Warringah Council

Final

Creek Management Study

March 2004

MWH
MONTGOMERY WATSON HARZA

in association with

4site natural solutions

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Executive Summary

Warringah has unrivalled natural assets - forests, heaths, beaches, lagoons, estuaries, waterfalls and creeks. Council, the community and governments devote time, money and energy to keeping them in good condition. Although attention and resources have been committed to the floodplain, coastline, coastal lagoons and some creeks, the upland streams have been less fortunate.

The Creek Management Study aims to provide a sound basis for deciding how best to go about protecting and repairing Warringah's creeks. This has been done by:

- developing an understanding of the state of the creeks and their values;
- identifying the scale of development and other pressures confronting the creeks; and
- providing Council with the information needed to implement effective long-term creek management strategies and development controls).

There are some 50 km of creeks in six major catchments. Creek condition varies from near natural to highly modified. In most catchments, development has resulted in:

- changes to creek flows, including increased flood frequencies and artificial barriers to flow such as weirs/culverts;
- increased sediment loads and bank erosion;
- a decline in water quality including increased nutrient, toxicant, sediment and litter; and
- clearing of vegetation and invasion by weeds in and around the creeks.

The Study has shown that virtually all of Warringah's creeks are at risk of further degradation. The level of risk varies widely, as does the sensitivity of creeks to further change. One feature is common to all creeks – they flow into receiving waters that are highly valued – the four coastal lagoons and the estuaries of Sydney harbour and the Hawkesbury River. Each of these is under stress from pollutants conveyed by the creeks.

Just three major creeks (Deep, Wheeler and Curl Curl) are mostly unaffected by development and protection of their catchments is critical. These 'Group A' creeks are of high landscape and ecological value and will degrade quickly if even minor changes occur (such as weed growth, vegetation clearing or urban development).

Wheeler Creek (Group A)

Several creeks (such as Kierans and Snake) have development in the upper reaches, but are important because they flow into National Parks or reserves and sensitive estuarine waters (Group B). Most of these are highly modified in the urban and rural areas, but are in good condition in the National Parks. There is some evidence to suggest that this group of creeks is at the point where any increase in flows or pollutants from the catchment could result in significant deterioration in the National Park sections.

Kierans Creek (Group B)

The remaining creeks flow into the coastal lagoons and catchment development has resulted in significant – and probably irreversible – changes to ecology and geomorphology (Group C). Many of these creeks – particularly close to the coast - have been subject to rehabilitation programs because Council and the community have expressed concern about the degree of degradation. To some extent the two largest creeks - Middle and South – have been given less attention and the scale of work needed to rehabilitate them is now very large.

Greendale Creek (Group C)

The implementation plan supports the continuance of the excellent rehabilitation programs that are happening collaboratively between Council, the community and other levels of Government. However, it seems that the levels of investment in these highly modified creeks would be most cost-effective if the aims are limited to:

- Ensuring that the creeks are not a health or safety hazard to people;
- Stabilising erosion and reducing downstream sedimentation;
- Enhancing riparian habitat and minimising the further spread of weeds; and
- Providing recreational opportunities.

A high priority for Warringah should be to protect and manage those creeks which are of high value (Groups A and B). This may involve new mechanisms such as voluntary conservation agreements, compensatory habitat, planning constraints and additional development and operational controls. Without these mechanisms, even modest increases in development are likely to lead to a substantial decline in creek values.

South Creek is in need of urgent attention to address a number of issues – including flooding, erosion, sedimentation and weed growth. An integrated approach to the creek presents an opportunity to involve the community in trials of new initiatives - such as water sensitive urban design – that have application throughout Warringah.

Middle Creek is a large and diverse system, with development and past clearing scattered throughout the largely undeveloped valley. It also provides a major, untapped recreational opportunity for a walking trail from the sea, via Narrabeen Lagoon to Oxford Falls. The Middle Creek reserve covers a large part of this area, and is the largest Council-owned creek corridor in Warringah. However, a major investment is required to deal with all of the issues as part of an integrated program. The existing weed problems alone would consume Council's entire bushland rehabilitation budget for years. As an interim measure, we have recommended improved development controls and minor management intervention until Council is able to develop and implement a creek management plan.

Overall, we recommend that Council:

- *Adopts the Creek Management Study as Council policy;*
- *adopts the creek management principles set out in section 7.1;*
- *amends the LEP and design guidelines as set out in chapter 8;*
- *requests Planning NSW (formerly the Department of Urban Affairs and Planning) to declare riparian zones and catchments of Group A creeks as environmentally sensitive for the purposes of SEPP 5 (see Figure 3.2.);*
- *prepares a Warringah creek policy in accordance with section 9.1;*
- *prepares creek management plans according to the priorities set out in Table 7.1; and*
- *modifies the water quality monitoring program to cover upland creeks and to develop a set of water quality objectives based on knowledge of local aquatic ecosystems.*

Warringah Council
Creek Management Study

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1. Introduction

Warringah is the largest local government area on Sydney's northern peninsula between the Pacific Ocean, Middle Harbour and the Cowan and Pittwater branches of Broken Bay. Over 40% of the total area of 153 km^2 is remnant bushland within protected areas. The total population is about 135,000 people, most of which is concentrated in the southern portion and along the coast.

Parts of Warringah are within 13 km of the city CBD, yet natural areas of bushland, creeks, lagoons, estuaries and oceans dominate many of the vistas. Some 50 km of creeks in six major catchments has been identified. Creek condition varies from near pristine to heavily modified and degraded and the condition of all creeks is under threat from existing and/or likely future development.

In most catchments, development has resulted in:

- changes to catchment runoff characteristics and creek hydrology including decreased flow concentration times through stormwater systems and artificial barriers to flow such as culverts and bridges;
- increased sediment loads and bank erosion probably as a result of changes in hydrology and vegetation removal and soil disturbance in the catchment;
- a decline in water quality including increased nutrient and gross pollutant loads; and
- removal and modification of vegetation in and around the creeks.

The beaches, floodplains and estuaries of Warringah have been the focus of a number of previous studies but the creeks have not been extensively studied. Yet there has been considerable resources applied to repairing and protecting some creeks by Council, the state government, businesses and the community. Consequently, it is timely to review what is being done and evaluate creek values and threats. This will provide a sound basis for deciding how best to go about protecting and repairing creeks.

Wheeler Creek Valley
(looking north-east)

Middle Creek
(below Oxford Falls)

2. Objectives and Scope

2.1 Study Objectives

The objectives of the Creek Management Study are as follows:

- develop an understanding of the hydraulic, sedimentary, water quality and ecological processes of creeks and associated habitats, the dependencies between them and the impact of catchment development and human usage on those processes;
- identify and describe existing and future development pressures confronting creeks;
- provide Council with the necessary information and recommendations to implement effective long-term creek management strategies and action policies (including development controls); and
- establish and evaluate short and long-term management options with consideration of their social, economic and environmental consequences.

2.2 Scope of Work

The Study considers the bed and bank, riparian zone and adjacent lands of freshwater creeks in Warringah except within National Parks. All catchment processes that affect creeks are also within the scope, including catchments which drain to National Parks. The specific services required in relation to these areas are to:

- identify gaps in existing data;
- identify creek and riparian management boundaries;
- assess existing creek characteristics;
- delineate creek management units;
- determine the ecological and social values of each unit or reach;
- work with the community to develop desired future values
- define actions required to achieve potential state; and
- prioritise actions.

2.3 Key Legislation Supporting Creek Management in Warringah

Several NSW statutes require Council to plan and manage creek and catchment health. The key legislation and relevant components are:

- *Local Government Act 1993* - Councils to *'have regard to the principles of ecologically sustainable development in carrying out their responsibilities'*;
- *Environmental Planning and Assessment Act 1979* – protection of the environment, including threatened species, communities or ecosystems; duty of Council to consider environmental impacts of development;
- *Threatened Species Conservation Act 1995* – protection and management of rare and threatened species and ecosystems and critical habitat;
- *Native Vegetation Conservation Act 1997* – conservation and sustainable management of native vegetation;
- *Fisheries Management Act 1994* – protection of fish populations through habitat and ecosystem conservation; and designation of key threatening processes, including *'degradation of native riparian vegetation'*; and
- *Rivers and Foreshores Improvement Act 1948* – prevention of erosion of lands by water.

3. Managing Warringah's creeks

3.1 Warringah's Creeks

Figure 3.1 shows Warringah's creek network and individual waterways are mapped in Appendix B. Every effort has been made to ensure that creeks have been correctly mapped and a number of modifications have been made as a result of community input to the draft study. Proposed amendments to include creek mapping in the LEP also include a process to allow further adjustment of creek locations, where inadvertent errors occur (see section 8.1).

The largest creek systems are those in the Narrabeen Lagoon catchment (South, Middle and Deep Creeks) which comprises approximately 40% of the study area (i.e. excluding National Parks). The smaller coastal Lagoons (Dee Why, Curl Curl and Manly) each have one or more creeks and together their catchments cover approximately 30%. This includes Manly Dam, which is the only unnatural lake of any size.

