchy of watercourse buffer requirements in the Blue Mountains.

Bond, N.R. and Lake, P.S. (2003). Local habitat restoration is streams: Constraints on the effectiveness of restoration of stream biota. Ecological Management & Restoration Vol 4 No 3 December 2003.

Bunn, S.E., Pusey, B.J. and Price, P. (eds) (1993). Ecology and management of Riparian Zones in Australia, LWRRDC Occasional Paper Series No. 05/93.

Burchmore, J.J. (1993) ed. Freshwater Habitat Management Guidelines. NSW Fisheries

Caterall, C. P (1993). The Importance of Riparian lands to terrestrial wildlife. In Bunn, S. E, Pusey, B.J and Price, P (eds) 1993: Ecology and Management of Riparian Zones in Australia, LWRRDC Occasional Paper Series No:05/93 ISSN 1320-0992 ISBN 0 642 167737.

Chafer, C.J. (1997). Biodiversity of Wetlands in the Illawarra: an inventory. Illawarra Catchment Management Committee, Wollongong.

Commission of Inquiry (1999). The long term planning and management of the Illawarra Escarpment. Wollongong local government area. Commissioners of Inquiry for Environment and Planning

Commission of Inquiry (2003). Land use planning for certain land at Sandon Point, Wollongong City. Commissioners of Inquiry foe Environment and planning.

Department of Infrastructure, Planning and Natural Resources (1996) The NSW Wetlands Management Policy

Department of Land and Water Conservation & Wollongong City Council (May 2002) Final Draft 17 August 1998 Storms in Wollongong Flood Data Report

Fisheries NSW (1998). Policy and Guidelines Aquatic Habitat Management and Fish Conservation (eds A K Smith and D A Pollard) NSW Fisheries, Sydney

Fisheries NSW (1999). Policy and Guidelines for Bridges, Roads, Causeways, Culverts and Similar structures. (eds S Faufull and S Carter) NSW Fisheries, Sydney.

Gordon, N.D., McMahon, T.A. and Finlayson, B.L. (1994). Stream Hydrology. An Introduction for Ecologists. John Wiley and Sons Pty Ltd

Greening Australia New South Wales (1999). Management Principles to Guide the Restoration and Rehabilitation of Indigenous Vegetation.

Grootemaat, G. (2000). Spatial characteristics of high magnitude storms and channel response, Illawarra, NSW. Unpublished BSc(Hons) thesis, School of Geosciences, University of Wollongong.

Hawkesbury Nepean Catchment Management Trust (2000). Focus on River Channels.

Illawarra Catchment Management Committee (1994). Management of Urban Watercourse Corridors.

Land and Water Resources Research and Development Corporation (1999a). Riparian Land Management Technical Guidelines. Volume One: Part A: Principles of Sound Management Part B: Review of Legislation Relating to Riparian Management.

Land and Water Resources Research and Development Corporation (1999b). Riparian Land Management Technical Guidelines. Volume Two: On-ground Management Tools and Techniques.

Landcom (2003). Draft Managing Urban Stormwater. 4th Edition.

Liverpool City Council (1999). Development Control Plan No. 8 Natural Assets

Lovett & Price (1999). Riparian Land Management Technical Guidelines, Volume One: Principles of Sound Management, Volume two: On-ground Management Tools and Techniques. LWRRDC.

Lynch, R.J and Caterall, CP. (1999a). Riparian wildlife and habitats. In Land and Water Resources Research and Development Corporation (1999a). Riparian Land Management Technical Guidelines. Volume One: Part A: Principles of Sound Management Part B: Review of Legislation Relating to Riparian Management.

Lynch, R.J and Caterall, CP. (1999b). Managing Riparian Land for Terrestrial Wildlife. In Land and Water Resources Research and Development Corporation (1999b). Riparian Land Management Technical Guidelines. Volume Two: On-ground Management Tools and Techniques.

Martin, G. (2003). The role of small ground-foraging mammals in topsoil health and biodiversity: Implications to management and restoration. Ecological Management & Restoration Vol 4 No 2 December 2003.

Nanson, G. C. and Young, R. W. (1981). Downstream reduction of rural channel size with contrasting urban effects in small coastal streams of southeastern Australia. Journal of Hydrology, 52, 239-255.

NSW Government (2001) Floodplain Management Manual: the management of flood liable land, January 2001.

NSW National Parks and Wildlife Service (2002). Native Vegetation of the Wollongong Escarpment and Coastal Plain.

Price, P. and Lovett, S. (2002). Maintaining in-stream life, Fact Sheet 4, Land & Water Australia, Canberra.

Price, P. and Lovett, S. (2002). Riparian habitat for wildlife, Fact Sheet 5, Land and Water Australia, Canberra.

Prosser, I, Bunn S, Thorsten M., Ogden R., and Karssies, L. (1999). The delivery of sediment and nutrients to streams. In Land and Water Resources Research and Development Corporation (1999a). Riparian Land Management Technical Guidelines. Volume One: Part A: Principles of Sound Management Part B: Review of Legislation Relating to Riparian Management.

Quinn, JM, Cooper, AB and Williamson RB (1993) Riparian Zones as buffer strips: a New Zealand perspective. In Bunn, S.E., Pusey, B.J. and Price, P. (eds) (1993). Ecology and management of Riparian Zones in Australia, LWRRDC Occasional Paper Series No. 05/93.

Reinfelds, I. and Nanson, G. C. (2001). Torrents of terror: the August 1998 storm and the magnitude, frequency and impact of major floods in the Illawarra region of New South Wales. Australian Geographical Studies, 39, 335-352.

Riding, T. and Carter, R. (1992). The Importance of the Riparian Zone in Water Resource Management. NSW Department of Water Resources.

Rutherford, ID., Jerie, K. and Marsh, N. (1999). A Rehabilitation Manual for Australian Streams, Volume 1. Land and Water Resources and Development Corporation and Cooperative Research Centre for Catchment Hydrology

Tubman, W and Price, P. (1999). The significance and status of riparian land. In Land and Water Resources Research and Development Corporation (1999a). Riparian Land Management Technical Guidelines. Volume One: Part A: Principles of Sound Management Part B: Review of Legislation Relating to Riparian Management.

Water Resources Council (1993). The NSW State Rivers and Estuaries Policy.

APPENDIX A

Riparian Management Objective Maps

Riparian Management Objectives
Map Overview:

Legend:

Airphotos ortho-rectified from 1998 photos sourced from Land and Property Information Division, Dept of Lands.
Also sourced from 2001 ortho-rectified photos from Wollongong City Council