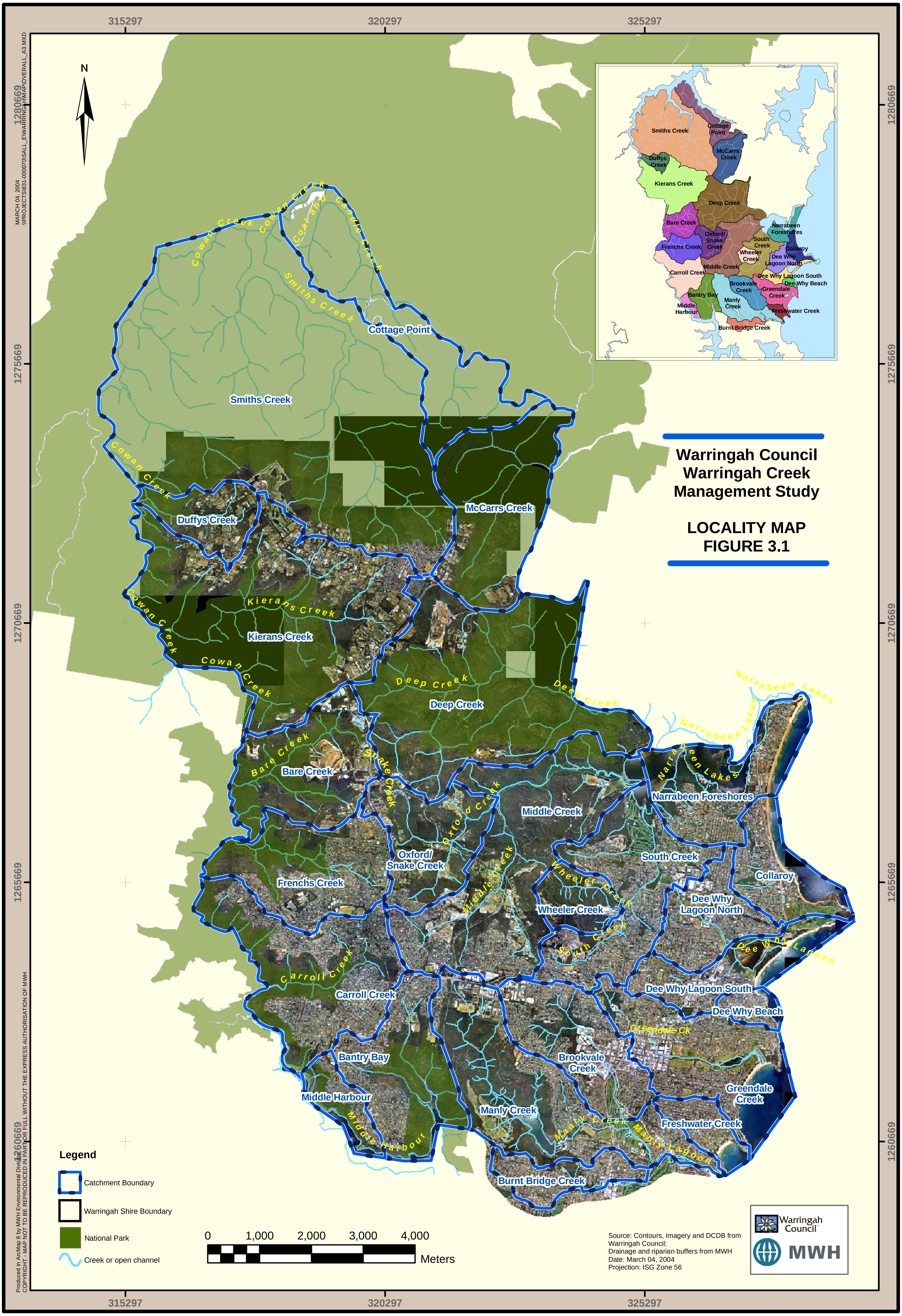
The other 30% is made up of about six small sub-catchments which drain into Cowan and Middle Harbour Creeks to the west. Each of these, plus Deep Creek, has headwaters in the study area but the majority of the stream is in National Park. These upper catchments have varying degrees of urban development that influence the creek characteristics.

Two features of the waterways are particularly worth noting:

- The creeks and their valleys are remarkably varied and they constitute a major natural asset so close to Sydney's centre. No other large city in Australia (and probably the world) can reproduce the combination of sandstone escarpments, waterfalls, rainforest streams, coastal lagoons and oceans.
- The creeks are largely hidden – and to many people – ignored. The degradation that has taken place in many creek corridors may not be wilful, but it certainly suggests a degree of neglect.

As elaborated later in this report, a cumulative process of degradation has affected every creek in the study area and even those within National Parks have been impacted by catchment changes.

Council, the state government and many community members are working hard to at least reduce the rate of decline and in some cases, have actually improved creek condition. However, our view is that without further significant intervention on two key issues – land development and weed proliferation – the remaining high quality natural areas will be lost and rather than being assets for future generations, they will become burdens.



Warringah Council
Warringah Creek Management Study

LOCALITY MAP
FIGURE 3.1

Source: Contours, Imagery and DCDB from Warringah Council;
Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56

Warringah Council
MWH

MARCH 04, 2004
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Produced in ArcMap 8 by MWH Environmental Division

Unsustainable practices in the past and present place a burden on the current generation of ratepayers. For instance, in an average year Council spends nearly $300,000 on removing litter and sediment from the stormwater system and nearly $400,000 on new pollutant traps. In addition, there is a continuing requirement for dredging sediments from the coastal lagoons, which itself has environmental impacts.

3.2 Land Use – Current and Future

The 60% of Warringah's area that is not within reserves is broadly broken down into urban, non-urban and open space. Table 3.1 sets out the current breakdown of land uses and provides comments on future changes.

Table 3.1: Land Use Distribution in Warringah

Land Use	Approximate Area (2001) (ha)	Comments on Projected Change
Urban	4200	Population increase by 4.9% projected to 2010 – primarily due to infill in Dee Why and Collaroy-Narrabeen.
Non-urban residential/ Cleared Open space	1300	No significant change in population projected to 2010 (minor declines predicted in Terrey Hills, Duffys Forest and Belrose). However, some bushland on suburban fringes is currently subject to development intentions.
Bushland outside National Parks	3000	The main projected changes relate to an approved development of approximately 50ha at Belrose and the potential for State Environmental Planning Policy 5 (SEPP5) developments in non-urban bushland. A 140 unit SEPP5 development application was lodged in 1999 in the Wheeler Valley. Other recent SEPP5 applications include a 57 unit development at Belrose (Snake/Oxford Valley) and 66 unit development at Forestville (Bantry Bay).

Council presently has a restriction on land releases in non-urban areas, and the main potential for urban expansion is SEPP5 developments and State Government land releases, over which Council has limited control. The table notes a number of pending SEPP5 applications, but the fate of other non-urban areas is difficult to predict because SEPP5 developments effectively bypass planning intentions in the Local Environmental Plan (LEP).

3.3 Impacts of Land Use Changes on Creeks

The impacts of land use changes on natural creeks are well documented and the following is a very brief summary of those changes, as a way of introducing some more specific information which can form the basis for future creek management in Warringah.

The following impacts have been well characterised and are discussed at some length in many publications (e.g. Wong et al 2000). Table 3.2 summarises the main changes to creek ecology and other values that are applicable in Warringah.

Table 3.2: Typical Changes in Creek Values Following Urbanisation

Primary change	Results in…..
Land clearing	▪ Direct loss of flora and fauna habitat; ▪ Increased peak flows leading to erosion and sediment deposition; ▪ Increased flood frequencies leading to more frequent habitat changes ▪ Reduction in base flows leading to changes to flora and fauna ▪ Loss of natural landscapes
Buildings and infrastructure (roads, carparks, etc.)	▪ Increased peak flows due to impervious surfaces; ▪ Transport of pollutants deposited on impervious surfaces (e.g. lead, fuels) leading ▪ Loss of natural landscapes and viewlines ▪ Reduced recreational opportunities
Channelisation and drainage (dredging, straightening, filling, embankment stabilisation)	▪ Simplification of habitat leading to loss of diversity ▪ Isolation of flood plains leading to changes in vegetation structure ▪ Reduction in alluvial deposition on floodplains leading to loss of soil productivity ▪ Increased peak flows and velocities leading to ecosystem stress ▪ Loss of natural landscapes ▪ Potential for increased safety risks with steep embankments
Sewage reticulation and on-site wastewater disposal	Leaks and overflows leading to: ▪ ecosystem degradation through nutrient enrichment, oxygen demand and toxins ▪ public health risks from pathogens and algal toxins ▪ public safety risks from biological slimes
Commercial operations (industry, retail etc.)	▪ Litter; ▪ Toxic materials causing acute or chronic damage to ecosystems ▪ Organic matter, sediments and nutrients causing ecosystem degradation
Agricultural operations (non-urban areas)	▪ Organic matter, nutrients and sediments causing ecosystem degradation ▪ Pesticides causing acute or chronic damage

The list illustrates that development in Warringah has a variety of direct and indirect effects. Recent research shows that aquatic ecosystems are more sensitive to urbanisation than previously believed and this may be due to the cumulative impacts of several of these effects.

The majority of Warringah's creeks do not have information about flood hydrology, peak flows or flood inundation levels. In general, the only available flood information is for the coastal waterways of Warringah's lagoons. Consequently, the study methodology was unable to specifically include flooding issues. However, hydrological impacts of urbanisation were considered by analysing the types of land use within each catchment.

Peak discharge is an important determinant of channel morphology and in turn sediment transport, riparian stability etc. The effect is most pronounced for low frequency events (Wong et al 2000). For example, when a catchment changes from a rural condition to 20% impervious, the discharge for a 10 year Average Recurrence Interval (ARI) flood event changes to an 8 month frequency. In other words, a flood which would have occurred on average once in 10 years now occurs 15 times in 10 years. A similar effect occurs with channel lining (i.e. concrete or rock wall).

This means that relatively small changes in catchment land use can have significant impacts on flows, which in turn can strongly influence ecology. Catchment imperviousness has been found to be a good predictor of biodiversity and other ecosystem attributes. Imperviousness reflects both general land use (which affects water quality) as well as hydrology (which affects the size and duration of flows).

Schueler (1987) suggested that aquatic insect diversity was markedly reduced at a threshold of 10-20% imperviousness. Walsh and Breen (1999) refined the concept by comparing benthic macroinvertebrates in catchments with the same impervious proportions, but different drainage systems. The more 'connected' urban catchment (i.e. piped and channelled drainage) caused greater degradation than a less connected rural catchment. The effect was noticeable at a threshold of 12% imperviousness. Walsh (pers. comm. 2001) also found that an endemic amphipod was found only in certain Melbourne streams with less than 13% connected imperviousness [*Note: **connectedness** of stormwater drainage infrastructure is undesirable, but **connectivity** of natural systems is a desirable outcome. Connectedness in this report is only used for the former*].

Similar thresholds also appear to apply for fish. Wang et al (2001) found a threshold of 8-12% *connected* imperviousness for fish species in 47 Wisconsin streams. The same authors noted that the effect was most pronounced within 50m of the stream

The fact that each of these studies focussed on different biota in different bio-regions suggests that the thresholds are reasonably robust.

Research results indicate that vegetation cover in the riparian zone (up to 100m wide) is the main control on fine sediment and erosion (Richards et al 1996, Allan et al 1997). Catchment processes are the main control on channel form, coarse sediments and nutrient supply.

All of these findings present a strong case for reducing peak hydraulic loads **and** maintaining natural creek forms - particularly for creeks in relatively natural condition. Walsh et al (2001) concluded that *'physical habitat restoration alone is unlikely to address the major constraints* [caused by]…*intensive stormwater drainage'*. Catchments with greater than 15% imperviousness are likely to have aquatic ecosystems in relatively poor condition and unless connectivity is reduced, restoration to a natural condition is extremely unlikely.

The approach most commonly used to address both quality and quantity impacts is Water Sensitive Urban Design (WSUD). This involves a range of design and management techniques to mimic the natural processes and move away from highly connected systems of oversized pipes and open channels. Techniques include rainwater capture, infiltration drainage and vegetated buffer strips. A draft report on WSUD applications in Warringah has been prepared for Council (MWH, 2002).

Any use of more infiltration drainage systems needs to take into account the potential for changes in sub-surface hydrology and nutrient concentrations. Both can cause plant species displacement and weed proliferation in bushland and riparian areas (Webb, 1995), particularly in the commonly nutrient poor soils of Warringah.

3.3.1 Urbanisation and water quality

The water quality factors that tend to receive most attention are nutrients and sediments. In most urban settings, these predominantly derive from stormwater, with the majority of sewage and industrial effluent being discharged to estuarine or marine waters. However, in some Warringah localities, on site wastewater systems and intensive rural activities are a significant source of pollutants.