▲ Town

Map Boundaries

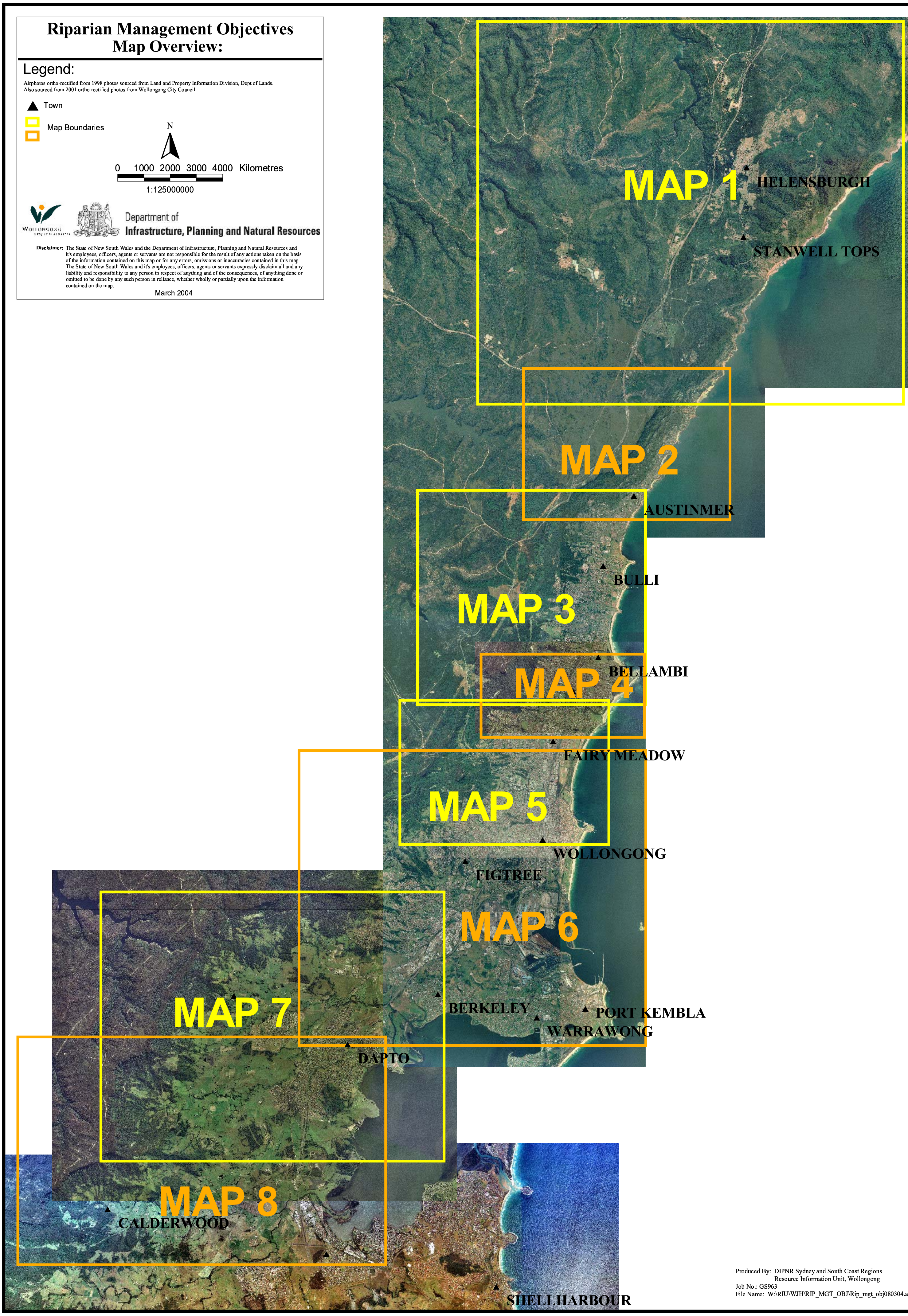
N

0 1000 2000 3000 4000 Kilometres

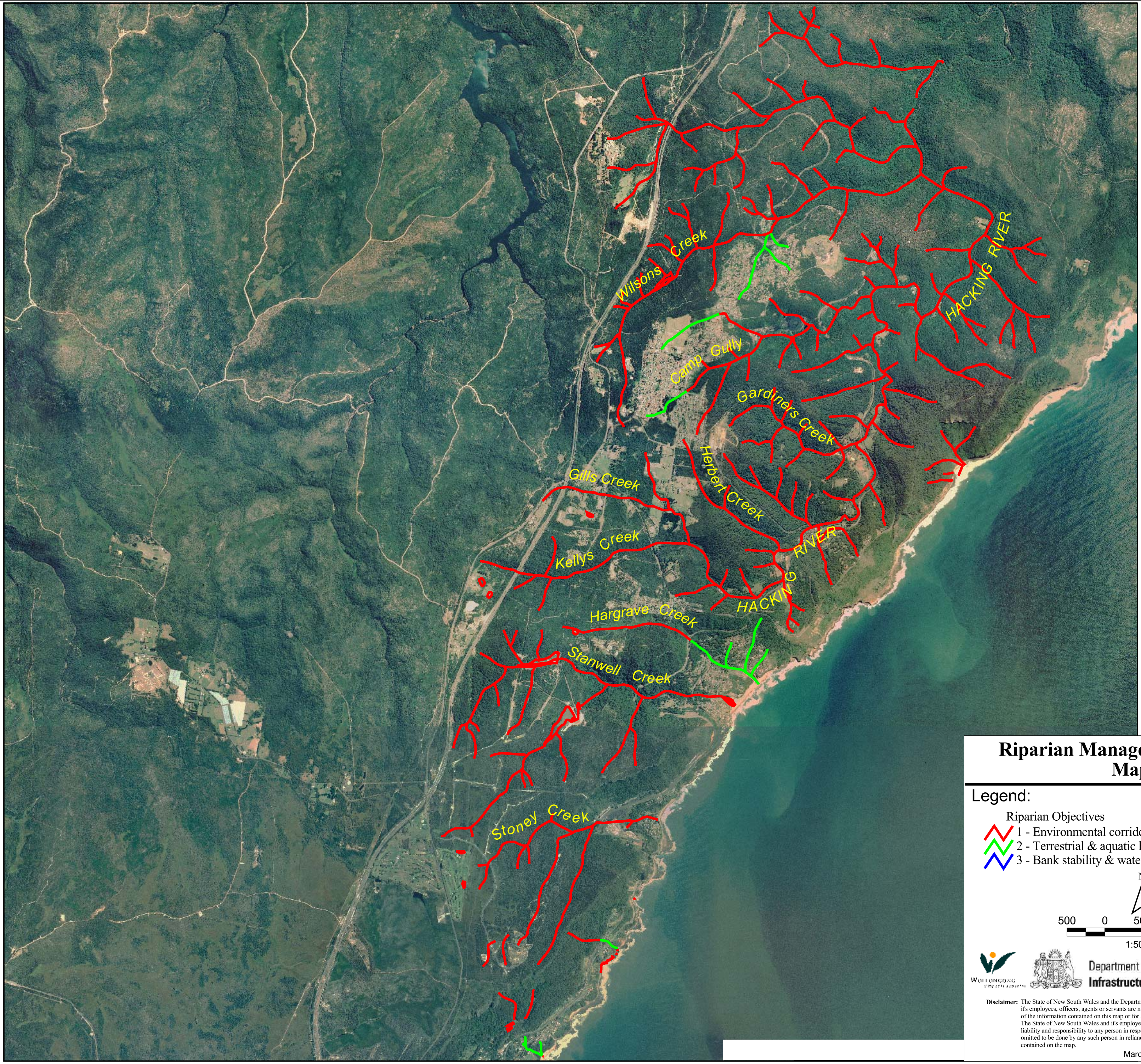
1:125000000

Department of
Infrastructure, Planning and Natural Resources

March 2004



Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Management Objectives
Map 1:

Legend:

Riparian Objectives
1 - Environmental corridor
2 - Terrestrial & aquatic habitat
3 - Bank stability & water quality

Airphotos ortho-rectified from 1998 photos sourced from Land and Property Information Division, Dept of Lands.

N

500 0 500 1000 1500 Metres

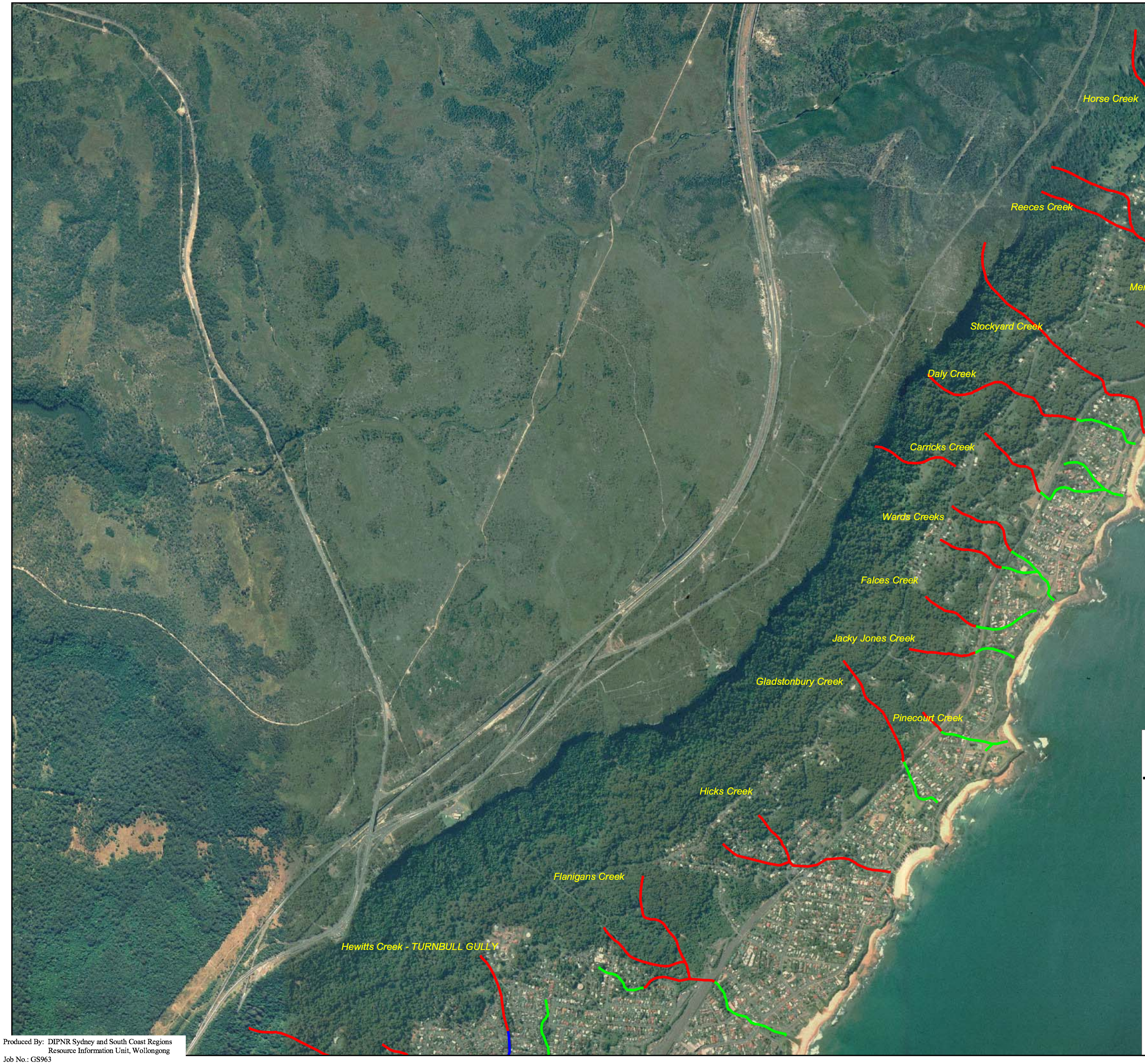
1:50000

Department of Infrastructure, Planning and Natural Resources

Disclaimer: The State of New South Wales and the Department of Infrastructure, Planning and Natural Resources and it's employees, officers, agents or servants are not responsible for the result of any actions taken on the basis of the information contained on this map or for any errors, omissions or inaccuracies contained in this map. The State of New South Wales and it's employees, officers, agents or servants expressly disclaim all and any liability and responsibility to any person in respect of anything and of the consequences, of anything done or omitted to be done by any such person in reliance, whether wholly or partially upon the information contained on the map.

March 2004

Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Management Objectives Map 2:

Legend:

Riparian Objectives
1 - Environmental corridor
2 - Terrestrial & aquatic habitat
3 - Bank stability & water quality

Airphotos ortho rectified from 1998 photos sourced from Land and Property Information Division, Dept of Lands.

N

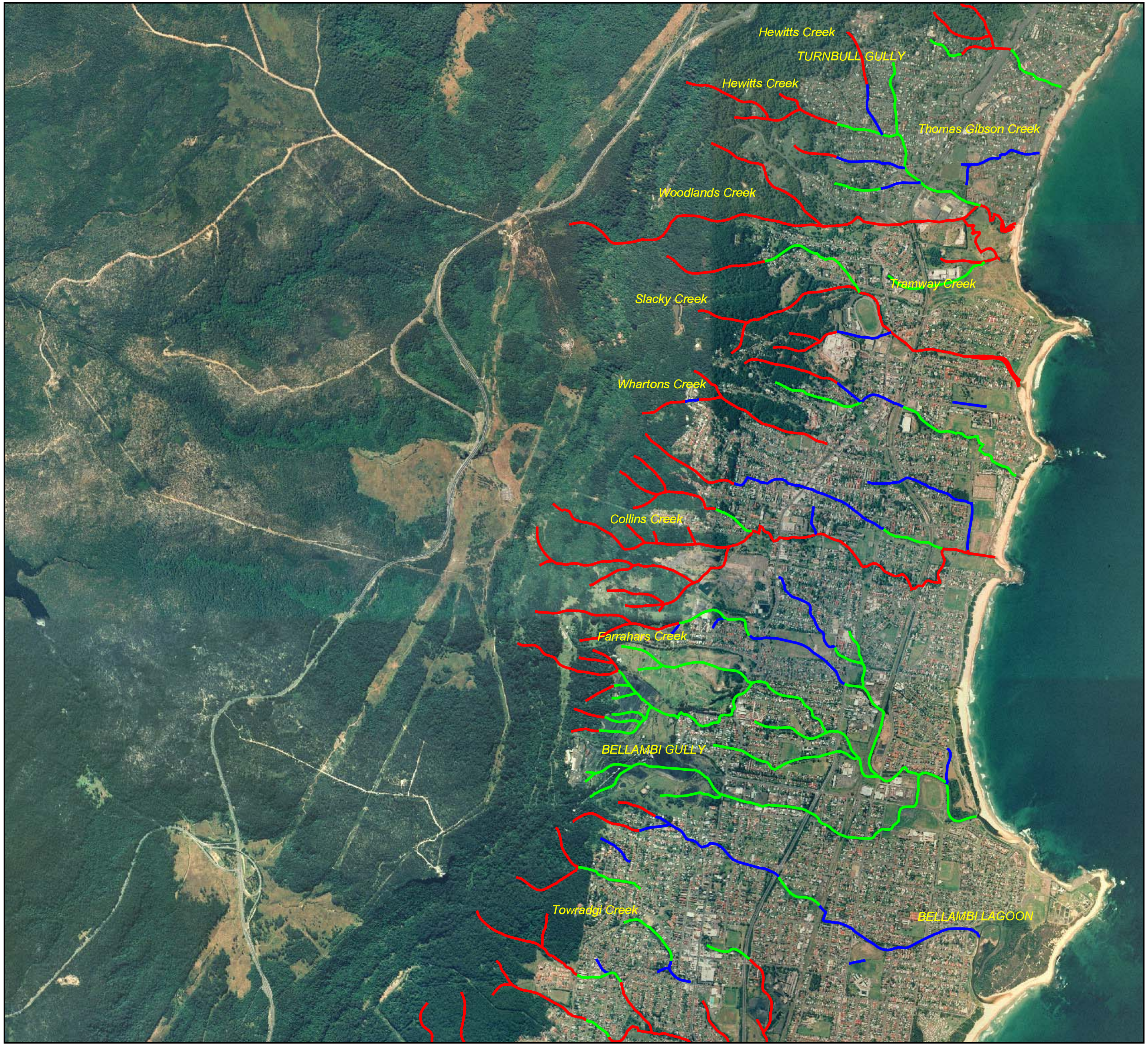
200 0 200 400 600 Metres

1:20000

Department of
Infrastructure, Planning and Natural Resources

March 2004

Produced By: DIPNR Sydney and South Coast Regions Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Management Objectives
Map 3:

Legend:

Riparian Objectives
1 - Environmental corridor
2 - Terrestrial & aquatic habitat
3 - Bank stability & water quality

Airphotos ortho rectified from 1998 photos sourced from Land and Property Information Division, Dept of Lands.

N

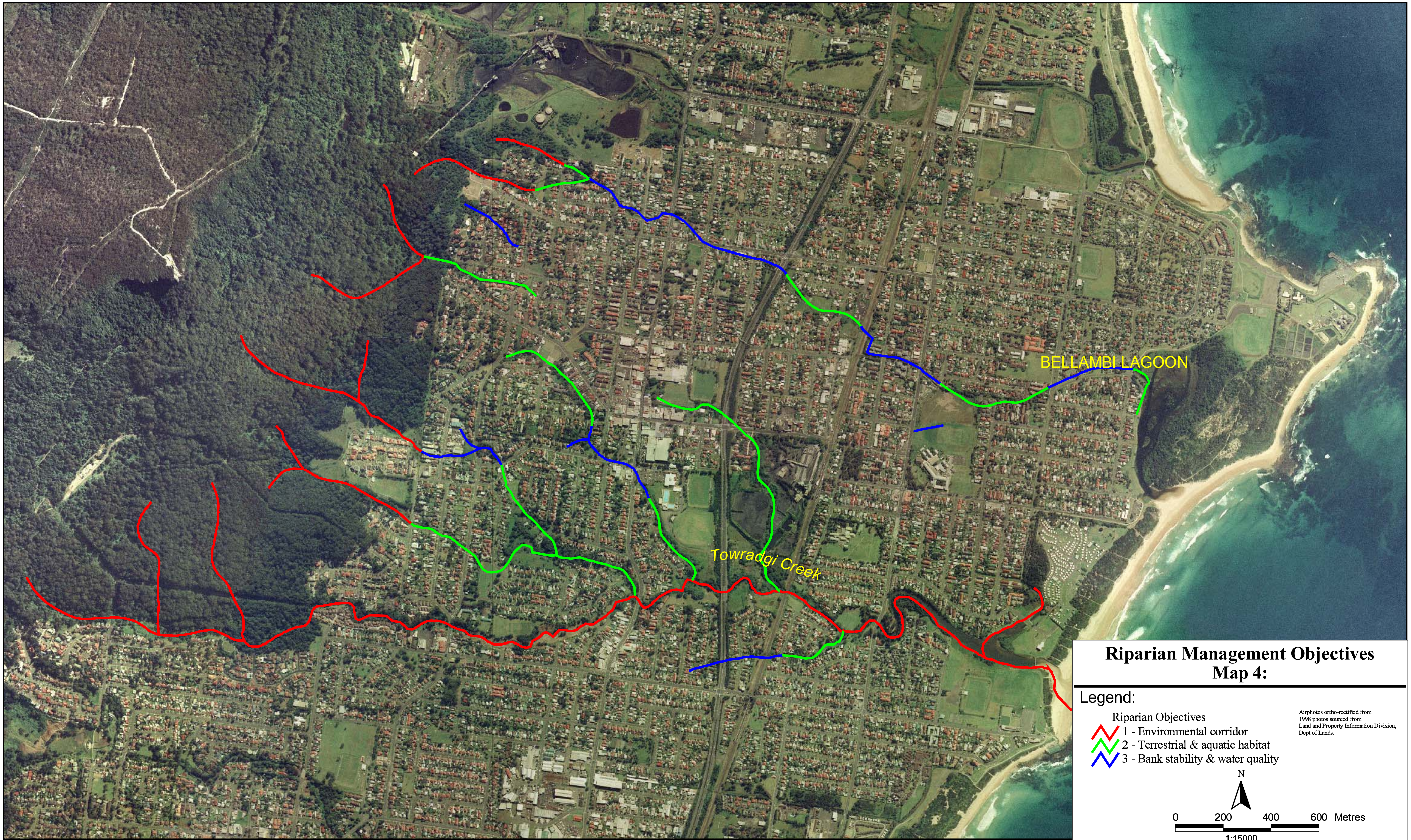
0 200 400 600 800 1000 1200 Metres

1:30000

Department of
Infrastructure, Planning and Natural Resources

March 2004

Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Management Objectives
Map 4:

Legend:

Riparian Objectives
1 - Environmental corridor
2 - Terrestrial & aquatic habitat
3 - Bank stability & water quality

Airphotos ortho-rectified from 1998 photos sourced from Land and Property Information Division, Dept of Lands.

N

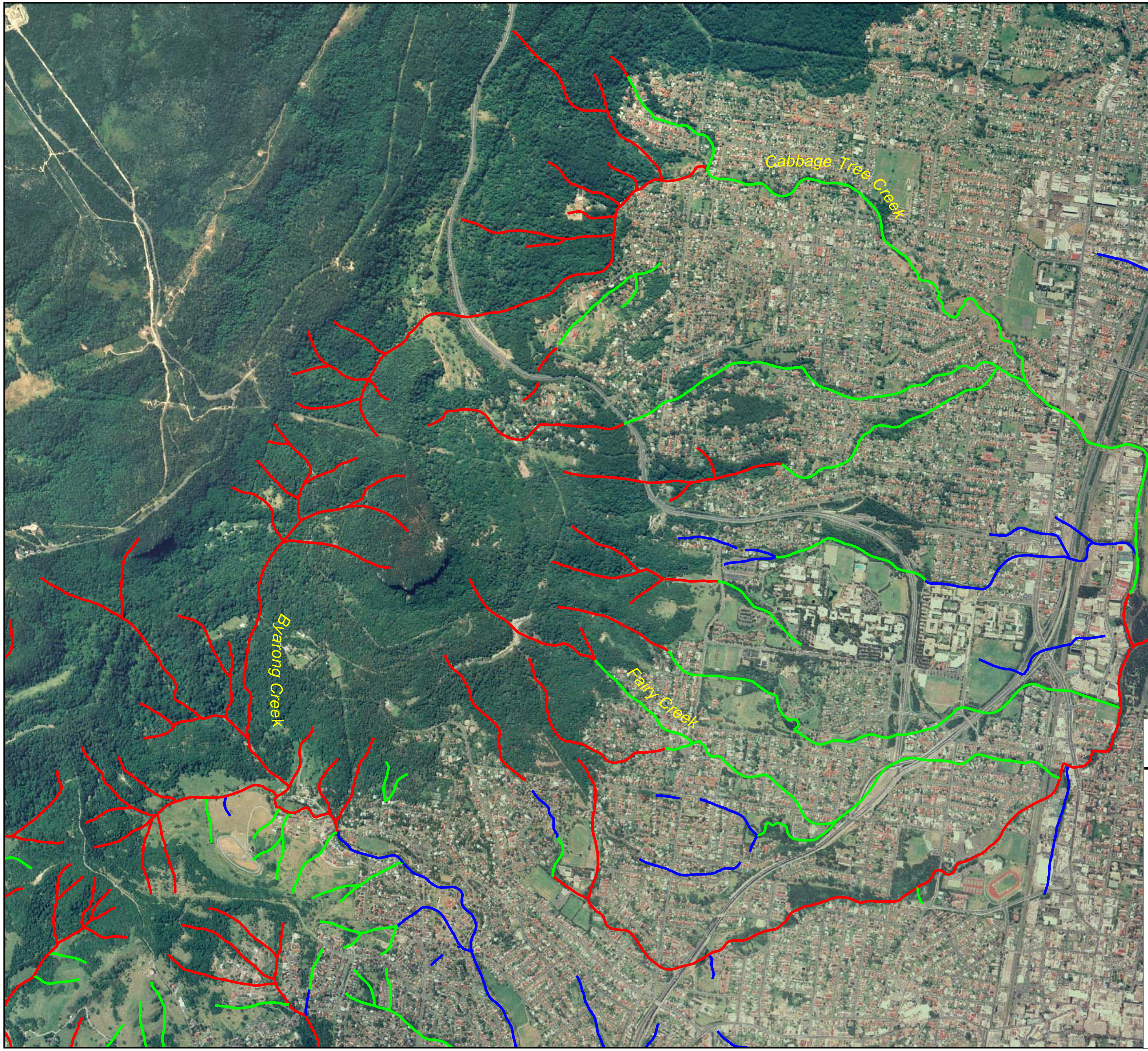
0 200 400 600 Metres

1:15000

Department of **Infrastructure, Planning and Natural Resources**

March 2004

Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Management Objectives
Map 5:

Legend:

Riparian Objectives
1 - Environmental corridor
2 - Terrestrial & aquatic habitat
3 - Bank stability & water quality

Airphotos ortho-rectified from 1998 photos sourced from Land and Property Information Division, Dept of Lands.