Australian runoff tends to have finer particles than in the USA and Europe and those smaller fractions are particularly associated with phosphates, metals and pesticides (Sartor et al 1974). The major source of toxicity in urban runoff was found by Peterson and Batley (1992) to be heavy metals, rather than petroleum hydrocarbons. Cadmium, copper, chromium, lead, zinc and nickel were of greatest concern. The dominant source of these is roads.

Therefore in managing water quality, a key is to *prevent fine particulates from entering waterways*. Once in the water, end of pipe solutions, such as Gross Pollutant Traps (GPTs) and sediment basins, are largely ineffective. Wetlands may assist, but they are usually limited by their small size relative to inflow volumes – particularly in flood events. The problem with not capturing flood events is that the particulates eventually end up in the coastal lagoons or in the estuaries, where phosphates and metals may become remobilised.

In relation to wastewater, there are currently approximately 250 approved on-site wastewater treatment systems of which the vast majority serve single households. Many of these systems have only rudimentary treatment capability and rely on soil infiltration for removing some of the pollutants. Systems which are not regularly maintained or in which the disposal area is too small can result in surface flows of effluent that can directly enter drainage lines or creeks. In most jurisdictions, including Warringah, older household systems produce effluents of relatively poor quality, but there is no approval mechanisms for requiring system upgrades.

Agricultural and related activities in the non-urban zone that can potentially export pollutants to waterways include animal husbandry, nurseries, landscape suppliers and wastewater from schools, hotels and other high occupancy uses. Most of these operations are likely to have limited impact from one site, but the cumulative impacts can be significant. The risk is greatest during rain events when surface runoff and hydraulic overload of on-site systems can occur. The result can be direct passage of nutrients, organics and pathogens to creeks and wetlands.

Warringah's current program of water quality monitoring has historically focused on the coastal creeks and long term monitoring is only available for Middle, Deep (downstream only), South, Dee Why, Greendale, Brookvale, Manly and Burnt Bridge Creeks. During the Study, a single monitoring program was undertaken to provide some snapshot data for the remaining creeks (Appendix A). Table 3.3 summarises the available data. It should be noted that the monitoring was undertaken on a random basis during fine weather and the results reflect prevailing (i.e. low flow) conditions. During flood events, pollutant loads would increase substantially.

Table 3.3: Summary of Water Quality in Warringah's Creeks

Reach	Sampling Number	Description[2]	Water Quality Parameter						
			Suspended Solids	Total Nitrogen	Nitrate and Nitrite	Total Phosphorus	Ortho-Phosphorus (FRP)	Biological Oxygen Demand	Faecal Coliforms
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	cfu/100 mL
Kierans Creek (upper)	13	Downstream of southern Terrey Hills	16	5.8	1	0.62	<0.01	<2	82
	14	Swamp, downstream of southern Duffys Forest	20	2.3	0.06	0.49	<0.01	10	250
	15	Downstream of western Terrey Hills	12	0.9	<0.01	0.05	<0.01	3	127 / 87
	16	Neverfail Gully, downstream of Kinma School	3	1.2	0.96	0.01	<0.01	<2	64
	20	Waterfall gully, downstream of eastern Duffys Forest	13	0.7	0.23	<0.01	<0.01	<2	0
Duffys Creek (upper)	19	Downstream of Rho-ker Reserve	***	0.7	0.03	<0.01	<0.01	12	1000
Duffys Forest (upper)	21	Downstream of Terrey Hills Golf Course	14	1.3	0.45	<0.01	<0.01	14	64
Greendale Creek (upper)	Laxton[1]	Central Brookvale	3.8	1.38	0.78	0.06	0.01	---	350
Greendale Creek (lower)	Laxton[1]	Downstream of Brookvale (John Fisher Park)	11.8	2.57	0.36	0.12	0.008	---	500
Dee Why Creek (upper)	Laxton[1]	Northern Cromer	13.1	0.82	0.04	0.25	0.04	---	200
Dee Why Creek (lower)	Laxton[1]	Downstream of eastern Cromer (Dee Why Park)	2.4	1.05	0.43	0.07	0.01	---	365
Brookvale Creek (lower)	Laxton[1]	Downstream of Warringah Mall (Warringah Golf Course)	3.9	0.87	0.22	0.06	0.01	---	400
Brookvale Creek (upper)	2	Upstream of Warringah Mall (Allenby Park)	5	1.6	0.67	0.19	0.1	10	2000
Curl Curl Creek	1	Upstream of Manly Dam (Manly Dam Reserve)	7	1.5	1.13	0.01	<0.01	<2	---
Manly Creek	Laxton[1]	Downstream of Manly Dam	2.1	0.49	0.1	0.03	0.004	---	250
Burnt Bridge Creek	Laxton[1]	Downstream of eastern North Balgowlah (Manly Golf Course)	3	0.75	0.19	0.06	0.007	---	500
Bare Creek (upper)	9	Downstream of northern Belrose (west of Forest Way)	8	0.5	0.19	<0.01	<0.01	<2	---
Frenchs Creek (upper)	10	Downstream of southern Belrose	15	2.4	0.92	0.26	0.04	<2	---
Carroll Creek (upper)	11	Downstream of Sorlie	17	3.5	2.06	<0.01	<0.01	<2	---
Bantry Bay Tributary (upper)	12	Downstream of southern Frenchs Forest	7	0.4	0.13	<0.01	0.01	<2	---
Deep Creek (upper)	6	Downstream of northern Belrose (east of Forest Way) – east branch	3	0.3	<0.01	<0.01	<0.01	<2	---
	7	Downstream of northern Belrose (east of Forest Way) – west branch	5	0.6	<0.01	<0.01	<0.01	<2	1
	8	Downstream of Kimbriki Waste Disposal and Recycling Centre	3	0.7	0.19	<0.01	<0.01	11	330
Deep Creek (lower)	Laxton[1]	Downstream of Garigal National Park (Deep Creek Reserve)	3.8	0.69	0.12	0.05	0.004	---	70
Middle Creek (upper)	Laxton[1]	Downstream of southern Oxford Falls	3.6	0.72	0.27	0.07	0.02	---	308
	3	Downstream of northern Frenchs Forest	17	0.7	0.22	<0.01	<0.01	<2	---
	4	Downstream of southern Oxford Falls	15	0.4	0.08	0.05	0.01	<2	---
Middle Creek (lower)	Laxton[1]	Downstream of Recreation Reserve	3.2	0.59	0.13	0.05	0.01	---	135
Snake/Oxford Creek (upper)	5	Downstream of retirement village	1	0.3	0.1	<0.01	<0.01	<2	---
South Creek (upper)	Laxton[1]	Downstream of northern Narraweena	2.7	0.8	0.27	0.04	<0.01	---	75
South Creek (lower)	Laxton[1]	Downstream of western Collaroy Plateau (Cromer Golf Course)	4.7	0.98	0.2	0.08	0.02	---	200
Wheeler Creek (upper)	17	Upstream of development	19	0.4	0.06	<0.01	<0.01	<2	---
	18	Downstream of development	11	0.4	0.04	<0.01	<0.01	<2	---
Wheeler Creek (lower)	Laxton[1]	Downstream of development	3.1	0.91	0.46	0.06	0.02	---	205
ANZECC (2000) Trigger Levels[3]				**0.35[7]**	**0.04[7]**	**0.025[7]**	**0.02[7]**		**<150[8]**
EPA (1999) Numerical Criteria[4]				**0.1-0.75[7]**		**0.01-0.1[7]**			**<1000[9]**
Liston and Maher (1997)[5]			**40**						
Tentative reference site concentrations			**3-5**	**0.3**	**<0.01**	**<0.01**	**<0.01**	**<2**	**0**
Typical urban stormwater concentrations[6]			**20-1000**	**0.6-8.6**		**0.12-1.6**			**4,000-200,000**

Notes:
1. Laxton, 2000. Water Quality of Warringah Lagoons in 1994-99 (50th percentile values).
2. Street locations are provided in Appendix A.
3. ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Highlighted values exceed ANZECC default trigger levels.
4. EPA (1999) Interim Water Quality Objectives for Sydney Harbour and Parramatta River Catchment.
5. Water Quality for Maintenance of Aquatic Ecosystems: Appropriate Indicators and Analysis.
6. Cooperative Research Centre (CRC) for Catchment Hydrology (2000)
7. For the protection of aquatic ecosystems.
8. For primary contact recreation.
9. For secondary contact recreation.
10. *** Analysis inconclusive.
11. --- Not Sampled.

From the results provided in Table 3.3, the following general points can be made (noting that samples generally reflect dry weather):

- Most creeks were clear, with suspended solids typically between 2 and 15 mg/L;
- Most creeks had nitrogen (total and oxidised/dissolved) concentrations higher than the recommended guidelines. Major sources of nitrogen (and phosphorus) include urban stormwater, runoff from intensive agricultural areas and large scale commercial properties, and wastewater;
- About half of the creeks had elevated total phosphorus concentrations, although ortho (reactive) phosphorus concentrations were below the recommended guideline for all but three creeks;
- The majority of creeks sampled for faecal coliforms are unsuitable for primary recreation, although most are suitable for secondary recreation. Major sources of faecal coliforms include animal husbandry practices and on-site wastewater systems in rural areas, and domestic animal waste and sewer overflows in urban/residential areas;

Results from statistical analysis of the data indicate that no strong correlations appear to exist between catchment development (i.e. imperviousness) and pollutant concentration for any of the parameters sampled. However, elevated concentrations recorded at certain sites may be related to specific land uses in the surrounding area. For example:

- Very high concentrations of nutrients and organics were observed in Kierans and Duffys Creeks and some of their tributaries. These sites are probably impacted by on-site wastewater effluents and, in one case, by runoff from horse paddocks.
- Creeks on the coast (Greendale, Dee Why, Brookvale, Manly and Burnt Bridge) showed moderate to high nitrogen and phosphorus concentrations, reflecting typical urban stormwater as well as some local increases due to specific factors (eg. potential landfill leachate to Greendale Creek and industrial runoff to Dee Why Creek). Even creeks with partial bushland (such as upper Brookvale) displayed typical stormwater concentrations, suggesting little attenuation or trapping by vegetation. Curl Curl Creek (which is surrounded by substantial bushland) also showed surprisingly high nitrogen concentrations, which may be reflecting upper catchment fertiliser use or polluted groundwater.
- The other less developed creeks (Deep, Snake and Wheeler) were generally close to trigger levels but showed sensitivity to localised influences (eg. Kimbriki Recycling and Waste Disposal Centre may be affecting Deep Creek). Lower Deep Creek has high nutrient and organic concentrations, possibly as a result of runoff from urban areas within Pittwater Local Government Area (LGA). Another localised influence is the effect of residential development in lower Wheeler Creek, which appears to have increased total nitrogen concentrations two-fold, nitrate concentrations ten-fold and total phosphorus concentrations at least six-fold, relative to upper reaches.
- Middle Creek concentrations are also moderate to high despite low levels of catchment development. The main source of pollutants is probably urban areas in the upper catchment, although concentrations are longitudinally uniform and do not appear to be attenuated by in-stream processes.

The last point is a concerning feature, because most creeks appear to show low assimilation capacity along their length and undue influence of local sources. This means that hotspots such as industrial areas, building sites, on-site wastewater disposal and landfills potentially have an inordinate impact on water quality. Potential concerns include:

- Kimbriki Recycling and Waste Disposal Centre;
- Belrose Waste Management Centre and Recycling Centre;
- Former landfill areas adjacent to Greendale Creek; and
- Cromer industrial estate.

It is important to note that these results are tentative and comparisons with national water quality guidelines only tell part of the story and do not take into account local or site-specific characteristics. Rather, exceedences of the ANZECC values provided in Table 3.3 should trigger further investigation (such as biological effects or reference conditions) to determine whether or not a real risk to the ecosystem exists. These trigger values can be adjusted to local conditions, as set out in the guidelines. For example, the interim water quality objectives for Sydney Harbour and the Parramatta River Catchment were developed after considering community views in the area.

No reference sites were available within Warringah to compare pollutant concentrations. However, taking into account current condition and the present sampling results, sites such as upper Deep Creek may be a useful reference stream for future water quality monitoring programs.

A more detailed description of water quality and probable pollutant sources for each of the sub-catchments is provided in Appendix B.

3.4 Current Waterway Management Approaches in Warringah

3.4.1 Past intervention

The community and Council are currently engaged in a range of activities to protect and repair waterways. These can be loosely classified as catchment protection, water quality control devices and creek rehabilitation.

The LEP 2000 is a major step forward in providing a better framework for waterways planning and management. The document is based on catchments, which allows a clearer focus on the relationship between locality plans and the waterways within and downstream of the locality. The principles and design guidelines also place some emphasis on waterway protection.

The primary protection for creeks is through the extensive system of National Parks and other public reserves. Although this system covers 40% of Warringah, there is no creek system that is entirely protected, because all have some urban or non-urban land in their upper catchments. The two creeks that currently have undeveloped upper catchments (Deep and Wheeler) are zoned non-urban but are not protected.

Many of the reserves are managed for multiple uses, of which creek protection is one aim (e.g. Dee Why reserve). This has introduced some compromises such as the encroachment of sports fields in the riparian zone. The largest and least developed reserve is Middle Creek. At present, this reserve has no plan of management and is slowly degrading through weed invasion and channel sedimentation/erosion.

Warringah Council has constructed a commendable array of stormwater infrastructure, including a total of 42 gross pollutant traps and 55 headwalls and sediment traps, for collecting sediments and litter, as well as 3 wetlands designed to trap sediments and nutrients.

A consideration with some of these structures is their effect on aquatic ecology by presenting a barrier to migration, altering habitat and reducing dissolved oxygen. Many of Warringah's systems are off-line or are at the heads of natural channels and do not present barriers to aquatic fauna movement. Some GPTs can impact on water quality if dissolved oxygen concentrations fall due to the organic matter held in the trap. Council has a 3 monthly cyclic maintenance program plus a system of priority maintenance during wet weather. Although there is limited data, Council has not recorded any adverse water quality impacts and the tonnages of pollutants collected have been significant.

The pattern of GPT placement in the past has not necessarily been part of a long term study. However, the recent advent of stormwater management plans and this Study have allowed Council to better target the placement and design of structures. This includes meeting requirements of NSW Fisheries for conserving habitat and providing fish passage.

Table 3.4 summarises current land use in each of the sub-catchments and the enhancements that have been put in place.

Table 3.4: Current Land Use and Baseline of Activities for Waterway Management

Catchment	Sub-Catchment	Sub-Catchment area (ha)[1]	% Urban/Industrial	% Rural residential/cleared open space	% Bushland (including National Park)	Sub-Catchment Imperviousness (%)	Water Quality Improvement Devices (no.)[1]	Water Quality Improvement Devices (% of catchment)[1]	Rehabilitation sites (% of length)[2]
Cowan	Kierans Creek	1450	2%	32%	66%	**7%**	1	5%	0
	Duffys Forest	225	0	40%	60%	**7%**	0	0	0
Curl Curl lagoon	Greendale Creek	485	80%	15%	5%	**47%**	5	42%	30%
Dee Why lagoon	Dee Why Creek	295	91%	9%	<1%	**52%**	24	100%	20%
Manly lagoon	Brookvale Creek	450	79%	5%	16%	**49%**	1	88%	15%
	Manly /Curl Curl Creek	815	39%	11%	50%	**23%**[3]	4	8%	10%
	Burnt Bridge Creek	175	88%	<1%	12%	**44%**	1	6%	40%
Middle Harbour	Bare Creek	545	10%	20%	70%	**11%**	0	0	0
	Frenchs Creek	550	63%	<1%	37%	**32%**	1	10%	0
	Carroll Creek	760	56%	<1%	44%	**28%**	1	3%	<1%
	Bantry Bay	510	50%	5%	45%	**24%**	3	19%	5%
Narrabeen Lagoon	Deep creek	1365	1%	3%	96%	**2%**	0	0	
	Middle creek	1030	32%	10%	58%	**19%**	12	7%	<1%
	Oxford/Snake	420	11%	19%	70%	**9%**	2	2%	0
	South Creek	605	80%	8%	12%	**43%**	12	20%	5%
	Wheeler creek	165	9%	<1%	91%	**5%**	0	0	0
	Narrabeen Foreshores	275	76%	<1%	24%	**38%**	25	22%	0
Collaroy	Collaroy Plateau	215	70%	15%	15%	**37%**	2	24%	40%

1. In Warringah only.
2. Figures are an indication only and may be in error.
3. For the entire Manly Creek sub-catchment. The sub-catchment upstream of Manly Dam is less than 10% impervious.

3.4.2 Non Urban Lands

A significant change in Council's approach to managing impacts of developments on waterways has followed the findings of the Non Urban Lands Study (NULS). The study identified areas of environmental significance (Figure 3.2). These are intended for use for determining areas unsuitable for urban development. The environmental criteria used were:

- Slope and terrain;
- Soils and erosion hazard;
- Visual quality;
- Cultural heritage;
- Bushfire hazard;
- Rare/threatened communities;
- Corridors and buffers;
- Biodiversity; and
- Creek conservation and habitat values (based on preliminary audit – Warringah Council, 1998b).

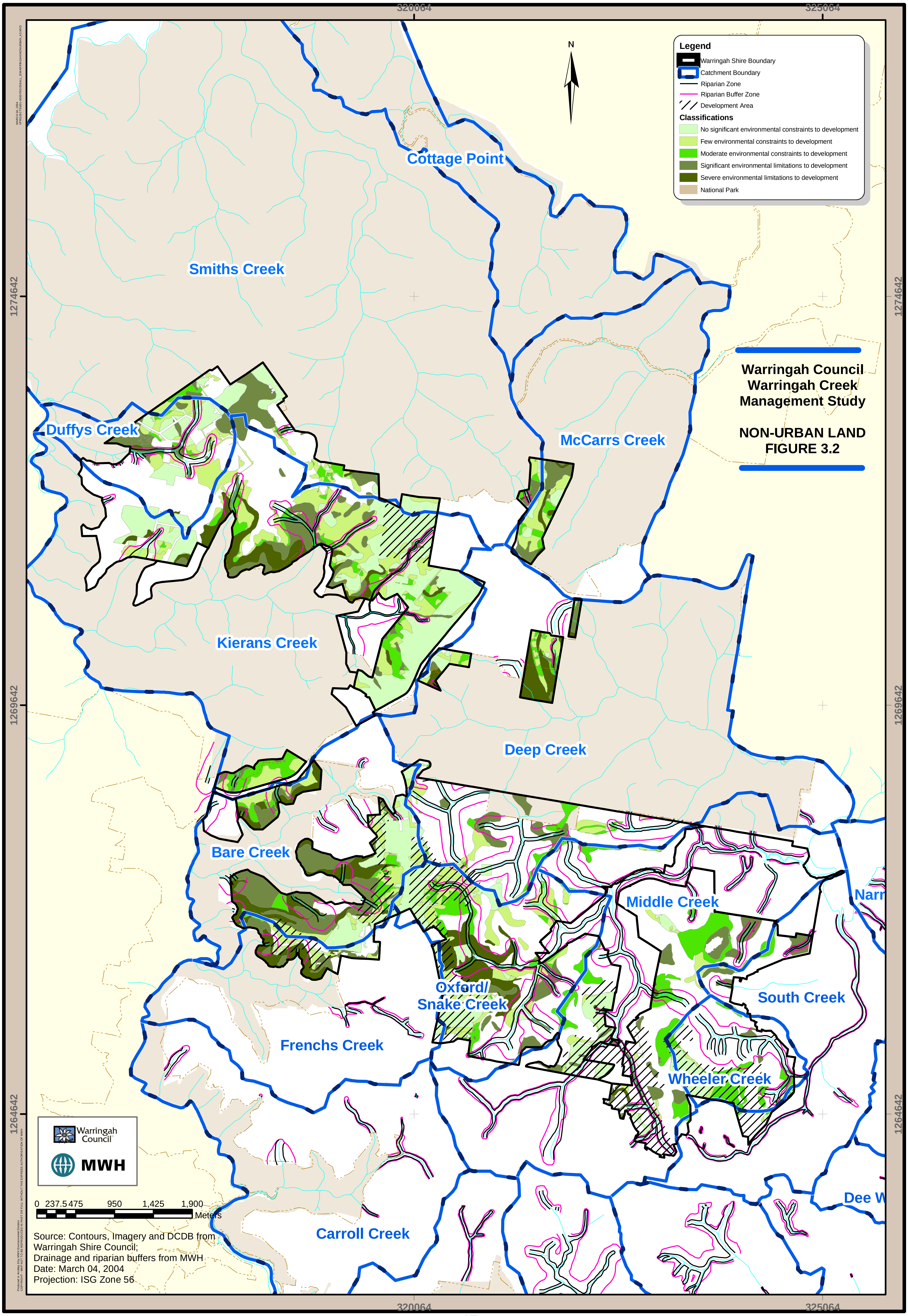
Following two additional studies of transport and water quality, Council resolved to retain all of the land as non-urban. However, those areas not defined as environmentally sensitive could potentially be developed, subject to adequate transport infrastructure and water management. At this stage, the environmentally sensitive areas have yet to receive any formal designation under the LEP, but an approach has been made to the state government to exempt the sensitive lands from future SEPP 5 applications.

For the purposes of creek management, the NULS analysis needs to be augmented by considering:

- Impacts on in-stream processes that affect their condition (such as sedimentation, and bed/bank erosion); and
- Impacts on riparian processes caused by encroachment of urban areas (such as weed infestations and loss of habitat).