N

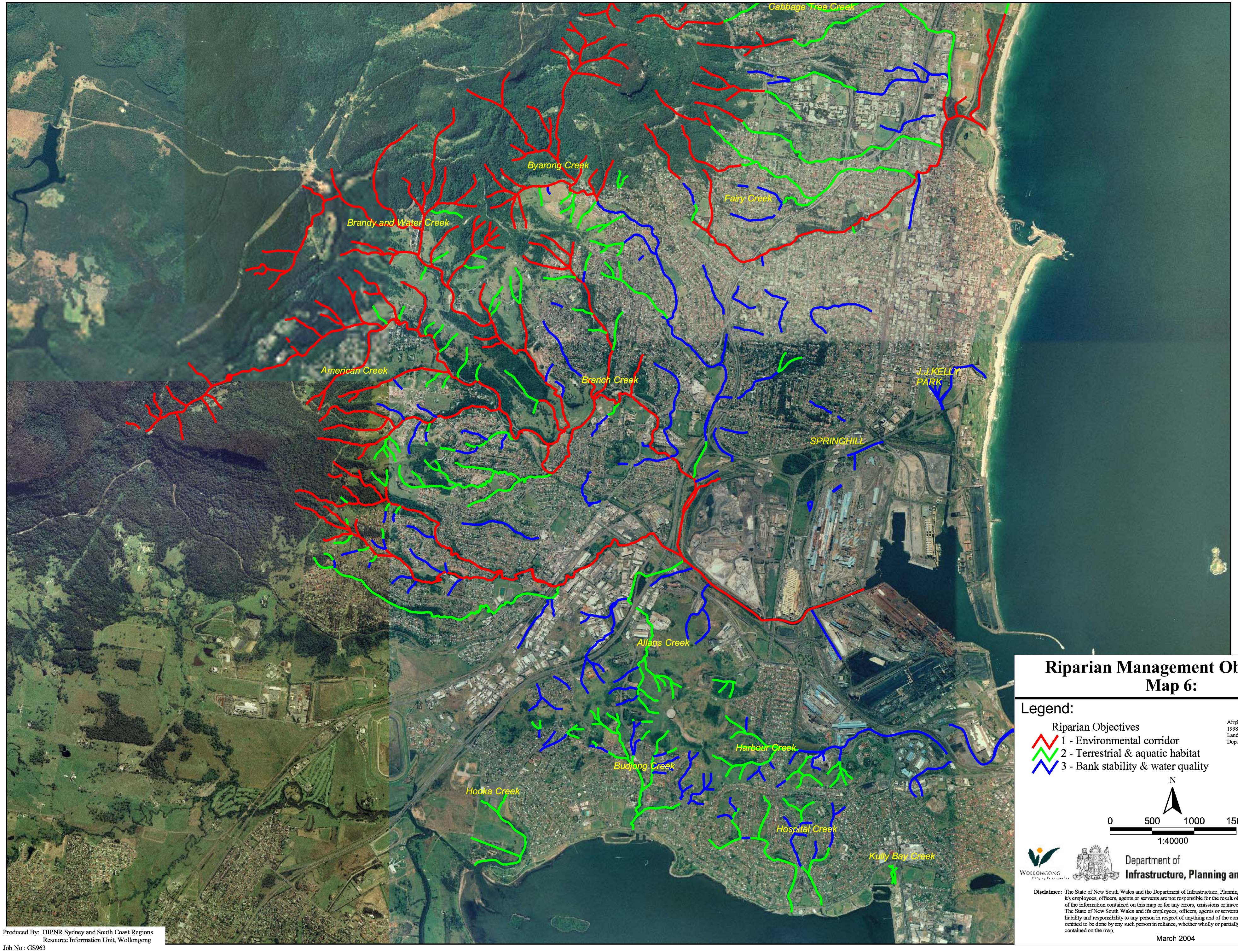
0 200 400 600 800 Metres

1:20000

Department of
Infrastructure, Planning and Natural Resources

March 2004

Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Management Objectives
Map 6:

Legend:

Riparian Objectives
1 - Environmental corridor
2 - Terrestrial & aquatic habitat
3 - Bank stability & water quality

Airphotos ortho-rectified from 1998 photos sourced from Land and Property Information Division, Dept of Lands.

N

0 500 1000 1500 Metres

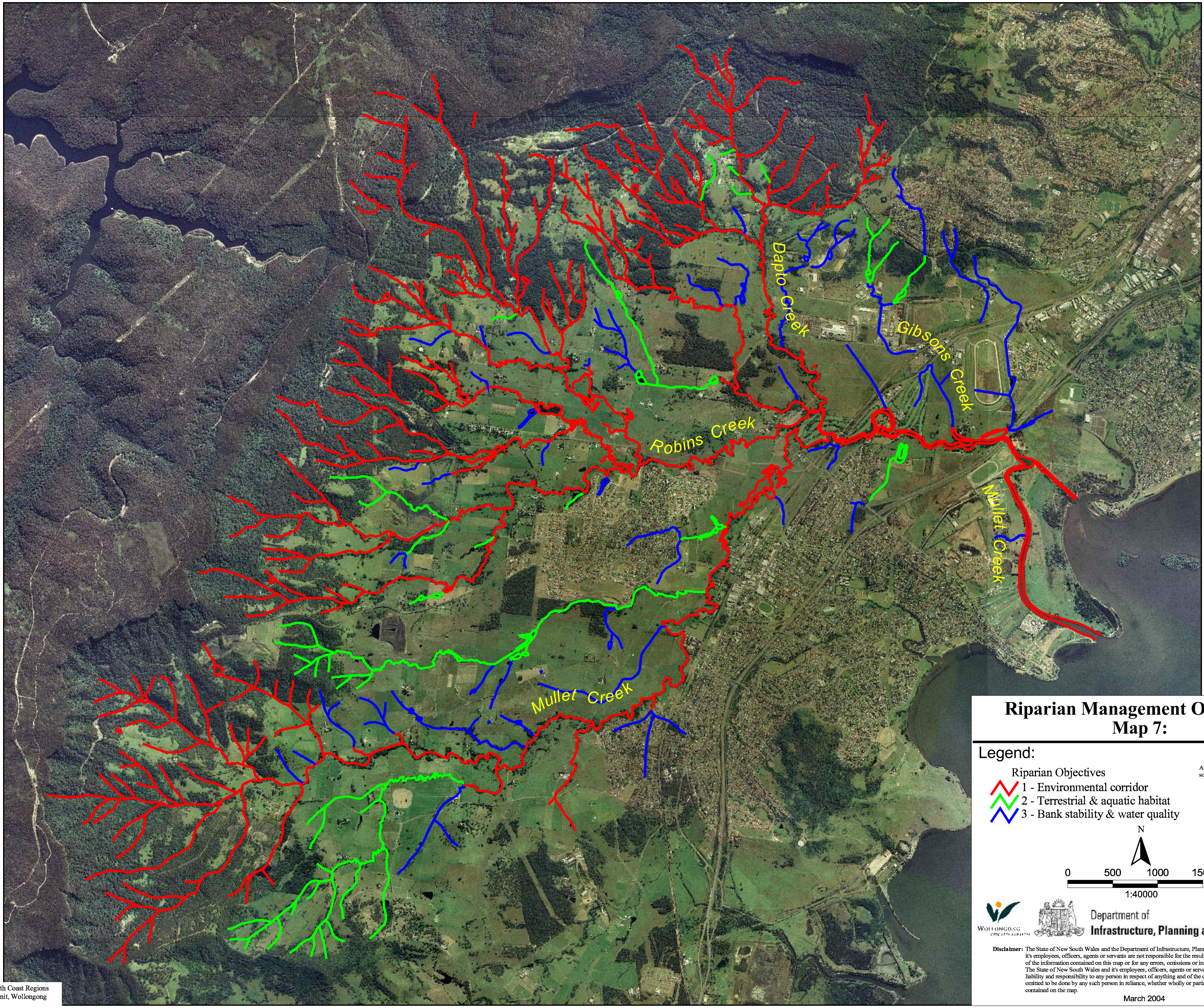
1:40000

Wollongong

Department of
Infrastructure, Planning and Natural Resources

March 2004

Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Management Objectives
Map 7:

Legend:

Riparian Objectives
- 1 - Environmental corridor
- 2 - Terrestrial & aquatic habitat
- 3 - Bank stability & water quality

Airphotos from 2001 ortho-rectified photos sourced from Wollongong City Council.

N

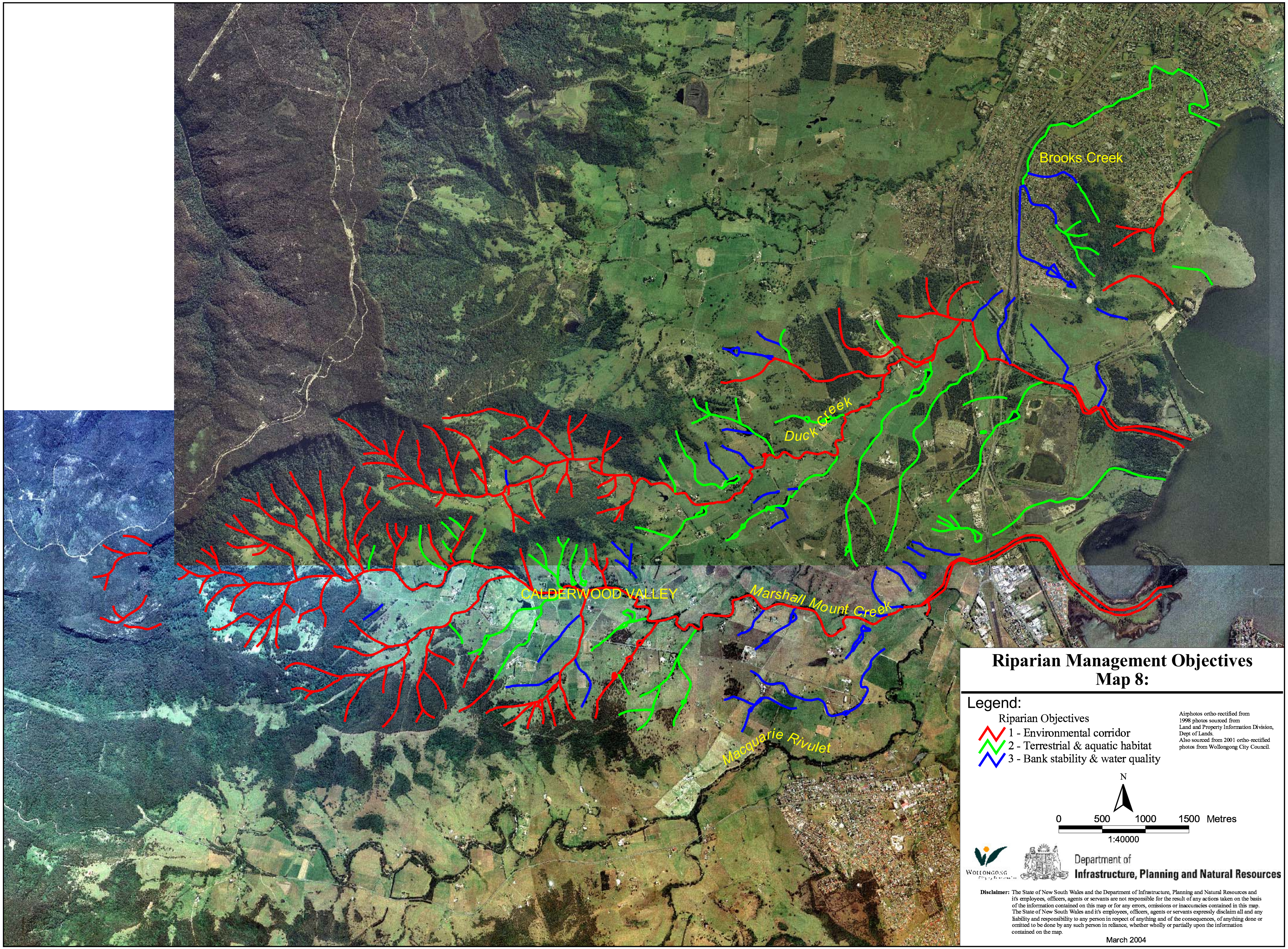
0 500 1000 1500 Metres

1:40000

Department of
Infrastructure, Planning and Natural Resources

March 2004

Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Management Objectives
Map 8:

Legend:

Riparian Objectives
- 1 - Environmental corridor
- 2 - Terrestrial & aquatic habitat
- 3 - Bank stability & water quality

Airphotos ortho-rectified from
1998 photos sourced from
Land and Property Information Division,
Dept of Lands.
Also sourced from 2001 ortho-rectified
photos from Wollongong City Council.

N

0 500 1000 1500 Metres

1:40000

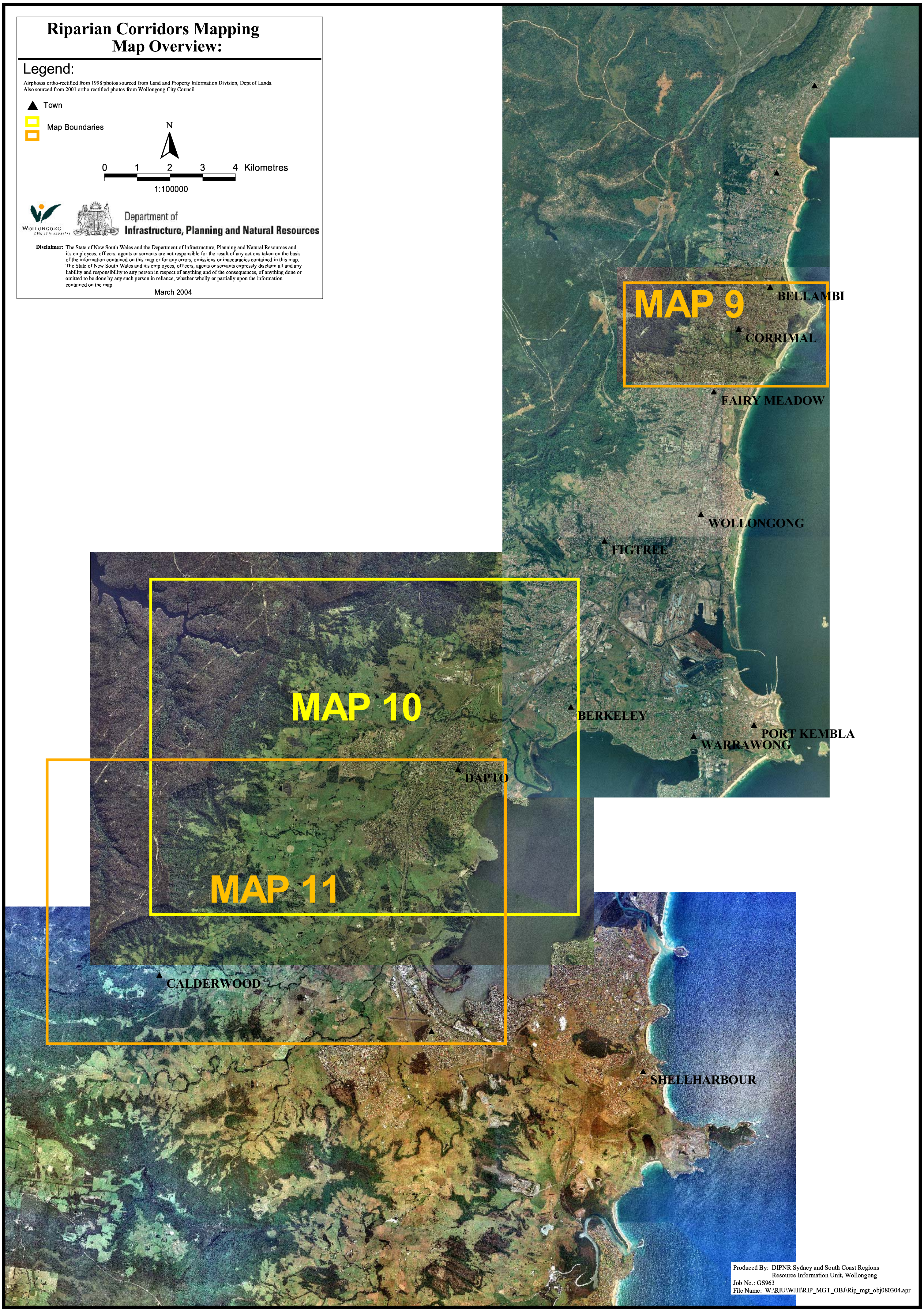
Department of
Infrastructure, Planning and Natural Resources

March 2004

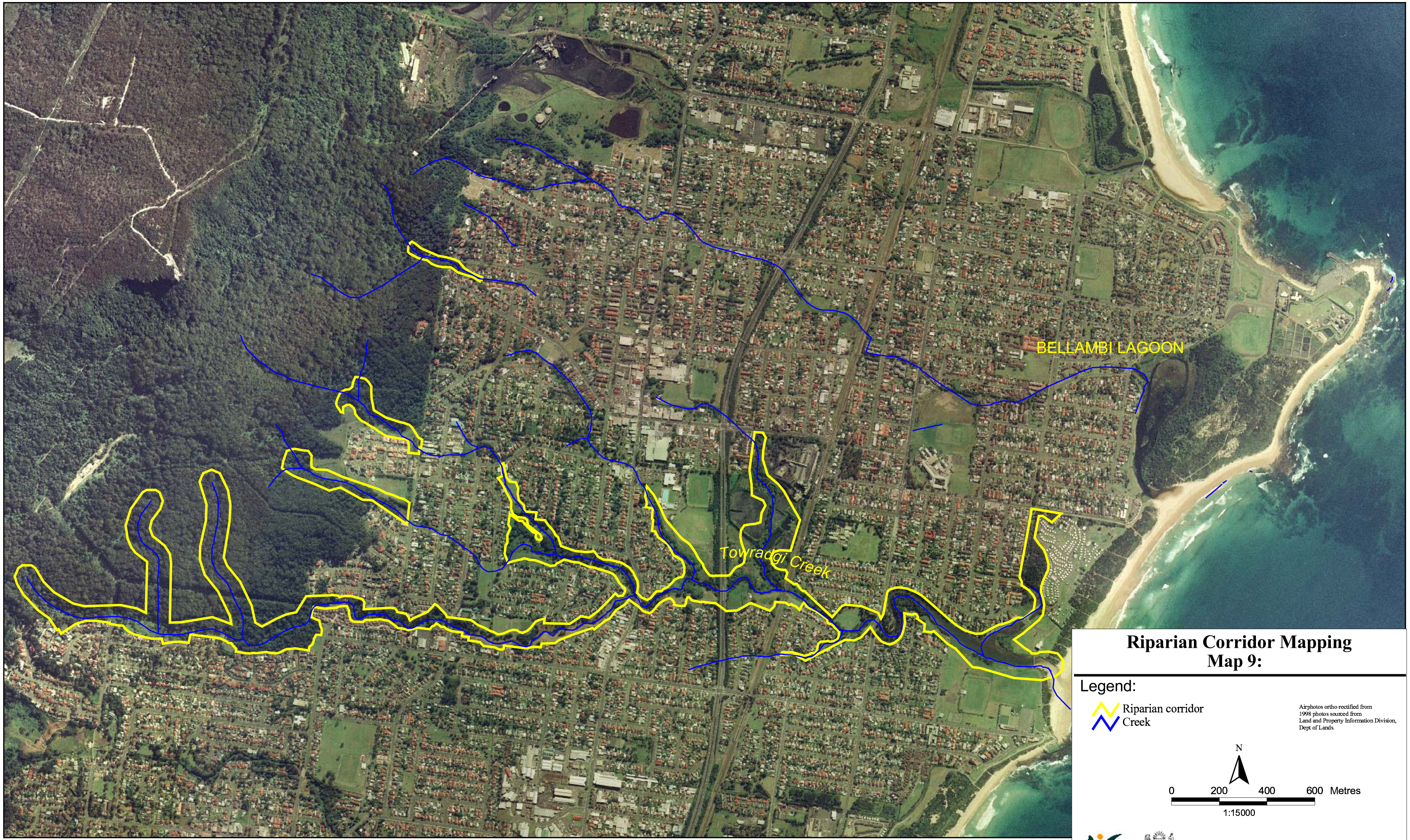
Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr

APPENDIX B

Riparian Corridor Boundary Maps



Riparian Corridors Mapping
Map Overview:
Legend:
Airphotos ortho-rectified from 1998 photos sourced from Land and Property Information Division, Dept of Lands.
Also sourced from 2001 ortho-rectified photos from Wollongong City Council
Town
Map Boundaries
N
0 1 2 3 4 Kilometres
1:100000
Department of
Infrastructure, Planning and Natural Resources
Disclaimer: The State of New South Wales and the Department of Infrastructure, Planning and Natural Resources and it's employees, officers, agents or servants are not responsible for the result of any actions taken on the basis of the information contained on this map or for any errors, omissions or inaccuracies contained in this map. The State of New South Wales and it's employees, officers, agents or servants expressly disclaim all and any liability and responsibility to any person in respect of anything and of the consequences, of anything done or omitted to be done by any such person in reliance, whether wholly or partially upon the information contained on the map.
March 2004
MAP 9
BELLAMBI
CORRIMAL
FAIRY MEADOW
WOLLONGONG
FIGTREE
MAP 10
BERKELEY
PORT KEMBLA
WARRAWONG
DAPTO
MAP 11
CALDERWOOD
SHELLHARBOUR
Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Corridor Mapping
Map 9:

Legend:

- Riparian corridor
- Creek

Airphotos ortho rectified from 1998 photos sourced from Land and Property Information Division, Dept of Lands.