The implications are that further development should not occur within riparian zones or within certain catchments. This will add to the environmentally sensitive areas in NULS and require a reduction in the crosshatched areas (i.e. potentially developable). In Figure 3.2, a number of crosshatched areas should be significantly reduced in scale, notably:

- Wheeler Creek – total developable area should be less than 10% of sub-catchment.
- Oxford/Snake, Bare, Kierans, Frenchs and Middle Creeks – as a minimum, remove crosshatching where it overlaps with riparian buffers. It is also desirable to remove all other crosshatching from the Snake/Oxford, Bare and Kierans sub-catchments because they are already close to the sustainability thresholds for Group B creeks (see section 5).


Legend
Warringah Shire Boundary
Catchment Boundary
Riparian Zone
Riparian Buffer Zone
Development Area
Classifications
No significant environmental constraints to development
Few environmental constraints to development
Moderate environmental constraints to development
Significant environmental limitations to development
Severe environmental limitations to development
National Park
Warringah Council
Warringah Creek
Management Study
NON-URBAN LAND
FIGURE 3.2
N
320064
325064
1274642
1269642
1264642
Cottage Point
Smiths Creek
Duffys Creek
McCarrs Creek
Kierans Creek
Deep Creek
Bare Creek
Middle Creek
Oxford/
Snake Creek
South Creek
Frenchs Creek
Wheeler Creek
Carroll Creek
Warringah
Council
MWH
0 237.5 475 950 1,425 1,900
Meters
Source: Contours, Imagery and DCDB from
Warringah Shire Council;
Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56

4. Study Methods

Figure 4.1 outlines the Study process. Details of the methods used are supplied in Appendix A.

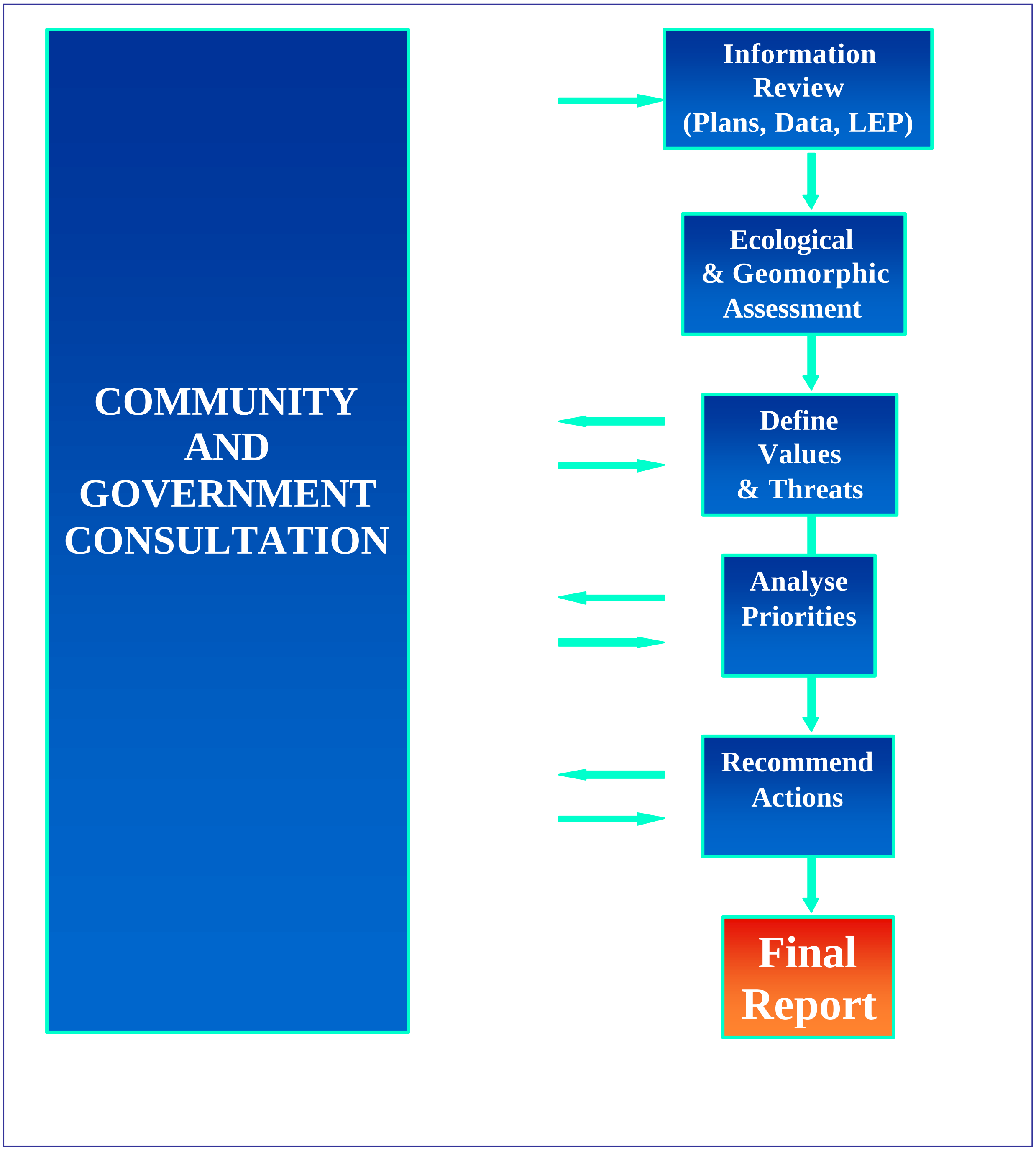


Figure 4.1 – Study Process

The outputs from the Study will assist Council in both statutory planning and other functions (such as creek rehabilitation, stormwater management and open space planning). Figure 4.2 shows various Study outputs and the planning and other functions that they can support. Some of the proposed guidelines support only statutory planning, some support other Council functions and the remainder target both.

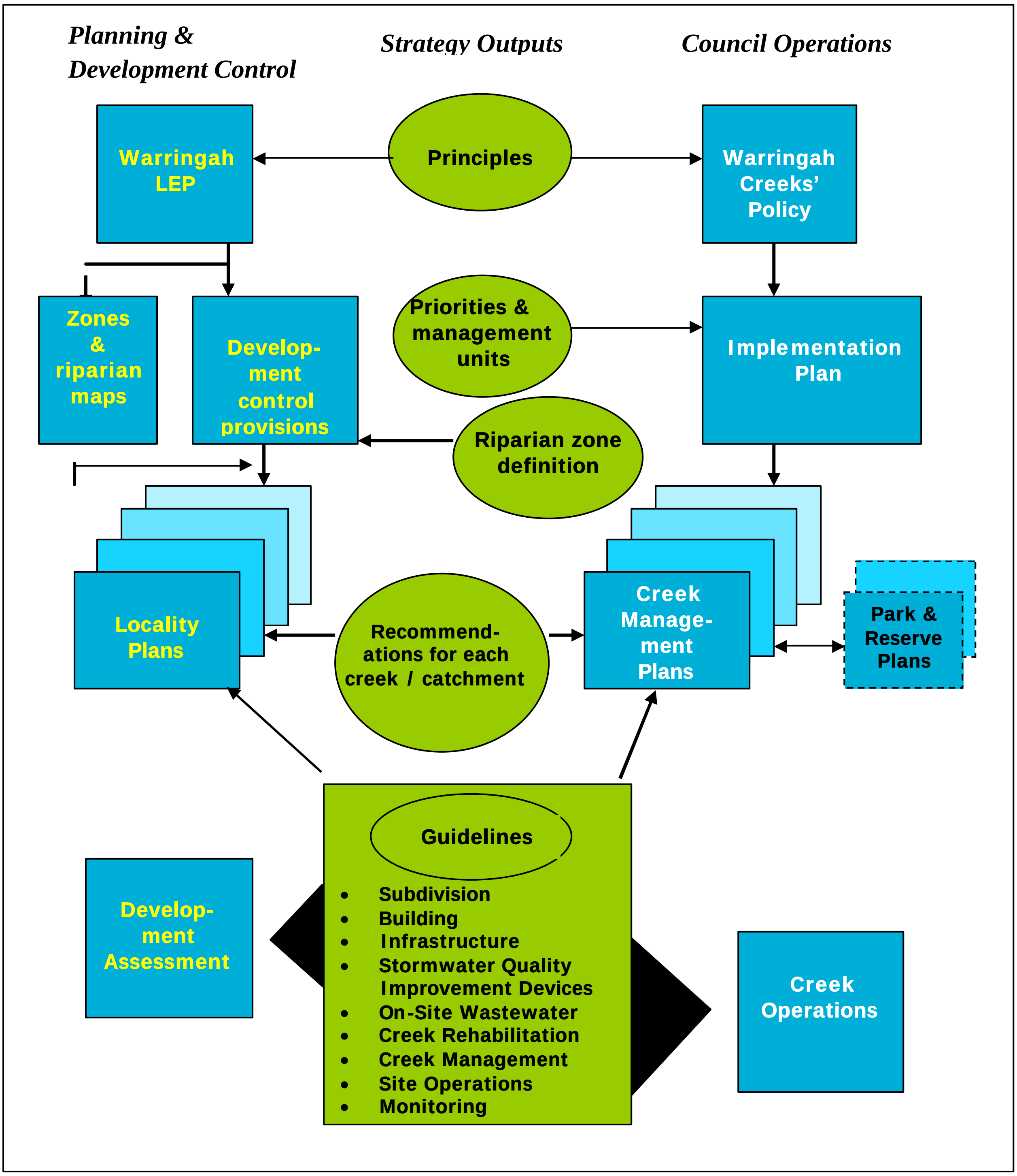


Figure 4.2 – Destination of Outputs

5. Overview of Values and Creek Health

The values assessment tells us what we *value*, rather than what is *healthy*. A person can be highly valued by his/her friends, but at the same time be very unhealthy. In ecological terms, unhealthy creeks have low resilience and minor external changes may be unsustainable.

The two concepts are related but independent. In the past, there has been a tendency to focus on unhealthy systems because they are appear to be most in need of our help. But we value people regardless of their health and in all cases, we encourage them to stay healthy through prevention.

An assessment of values for each reach is provided in Appendix B. The hierarchical numbering system to identify creeks and reaches within the study area is provided in Appendix I.

5.1 Are Warringah's Creeks healthy?

The definition of waterway health is a minefield that has been discussed endlessly elsewhere. One definition is that a healthy ecological system is *'stable and sustainable – that is, if it is active and maintains its organisation and autonomy over time and is resilient to stress'* (Haskell et al 1992, see Wong et al, 2000 p 19).

Health is clearly a continuum with no clear cut-off between healthy and unhealthy. A creek can have some aspects which are unhealthy (such as weed invasion) but others which are healthy (such as bank stability). The most difficult part is defining when a stream is past the point of no return.

This Study had insufficient data to confidently determine stream health. Some creeks appeared to be healthy on the basis that the vegetation, water quality and catchment land use data all pointed to relatively natural condition. Some creeks were clearly unhealthy due to singular factors such as water quality (e.g. Kierans Creek), channelisation (e.g. Greendale Creek), riparian weeds (e.g. Middle Creek) or bank erosion (e.g. South Creek).

A difficulty with the health concept is that some indicators, such as water quality, streamflow and riparian vegetation, are often insensitive to the subtle changes that can take place in aquatic ecosystems. Because health is a biological concept, the surest way to measure is by examining stream biology. In the absence of key indicator data such as macroinvertebrates, amphibians and fish, we were unable to be definitive in this Study.

However, the creek groupings noted in 5.3 probably reflect gradations from healthy (Group A) to unhealthy (Group C).

The values assessment raises similar issues, but there is more data available and we can be more conclusive, as set out in section 5.2.

5.2 How much do we value Warringah's creeks?

Table 5.1 summarises values for the creeks. The ratings are based on the more detailed assessments for each reach, as set out in Appendix B. For simplicity in the summary, reaches have generally been combined into whole creeks and ecological value criteria (naturalness, rarity etc) have been combined into a single rating.

Table 5.1: Summary of the Values Assessment

		Value				
Sub-Catchment (Locality)	**Creek**	**Ecological**	**Recreational**	**Landscape**	**Cultural[2,4]**	**Educational/ scientific[3]**
Kierans (Terrey Hills)	Kierans (upper)	Low	Low	Low		
	Kierans (lower) [6]	Moderate	Low	High		
Duffys (Duffys Forest)	Duffys (upper)	Moderate	Moderate	Moderate		
	Duffys (lower) [6]	High	Low	High		
Curl Curl (Allambie Heights)	Greendale	Low	High	Moderate		
Dee Why[4]	Dee Why	Very Low	Moderate	Moderate		
Brookvale	Brookvale (upper)	Moderate	Low	High		
	Brookvale (lower)	Moderate	Moderate	High		Moderate [5]
Manly (Manly Vale)	Curl Curl	High	Moderate	Very High		
	Manly	Low	Moderate	Moderate		
Burnt Bridge	Burnt Bridge	Moderate	Low	Moderate		Moderate [5]
Bare (Belrose)	Bare (upper)	Moderate	Low	High		
	Bare (lower)[6]	High	Moderate	High		
Frenchs (Frenchs Forest)	Frenchs (upper)	High	Low	High		
	Frenchs (lower)[6]	High	Moderate	High		
Carroll (Frenchs Forest)	Carroll (upper)	Moderate	Low	Low		
	Carroll (lower) [6]	High	Moderate	High		
Bantry Bay (Forestville)	Tributaries (upper)	Moderate	Moderate	High		
	Tributaries (lower) [6]	High	Moderate	High		
Deep (Belrose)	Deep	Very High	Low	Very High	High	High
Middle	Middle (upper)	Low	Low	Moderate		
	Middle (mid)	Moderate	Low	Moderate		
	Middle (lower)	Low	Low	Low		
Oxford/Snake (Belrose/Frenchs Forest)	Oxford/Snake	Moderate	Low	Moderate [1]		
South	South (upper)	Moderate	Moderate	Moderate		
	South (lower)	Low	Low	Moderate		
Wheeler (Cromer)	Wheeler (upper)	Very High	Low	Very High	High	High
	Wheeler (lower)	Low	Low	Low		

Notes:
1. Occasionally high landscape value – such as waterfalls.
2. No field assessment undertaken; information based on community input.
3. The small wetland has high ecological value, but most of the creek is channelised.
4. Cultural Heritage report appears at Appendix C.
5. Educational value associated with rehabilitation.
6. For creeks entering National Parks, 'upper' means outside and 'lower' means within the National Park.
7. Field assessments were not made within National Parks and values are based on information review, aerial photography and discussions with community members.

5.3 Creek classification

Warringah's Creeks fall into three groups on the basis of current ecological values and catchment land uses:

- **Group A**: very high ecological value; with less than 10% connected impervious area (Wheeler, Deep, Curl Curl,)
- **Group B**: some degradation in the upper catchments, but high ecological value downstream; generally 10-15% connected impervious area (Snake, Oxford, Duffys, Kierans, Bare)
- **Group C**: generally of low to moderate ecological value with moderate to highly developed catchments - 15-50% connected impervious area (Bantry Bay, Carroll, Frenchs, Middle, South, Manly, Dee Why, Greendale, Brookvale, Burnt Bridge).

These groups are important because they fall on both sides of the thresholds discussed in section 3.3. Group A is generally below the threshold range of 8-12%. Group B is close to the range and Group C is well above the threshold. In simple terms, this means that Group A and B creeks can sustain very little further development before their aquatic ecosystems will change substantially. Some Group B creeks (e.g. Kierans Creek) may already be moderately impacted due to factors such as specific land uses and on-site wastewater discharges.

It is important to note that the groupings themselves (i.e. A, B or C) do not necessarily reflect a priority. The groups are used as the basis of further analysis of risks and priorities in subsequent sections.

6. Overview of Threats to Values (Sustainability)

The major threats to Warringah's creeks vary for each of the creek groups (see section 5.3).

Group A creeks are in close to natural condition and minor perturbations can have a major impact. This group is primarily threatened by weed invasion, which is an ever-present threat. There is only a limited capacity for low intensity development outside the riparian buffers. If further SEPP 5 developments were permitted in the Wheeler creek catchment, they could cause substantial loss of values. However, Deep Creek and Curl Curl Creek are not so threatened.

Group B creeks are close to the threshold for catchment development and further changes could substantially impact on stream ecology. The upper reaches are partially or fully developed and pollutants and weeds are constantly being transported downstream into National Park areas.

Group C creeks are well above catchment development thresholds and the ecosystems are already substantially modified. Weed growth is a threat to remnant native vegetation and replanted vegetation in the riparian zone. Water quality is at or above acceptable limits, which can result in occasional stress symptoms (e.g. fish kills, nuisance algal growth and high turbidity).

Table 6.1 summarises the threatening process and their relative risk for each of the three key groups.

Table 6.1: Key Threatening Processes

Threatening process	Group A	Group B	Group C
Urban development – sedimentation, erosion & water pollution	✓✓	✓✓✓	✓
Vegetation clearing	✓✓✓	✓	✓
Weed proliferation	✓✓✓	✓✓✓	✓✓
Industrial and commercial operations[1]	✓	✓✓	✓✓
Agricultural operations[2]		✓✓	
On site wastewater[2]		✓✓	

✓ - low risk; ✓✓ - medium risk ✓✓✓ - high risk

Notes:

1. Including landfill
2. In the Duffys Forest Terrey Hills area, the risk is high. In most other areas, the risk is low

An important recent change is that '*clearing of native vegetation'* has now been determined to be a *key threatening process* under the NSW *Threatened Species Conservation Act 1995*. This determination is consistent with a previous listing under the Commonwealth's *Environmental Protection and Biodiversity Conservation Act 1999*. The determination by the Scientific Committee specifically noted the degradation of riparian zones through clearing. Species, communities and populations listed under the Act are at risk, as well as those that may become threatened as a consequence of clearing. "Degradation of native riparian vegetation along New South Wales water courses" is also identified as a key threatening process under the *Fisheries Management Act 1994*.

The effect of the determination will be to place greater scrutiny on clearing in the determination of development applications. It places an obligation on Councils and state government agencies to ensure that the impacts of clearing are addressed through planning and development assessment.

7. How Can We Set Priorities?

The first step in setting priorities is agreeing to a common set of principles which can be used by Council to plan land uses, manage development and undertake works, as well as support community initiatives. The second step is to compare the values and threats to each creek and consider how likely it is that values could be lost if the creeks continue to be managed in the same way. The third step is to consider the community's desired values for each creek and assess whether they are possible and define the actions and associated costs. The final step is to set out a long term program of action to work towards the desired values in a systematic and affordable way. Chapters 7-10 set out recommendations for each step.

7.1 Principles for Creek Protection and Management

The following goal and principles are adapted from the *'Guidelines for Protecting Australian Waterways'* (LWA, 2002). Principles for social and cultural heritage values have also been added for the purposes of this Study.

The goal of creek planning and management in Warringah is to:

Protect creek values and maintain healthy ecosystems.

This can be achieved by the following principles:

For all creeks:

- *Support the health of target species/communities*
- *Protect rare or threatened species and natural features*
- *Prevent serious loss of natural diversity*
- *Minimise damage to public and private property through creek processes*
- *Maintain and enhance creek landscapes*
- *Create opportunities for public access and recreation in waterway corridors*
- *Ensure that people are safe in and around waterways*
- *Preserve cultural heritage values*

Additional protection for creeks of high ecological value:

- *Preserve all natural components that contribute to ecological value – particularly streamflow, water quality and flora/fauna.*

Stream health (the first principle) is dependent mainly on streamflow, habitat and water quality. The selection of target species/communities is a matter for Council to consider when more ecological survey information is available. The targets should be chosen on the basis of local or regional significance.

The last principle only applies to a small number of creeks in near pristine condition.

Connectivity and biological linkages are pervasive concepts within the principles and have been acknowledged by DLWC as key components of creek management. A proposed new schedule to the LEP and design guideline include specific reference to these concepts as part of achieving sustainability (see section 8). Similarly the important concept of ecosystem services also pervades the philosophy embodied in the principles.

7.2 Analysing priorities

As discussed in Section 5.3, creeks were initially classified into three Groups on the basis of values and catchment imperviousness. As a further basis for developing priorities, each creek was plotted on a matrix of risk and value. Figures 7.1 and 7.2 show how the creeks tend to group when risk is plotted against ecological value and highest value, respectively (note: U/S = upstream and D/S = downstream).