N

0 200 400 600 Metres

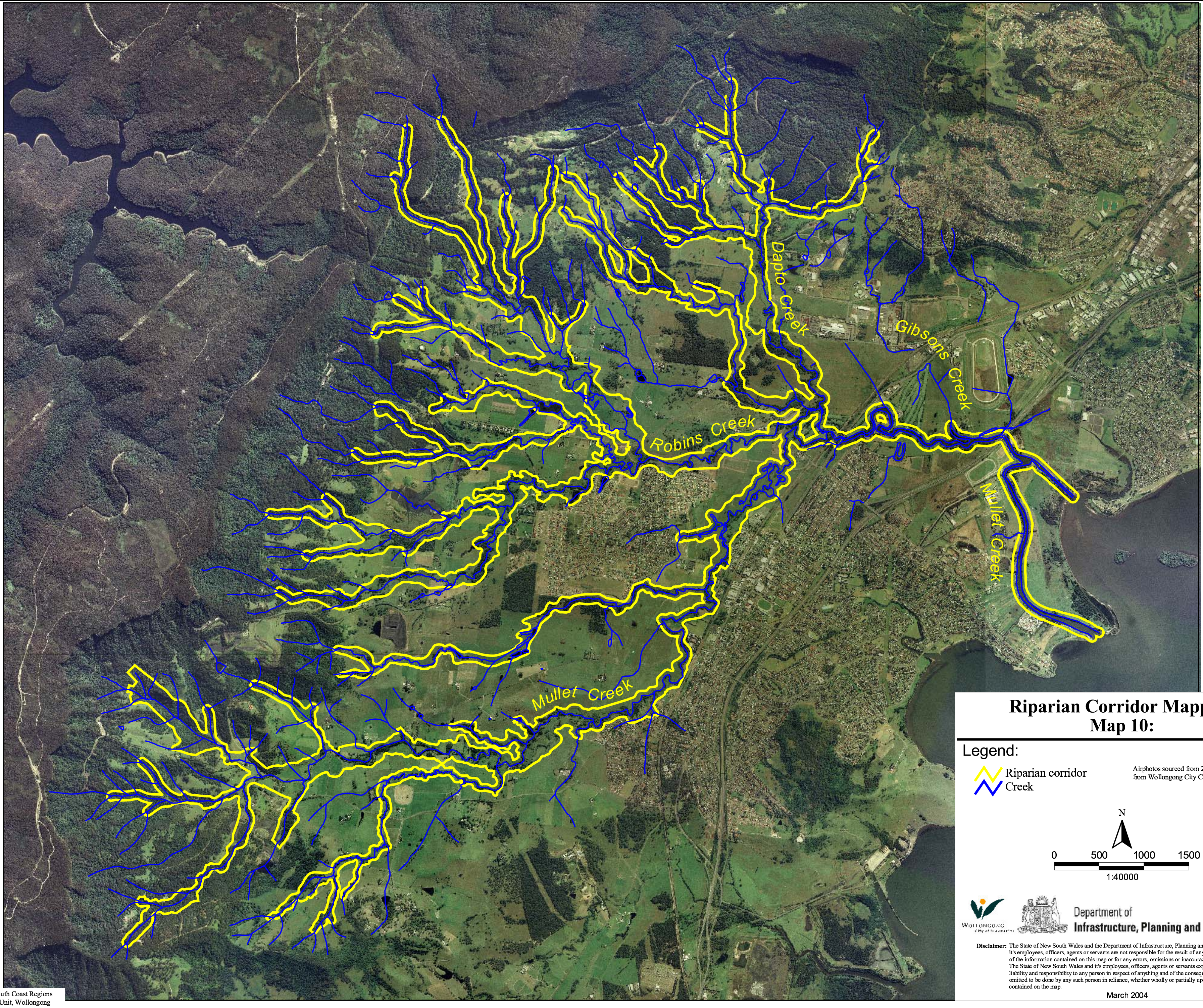
1:15000

Department of
Infrastructure, Planning and Natural Resources

March 2004

Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr

Riparian Corridor Mapping
Map 10:



Legend:

- Riparian corridor
- Creek

Airphotos sourced from 2001 ortho-rectified photos from Wollongong City Council.

N

0 500 1000 1500 Metres

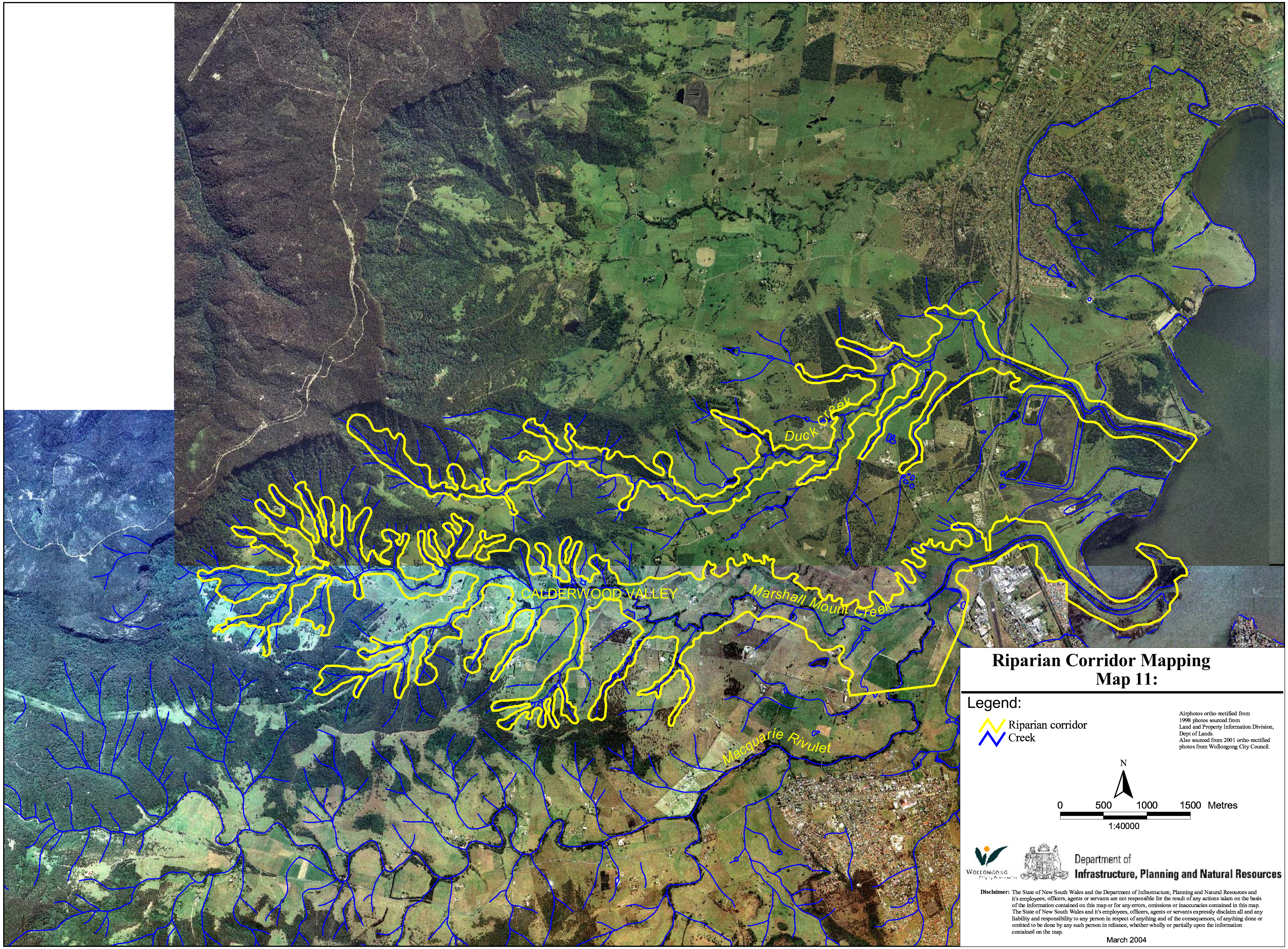
1:40000

Department of
Infrastructure, Planning and Natural Resources

Disclaimer: The State of New South Wales and the Department of Infrastructure, Planning and Natural Resources and it's employees, officers, agents or servants are not responsible for the result of any actions taken on the basis of the information contained on this map or for any errors, omissions or inaccuracies contained in this map. The State of New South Wales and it's employees, officers, agents or servants expressly disclaim all and any liability and responsibility to any person in respect of anything and of the consequences, of anything done or omitted to be done by any such person in reliance, whether wholly or partially upon the information contained on the map.

March 2004

Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr



Riparian Corridor Mapping
Map 11:

Legend:

Riparian corridor
Creek

Airphotos ortho-rectified from
1998 photos sourced from
Land and Property Information Division,
Dept of Lands.
Also sourced from 2001 ortho-rectified
photos from Wollongong City Council.

N

0 500 1000 1500 Metres

1:40000

Wollongong

Department of
Infrastructure, Planning and Natural Resources

March 2004

Produced By: DIPNR Sydney and South Coast Regions
Resource Information Unit, Wollongong
Job No.: GS963
File Name: W:\RIU\WJH\RIP_MGT_OBJ\Rip_mgt_obj080304.apr

APPENDIX C

Representative Riparian Cross Sections

Principles

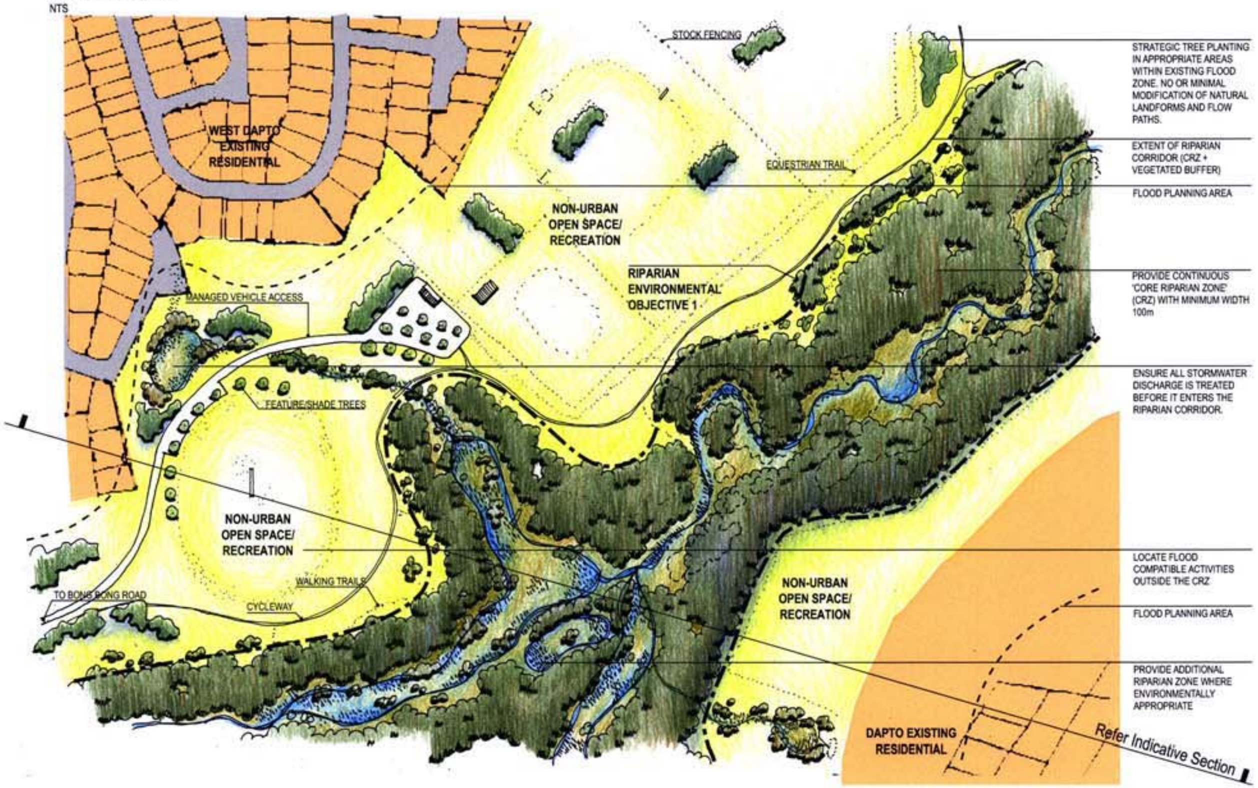
RURAL SHOULDERS

BROAD RIPARIAN ZONE

RECREATIONAL EDGES

Indicative Plan

NTS



Indicative Plant Species

Vegetation descriptions are based in part on draft NPWS mapping of the Native Vegetation of the Wollongong Escarpment and Coastal Plain