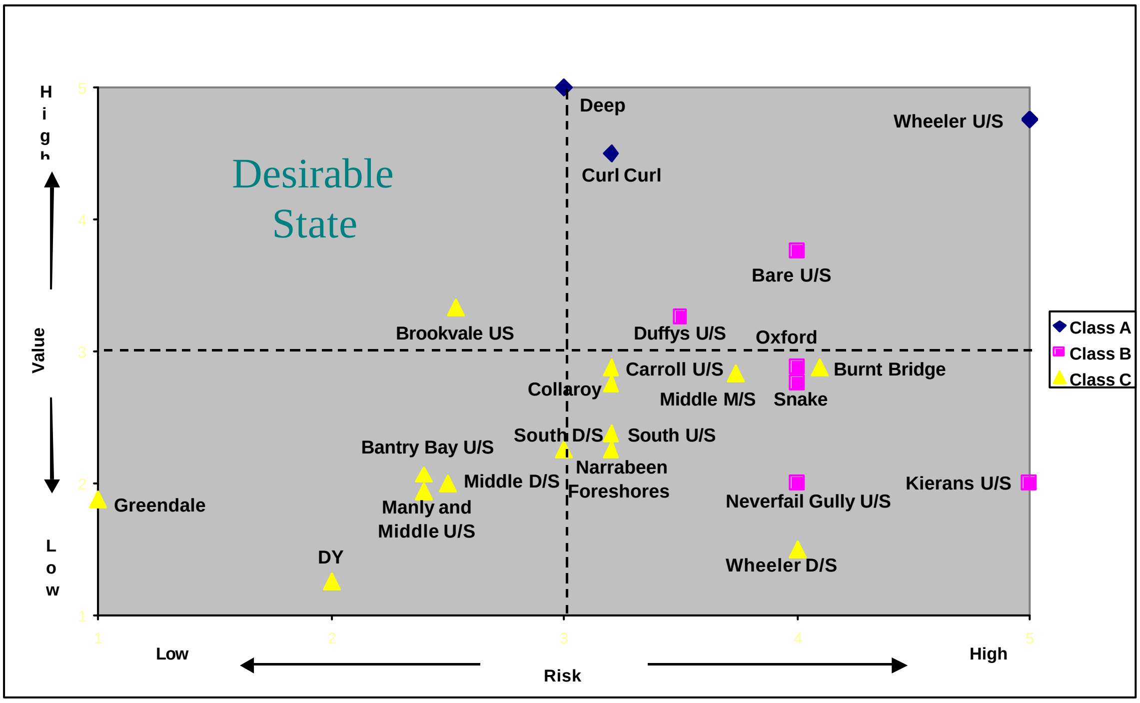


Figure 7.1 Ecological Value vs Risk

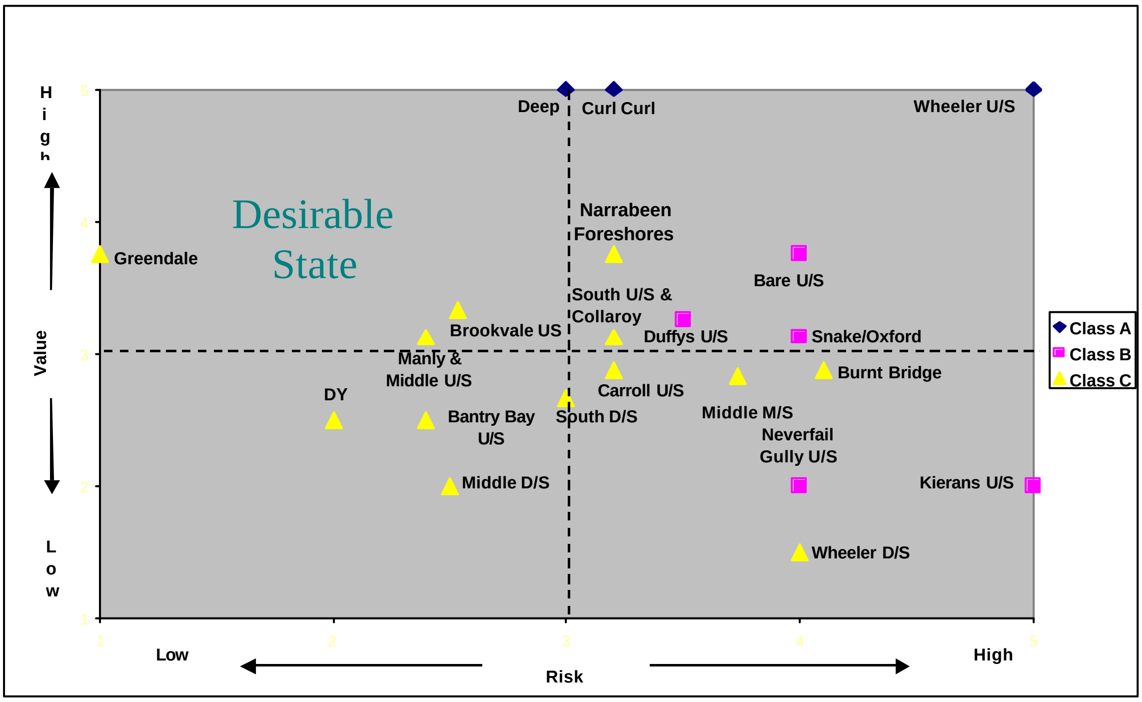


Figure 7.2 Highest Value vs Risk

The upper left quadrant in both figures is the desirable place for all creeks to be (i.e. high value and low risk). As shown in Figure 7.1 however, only one creek (upper Brookvale Creek) is considered to have high enough value and be under low enough threat to exist within this quadrant (albeit only just). Most Group A and B creeks cluster in the upper right quadrant, which means that they have high value, but are under high threat.

The matrices provide a basis for assigning priorities for both protection and repair, with certain creeks warranting high priority action to address specific and immediate threats. The desired future state for each reach/creek was also considered with respect to the following factors:

- **Current state** – How degraded is the system?
- **Resilience** – How rapidly does the system recover when disturbed?
- **Vulnerability** – How susceptible is the system to irreversible change?
- **Connectivity** – Is the system part of a habitat corridor?
- **Scale** – What minimum area would need to be rehabilitated? (E.g. does it include catchment and riparian buffer areas?)
- **Time** – How long will it take to achieve significant progress towards the desired state?
- **Stresses or threats** – To what degree can threats be controlled in practice?
- **Community perceptions** – What are the community's perceptions of the desirable state for each creek? and
- **Cost** – What are the likely costs of achieving various improved states?

Table 7.1 summarises the priorities of a range of actions for each sub-catchment. More detail on the actions for individual creeks or reaches is provided in Appendix B. These provide a blueprint for developing creek management plans for each catchment. All of the actions in Table 7.1 are required, but lower priorities are less urgent and can be delayed for a few years if budgets are limiting. The priority for producing the creek management plans reflects the following criteria:

- Existing problems which can be reversed and/or are getting worse;
- Problems may not be evident, but they are very likely to occur at any time;
- High ecological value which requires immediate land use planning controls (i.e. Group A); and
- High ecological value downstream which requires operational controls on existing activities (Group B).

Table 7.1: Summary of Action Priorities

Creek	Creek management plan	Catchment planning control[1]	Development control	Industry/commercial operations control	Agricultural operations control	On-site sewage control	Revegetation and weed control[8]	In-stream erosion repair[8]	Stormwater quality control devices	Recreational and access trail[6]
Kierans, Duffys	h	h	h	h	h	h	h	s	m	
Greendale	s	s	m[4]	m[5]			s	s	s	
Dee Why	s	s	s	s			s	h	m	
Brookvale	s	s	s	s			s	s	s	
Curl Curl	h	h	h	m			h	s	m	
Manly	s	s	s	s			m	m		
Burnt Bridge[3]	s	s	s	s			s	h	m	m
Bare, Frenchs	m	m	h	s			m	s	s	
Carroll, Bantry Bay,	s	s	m	s			m	s	s	
Deep[7]	h	h	h	s			h			
Middle, Snake, Oxford[7]	m	h	h	m	s		m[2]	s	s	m
South	h	s	h	m			h	h	h	m
Wheeler[7]	h	h	h				h	m	s	s
Collaroy	s	s	s	s			m	s	s	

h – high; m – moderate; s – standard; blank - not applicable

Notes:

1. Refers to catchment outside National Parks.
2. Appendix B - Section 12.3 explains that weeds are a major issue for Middle Creek but there are other priorities that will bring greater results with fewer resources.
3. The lower priorities for Burnt Bridge creek recognise that the creek has been extensively rehabilitated and the continuation of the program is strongly recommended.
4. Headwaters of catchment have some bushland and an adjacent housing development is proposed.
5. Leachate from former landfills.
6. Many of the coastal and National Parks creeks already have recreational trails and access.
7. Substantially non-urban catchments with some natural areas currently subject to SEPP 5 development – particularly in Wheeler Creek.
8. A recent Landcare publication suggested that riparian restoration should '*always work from the least degraded areas or best areas to the worst areas…. Ideally, riparian restoration needs to be approached on a subcatchment or drainage line basis, working from top to bottom, best to worst.*'

8. Planning and Development Controls

The main components of the Warringah planning system that influence waterway management are:

- Warringah Local Environmental Plan 2000:
  –General Principles of Development Control;
  –Schedules; and
  –Locality Statements.
- Interim Warringah Design Guidelines:
  –General Principles of Development Control.

The LEP and the Design Guidelines apply to the entire LGA, although two Schedules are area specific. All Locality Statements are area specific and are grouped by catchment. However, there is no specific text applying to individual catchments and the locality boundaries often include more than one sub-catchment. For example, Oxford Falls Valley is entirely within the Narrabeen Lagoon catchment, but includes parts of the Middle Creek sub-catchment and the Wheeler/South Creek sub-catchments. This means that setting catchment-specific planning controls is difficult to achieve with the existing locality boundaries.

The focus of the Group A and B creeks should be protection (particularly through the LEP). Group C creeks are substantially modified systems that are usually in developed catchments. Although of low ecological value, they are generally of high recreational value. These should be protected from further degradation, but the main management tool is likely to be repair (stormwater quality management, revegetation, bank stabilisation, weed removal etc) rather than planning control.

A comprehensive set of recommended changes to the LEP is set out in Appendix E. More specific recommendations relevant to statutory planning are summarised below.

8.1 Proposed LEP Changes

For convenience, the recommendations for LEP changes are grouped into categories, although some are applicable to several parts of the LEP.

As discussed in section 3.1, every effort has been made to ensure mapped creek centre lines and riparian areas are in the correct location. There will be opportunities to update and include any new creek centre lines, riparian zones and riparian buffers found to be missing or incorrect through a review process.

In cases where a creek exists, but has been omitted or incorrectly mapped on Council's Geographic Information System, it is still subject to the same conditions and recommendations as other creeks, at the discretion of Council staff.

8.1.1 Riparian Zones

- Creek protection should consider both the waterway itself and the adjacent riparian zone (see Appendix D *'Estimating the Extent of Riparian Zones and Buffers'*). Therefore any protective buffer must be sufficiently wide to protect both. Protection should:
  - exclude development from riparian zones, and
  - restrict development in riparian buffer zones.
- Riparian zones and buffers vary in width depending on a number of factors. They should be delineated on maps to accompany the LEP, rather than be based on a nominated distance.
- The table identifies developments which are permissible with consent in the riparian zone of creeks, *provided that*:
  - no reasonable alternative location is available; and
  - a waterway impact study (see Appendix E) demonstrates that the proposed development meets the principles set out in section 7.1 (codified in a new Schedule 18 of the LEP and supported by a new design guideline):

Creek Group	Permissible development in Riparian Zone
A	public footbridge, unsealed pedestrian trail
B	public footbridge, vehicular bridge and associated roadway, pedestrian walkway or recreational trail, off-stream stormwater management device
C	footbridge, vehicular crossing and associated roadway, pedestrian walkway or recreational trail, in-stream or off-stream stormwater management device.

The width of a particular riparian buffer may vary over time as a result of revegetation projects. For example, new linkages may be established with bushland, previously separated by cleared open space. In these circumstances it will be important to re-map the riparian buffer, as the actual cover increases.