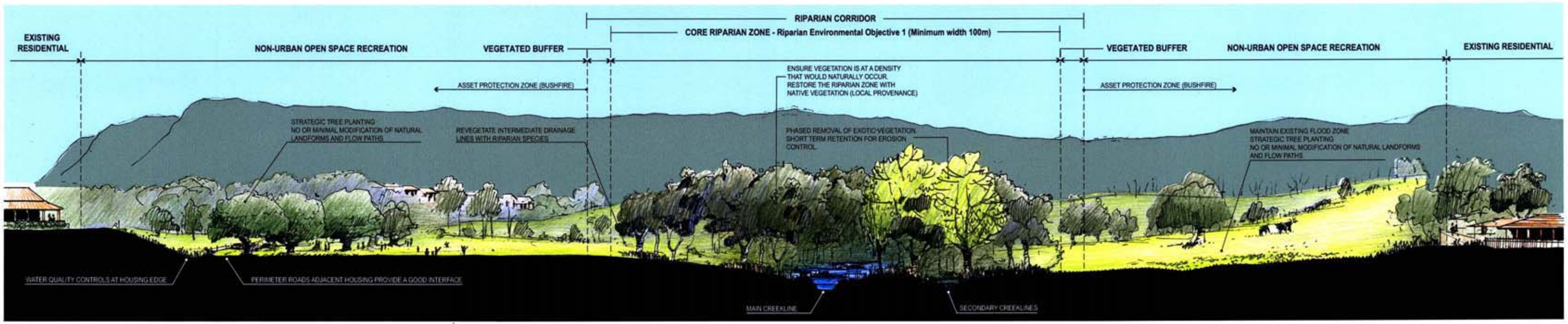
Site 1 is situated within the broad lower floodplain, where Lowland Woollybutt-Melaleuca Forest is a typical vegetation type (see Site 4). Along the stream banks, however, there would have been a virtually continuous corridor of River Oak Forest.

Streamside vegetation is dominated by specially adapted riparian tree species such as River Oak *Casuarina cunninghamia* and Prickly-leaved Paperbark *Melaleuca styphelioides*, as well as the widespread Forest Redgum *Eucalyptus tereticornis*.

Spiny Mat Rush *Lomandra longifolia* often forms a dense stream-fringing border

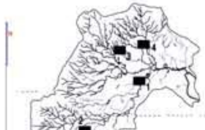
Sandpaper Fig *Ficus coronata* is common, along with moist forest trees such as Red Ash *Alphitonia excelsa*, shrubs such as Tree Violet *Hymenanthera dentata*, and Wattles such as *Acacia mearnsii* & *A. binervata*. There may be a range of other species that are more typically found in rainforests.

Floodplain wetland species would occur in suitable locations (see Site 4).



Indicative Section

NTS



LOCATION DIAGRAM

SITE 1 FLOODPLAIN DOMINATED AREA - WEST DAPTO

EXAMPLE OF CATEGORY 1 STREAM (ENVIRONMENTAL CORRIDOR) IN EXISTING URBAN AREA

MULLET CREEK RIPARIAN ZONES

DPWS for DLWC

February 2003

Principles

PROTECT EXISTING ASSETS

MAINTAIN VIABILITY OF VEGETATION

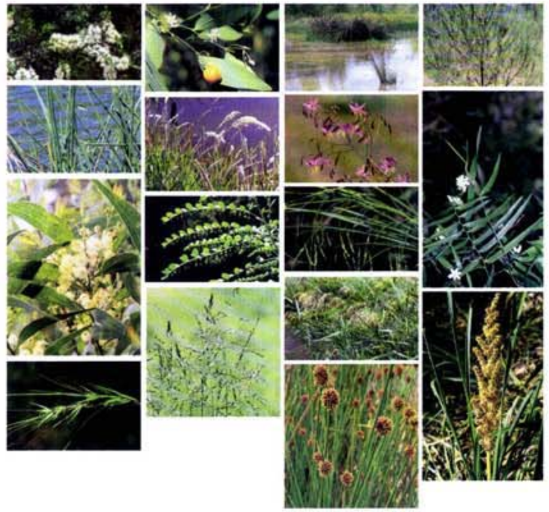
REHABILITATE DEGRADED RIPARIAN VEGETATION

Indicative Plan

NTS

Indicative Plant Species

Vegetation descriptions are based in part on draft NPWS mapping of the Native Vegetation of the Wollongong Escarpment and Coastal Plain



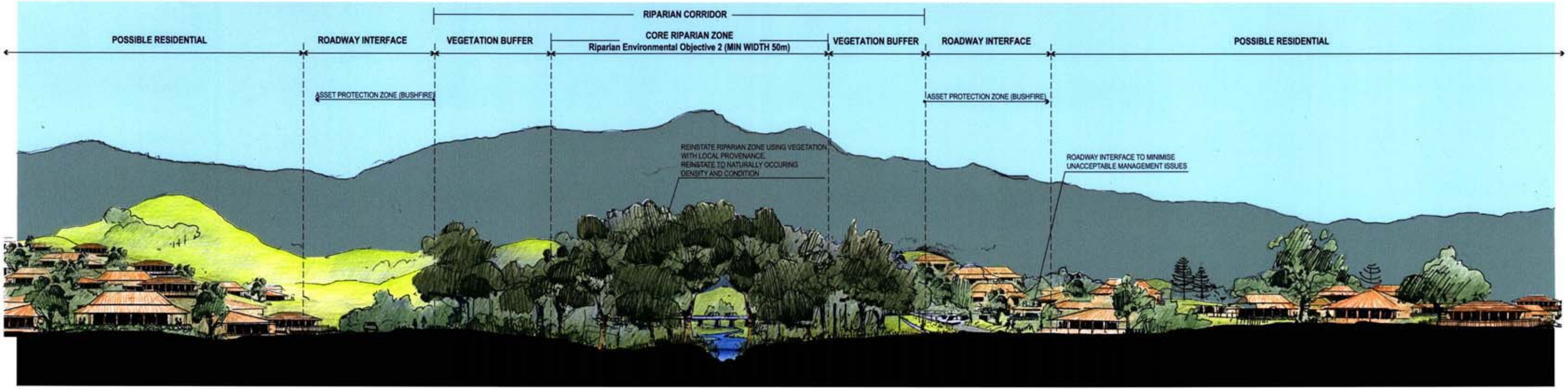
The undulating landscape around Site 2 is typical of exposed lower escarpment footslopes. It is likely to have had native vegetation similar to the Grassy Redgum Forest that can still be seen in areas nearby.

Such locations characteristically have a dense cover of native grasses beneath a canopy that includes Forest Redgum *Eucalyptus tereticornis*, Thin-leaved Stringybark *E. eugenioides*, and Rough-barked Apple *Angophora floribunda*.

The Shrub layer is fairly sparse, but includes species such as Hickory *Acacia maidenii*, and Mutton Wood *Rapanea variabilis*.

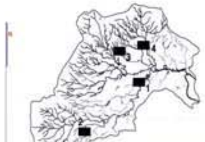
The dense groundcover has grasses, including Kangaroo Grass *Themeda australis*, Hedgehog Grass *Echinopogon ovatus*, Drooping Lovegrass *Eragrostis leptostachya*, Tussock Grass *Poa labillardieri*, Weeping Grass *Microlaena stipoides*, Bluegrass *Bothriochloa decpiens* and Tall Chloris *Chloris ventricosa*. Other common plants include Bergalia Tussock *Carex longbrechtiata*; the herb *Pratia pupurascens*; and the twiners *Glycine clandestina* and *Geitonoplesium cymosum*.

Generally it is the more sheltered foothill areas or areas of richer soils that support moist forest species (see Site 3), but favourable spots along the stream near Site 2 would have some of these species in the understorey as well.



Indicative Section

NTS



LOCATION DIAGRAM

SITE 2 MID CATCHMENT – AVONDALE ROAD

EXAMPLE OF CATEGORY 2 STREAM (TERRESTRIAL AND AQUATIC HABITAT)

MULLET CREEK RIPARIAN ZONES

DPWS for DLWC *February 2003*

Principles

SMALLER RIPARIAN CORRIDOR

NATURAL RIPARIAN QUALITIES

WATER QUALITY CONTROLS

Indicative Plan

NTS

WATER QUALITY AND QUANTITY MANAGED AT SOURCE BEFORE ENTERING RIPARIAN CORRIDORS E.G WATER SENSITIVE URBAN DESIGN

RIPARIAN ENVIRONMENTAL OBJECTIVE 3

MINIMISE ROAD CROSSINGS

WATER QUALITY AND QUANTITY CONTROLS IN UPPER CATCHMENT ON CATEGORY 2 & 3

PROVIDE SUITABLE INTERFACE BETWEEN RIPARIAN ZONE AND URBAN DEVELOPMENT

NATURAL CHANNEL DESIGN FOR RIPARIAN CORRIDOR

MAXIMISE ADDITIONAL RESTORATION OF HABITAT WHERE POSSIBLE. REVEGETATE USING SPECIES OF LOCAL PROVENANCE

INTEGRATE PASSIVE RECREATION AND OPEN SPACE INTO RIPARIAN CORRIDORS

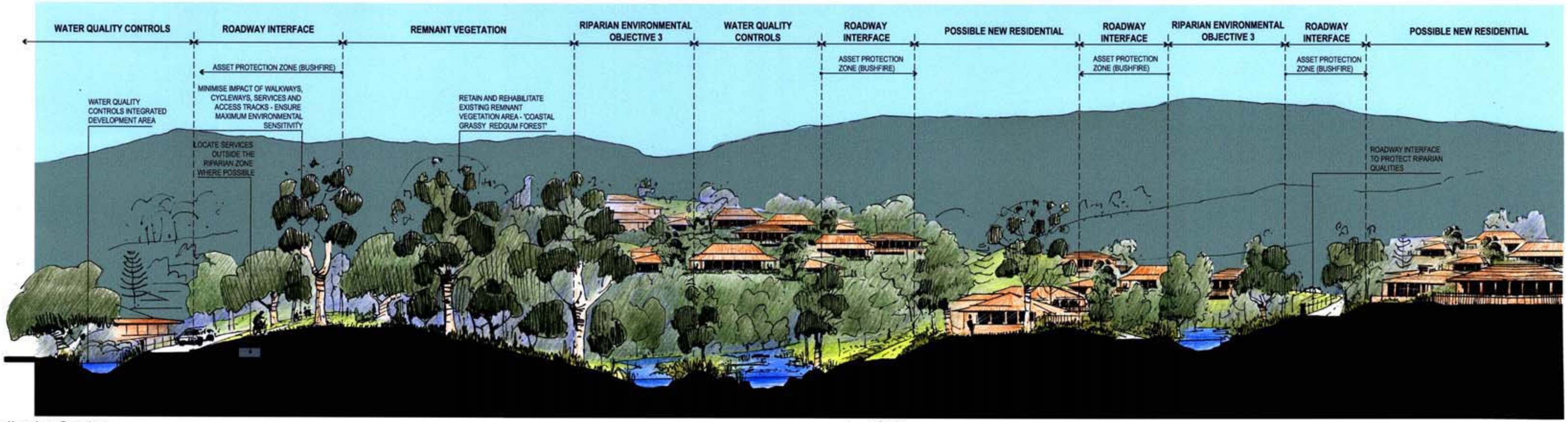
Indicative Plant Species

Vegetation descriptions are based in part on draft NPWS mapping of the Native Vegetation of the Wollongong Escarpment and Coastal Plain

Vegetation at Site 3 would have been Grassy Redgum Forest (like Site 2). Close proximity to the Moist Box-Foothills Forest of the steep, sheltered (generally south-facing) slopes immediately upstream would have a noticeable effect.

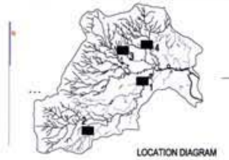
In addition to the usual Grassy Redgum Forest species, such as Forest Redgum *Eucalyptus tereticornis*, there would also be *Melaleuca styphelioides* and possibly *Eucalyptus quadrangulata*. There would have been a tendency to a denser shrub layer including hardy rainforest species such as Grey Myrtle *Backhousia myrtifolia* and Whalebone *Streblus brunonianus*. There would be Red Ash *Alphitonia excelsa*, Native Peach *Trema aspera* and *Cassine australis var. australis*. Shaded ground beneath the somewhat shrubby understorey would have relatively sparse patches with ferns such as Rasp Fern *Doodia aspera* and Sickle Fern *Pellaea falcata*. Pretty creepers such as Wonga Vine *Pandoraea pandorana* and, especially, Gum vine *Aphanopetalum resinosum* can be quite common.

The vegetation continues to change rapidly upslope from Detail Site 3 as it gives way to moist forest associations and even to Coachwood Rainforest with Lilly Pillies and Cabbage Palms on the steepest fertile slopes above.



Indicative Section

NTS



LOCATION DIAGRAM

SITE 3 UPPER SLOPES – PAYNES ROAD

EXAMPLE OF CATEGORY 3 STREAM (BANK STABILITY AND WATER QUALITY) UPPER CATCHMENT

MULLET CREEK RIPARIAN ZONES

DPWS for DLWC *February 2003*

Principles

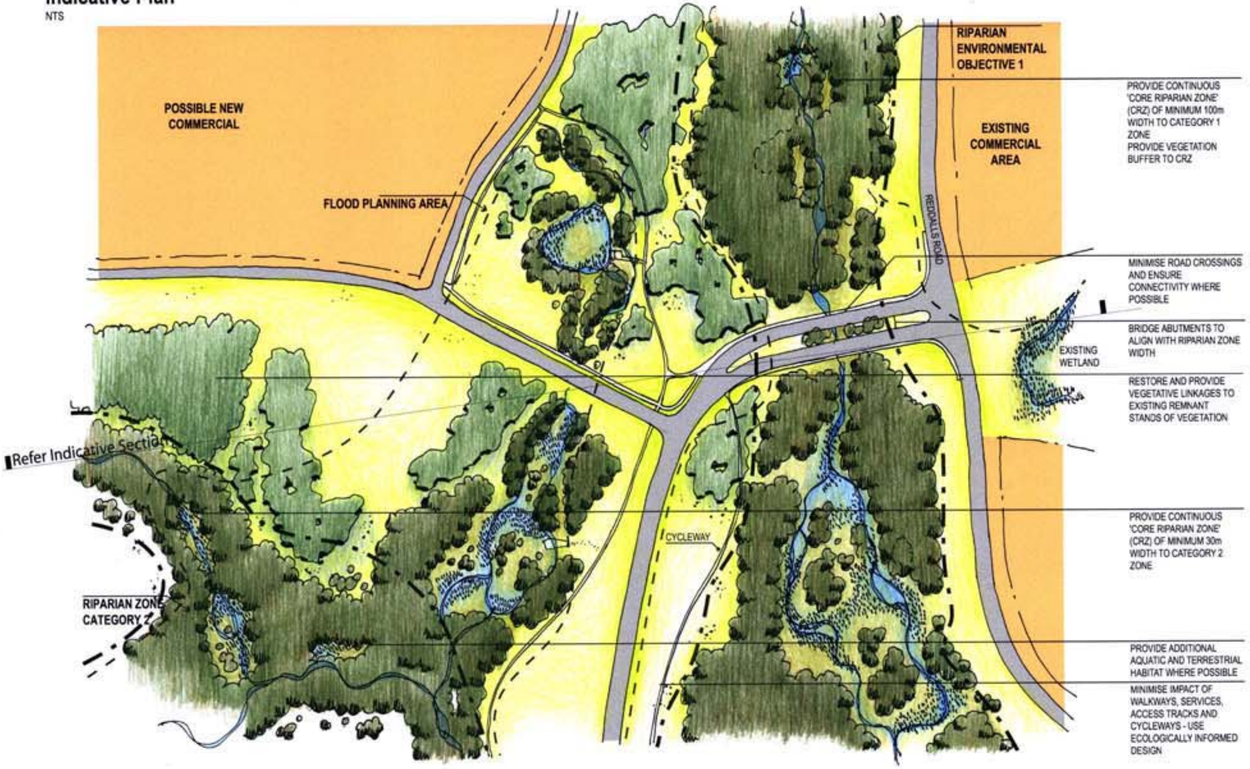
BRIDGES TO ENABLE CONNECTIVITY

COMPATIBLE RECREATION ACCESS

REHABILITATE EXISTING WETLANDS

Indicative Plan

NTS



Indicative Plant Species

Vegetation descriptions are based in part on draft NPWS mapping of the Native Vegetation of the Wollongong Escarpment and Coastal Plain

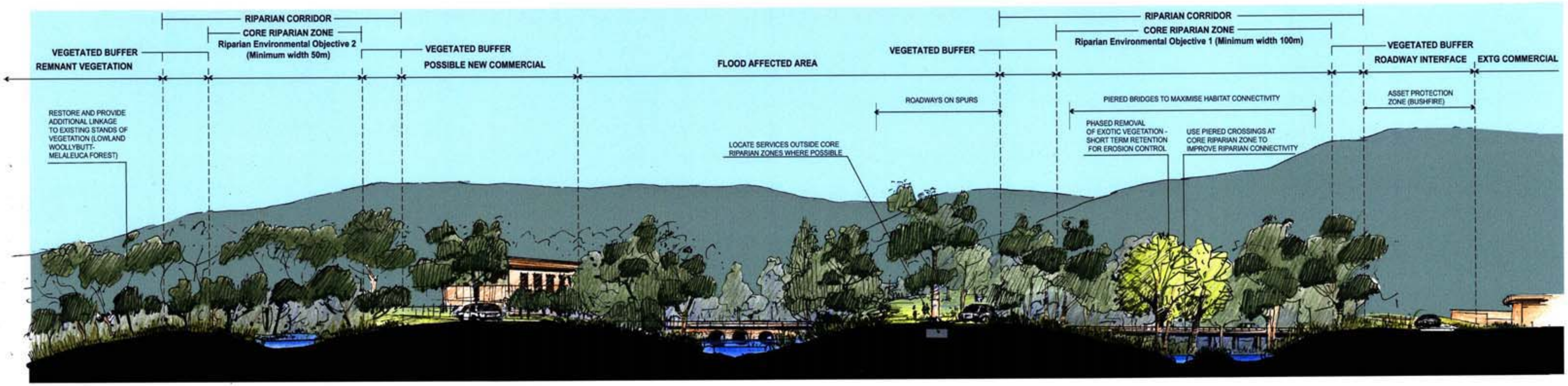
The area around Site 4 would have been covered with Lowland Woollybutt-Melaleuca Forest, as was much of the very flat ground of the Illawarra coastal plain. This vegetation type has a canopy with *Eucalyptus longifolia*, *E. globoidea* and *E. eugenoides*. There is always a dense sub-canopy dominated by Paperbark *Melaleuca* species.

There would be a grassy understorey with some shrubs such as Bearded Heath *Leucopogon juniperus*, Paper Daisy *Ozothamnus diosmifolius*, *Acacia falcata*, Tick Bush *Kunzea ambigua* and Bush Pea *Pultenaea villosa*.

Groundcovers include Bladey Grass *Imperata cylindrica*, Love Creeper *Glycine tabacina*, the ground fern *Cheilanthes sieberi*, Flax Lily *Dianella longifolia* and Spiny Mat Rush *Lomandra longifolia*.

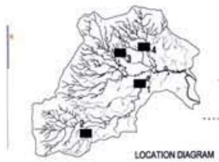
Lowland Woollybutt-Melaleuca Forest is a component of the Illawarra Lowlands Grassy Woodland Endangered Ecological community.

Areas where water is more or less permanently ponded would have Floodplain Wetland species with fringing plants such as the Water Peppers *Persicaria* species and the Common Rush *Juncus usitatus*. Rushes include Cumbungi *Typha orientalis*, Tall Spike Rush *Eleocharis spacelata* and Club Rush *Schenoplectus validus*. Aquatic plants include Water Ribbons *Triglochin microtuberosum*, *Ludwidgia peploides*, Woolly Frogmouth *Philydrum lanuginosum*, Swamp Lily *Ottelia ovata* and Water Plantain *Alisma plantago-aquatica*.



Indicative Section

NTS



LOCATION DIAGRAM

SITE 4 COMMERCIAL AREA – REDDALLS ROAD

EXAMPLE OF CATEGORY 1 and 2 STREAM (ENVIRONMENTAL CORRIDOR) EMPLOYMENT LAND AREA

MULLET CREEK RIPARIAN ZONES

DPWS for DLWC *February 2003*