Particular consideration should also be given to the maintenance of natural vegetation cover within riparian zones and buffers.

More than 100 properties were identified in the draft Study as being affected by the proposed riparian zone. As part of community consultation, landholders were notified of the proposed changes. Most of these properties exceed 0.5 ha, are in non-urban areas and are already developed to their full potential. There are a very few exceptions and these are urban properties which may be affected by the riparian due to a creek line actually running through the property. The percentage of each property affected ranges from 0.5% to 90%.

It should also be noted that the riparian zones shown are indicative only and will need to be verified on site by survey.

8.1.2 Catchment Land Use

- Catchment land use is a major (if not ***the*** major) factor governing condition of most creeks. Creek management must include consideration of catchment land use and in-stream activities (such as riparian clearing, placement of structures, dredging).
- Creeks flowing into National Parks from urban areas can potentially impact on the values of the parks. It is important to regulate land uses in those catchments.
- Conventional subdivision and drainage design in relatively undeveloped catchments will lead to substantial losses of creek values.
- The keys to maintaining creeks with high ecological values through catchment controls are to:
  - Limit impervious areas to less than 10-15% (depending on degree of drainage connection) of the catchment; and
  - Minimise direct connectivity between creeks and drainage system.
- Some areas – particularly those draining to National Parks – could be considered for retro-fitting drainage systems (including houses) to reduce peak flows and pollutant loads. This will mostly occur through Council operations, but any new development could also be captured through the LEP.
- Compensatory habitat may be possible in some instances where the net impacts are sustainable.

8.1.3 Construction

- All development has short term consequences during construction and it is essential to provide a series of redundant safeguards for development near any creek or in the catchments of Group A and B catchments. For example, a combination of source controls, interception devices and rehabilitation of any offsite impacts.

8.1.4 Development Intensity

Creek catchments have been classified into three groups (Figure 8.1) based on the ecological values and the extent of catchment imperviousness, as a sustainable development (catchment capacity) limit:

- **Group A**: maintain at less than 10% connected impervious area (Wheeler, Deep, Curl Curl);
- **Group B**: maintain at less than 15% connected impervious area, with all future developments incorporating WSUD (Snake/Oxford, Duffys, Kierans, Bare); and
- **Group C**: no additional catchment constraints, but require development controls to prevent further deterioration (Bantry Bay, Carroll, Frenchs, Middle, South, Manly, Dee Why, Greendale, Brookvale, Burnt Bridge).

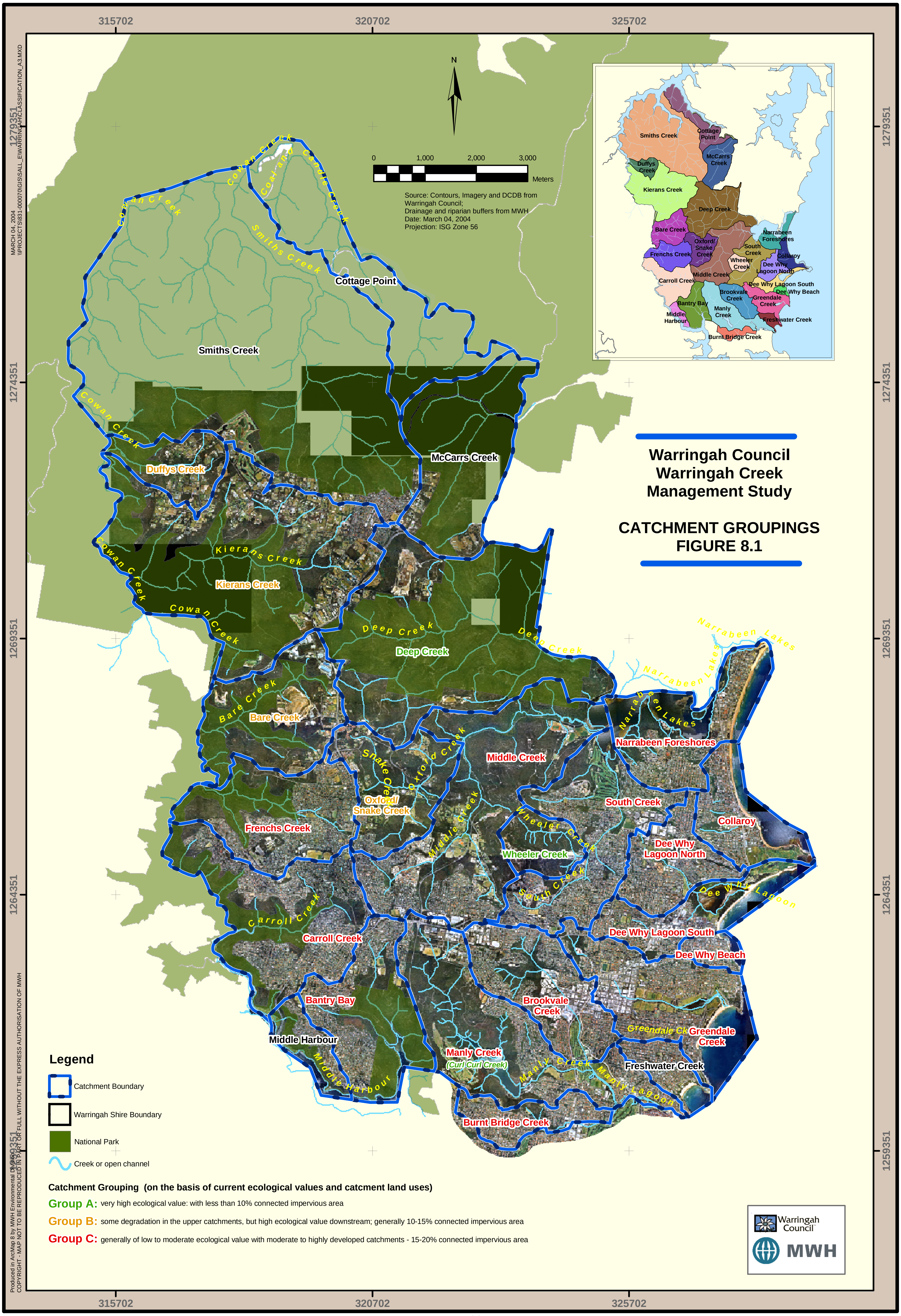
The limits on impervious area in Groups A and B catchments provide a target to control catchment development below the identified thresholds of imperviousness. The mechanism for allocating 'spare capacity' could be some combination of tradable rights, compensatory land/habitat, rates concessions, building location envelopes parcels, site discharge indices etc. If a catchment is at capacity, then development should only be allowed if the increased imperviousness is offset by appropriate stormwater management controls that result in no net change in peak flows or pollutant loads.

As noted previously, the current locality boundaries in the LEP do not correspond to sub-catchments. This means that the LEP and development approval system would require substantial changes and the approval of the state government. The package of amendments should be considered as a longer term aim. As an interim step, the Creek Management Study recommendations could be adopted as a Council policy and the 'Desired Future Character' of localities revised to reflect Group A, B and C catchments. Another interim solution is to add to the LEP a new Schedule 18 - *Guiding Principle for Environmentally Sensitive Catchments and Waterways* (see section 8.1.5 and Appendix E), that would delineate:

- A map of catchment boundaries and their relationship to localities
- A table classifying catchments into Groups A, B and C
- Principles and performance criteria for protecting and managing waterways

Most creeks are Group C, and these are beyond protection through strict catchment density controls. Group C creeks will be protected by a combination of riparian zone and buffer zone development controls (see section 6), plus comprehensive land management. Groups A and B will also require these as additional controls.

The minimum target for all creeks is no further deterioration in stream health. In many cases, there will also be enhancement programs, so that health and values will increase (particularly for Group C creeks, most of which are close to residential and recreational areas).


Warringah Council
Warringah Creek
Management Study
CATCHMENT GROUPINGS
FIGURE 8.1
Source: Contours, Imagery and DCDB from Warringah Council;
Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56
0 1,000 2,000 3,000
Meters
N
315702
320702
325702
1279351
1274351
1269351
1264351
1259351
Smiths Creek
Cottage Point
McCarrs Creek
Duffys Creek
Kierans Creek
Deep Creek
Bare Creek
Middle Creek
Narrabeen Foreshores
Oxford/ Snake Creek
Frenchs Creek
South Creek
Collaroy
Wheeler Creek
Dee Why Lagoon North
Carroll Creek
Dee Why Lagoon South
Dee Why Beach
Bantry Bay
Brookvale Creek
Greendale Creek
Middle Harbour
Manly Creek (Curl Curl Creek)
Freshwater Creek
Burnt Bridge Creek
Cowan Creek
Coal and Candle Creek
Narrabeen Lakes
Manly Lagoon
Legend
Catchment Boundary
Warringah Shire Boundary
National Park
Creek or open channel
Catchment Grouping (on the basis of current ecological values and catcment land uses)
Group A: very high ecological value: with less than 10% connected impervious area
Group B: some degradation in the upper catchments, but high ecological value downstream; generally 10-15% connected impervious area
Group C: generally of low to moderate ecological value with moderate to highly developed catchments - 15-20% connected impervious area
Warringah Council
MWH
Produced in ArcMap 8 by MWH Environmental Division
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8.1.5 Evaluation of Development Proposals

The principles set out in Section 7.1 are broad and there is a need to provide more detail to assist proponents and Council officers in the development assessment process., a proposed new schedule in the LEP (Schedule 18) sets out 'performance criteria' and a proposed new design guideline suggests 'acceptable solutions' for each criterion (see Appendix E).

Part of the proposed Schedule 18 is reproduced below.

Principle 1: ***Support the health of target species/communities*** *(e.g. migration routes, habitat, streamflow, water quality)*
Performance criteria
Maintain natural habitats
Provide fauna movement routes
Prevent unnatural erosion or sediment deposition
Maintain acceptable water quality
Maintain connectivity between creeks and floodplains

Principle 2: ***Protect rare or threatened species and natural features***
Performance criteria
Prevent the loss of any rare or threatened natural features
Maintain existing protected creek areas
Maintain the total area of creeks designated as high value
Protect downstream protected areas, such as National Parks

Principle 3: ***Prevent serious loss of natural diversity***
Performance criteria
Avoid introducing plants or animals which may displace natural species
No increase in nutrient loads to riparian soils and creeks
Avoid displacing species by habitat changes
Protect natural areas from contamination

Principle 4: ***Maintain and enhance creek landscapes***
Performance criteria
Avoid development which is visible from riparian areas in Group A catchments
Avoid development which obscures views of natural valleys in Group A or B catchments

Principle 5: ***Minimise damage to public and private property through creek processes***
Performance criteria
Avoid increases in peak channel flows and sediment exports for events smaller than 2

year ARI.
Avoid local erosion at stormwater outlets
Avoid export of weeds from private properties into creeks

Principle 6: ***Create opportunities for public access and recreation in waterway corridors***
Performance criteria
Provide public access along creek corridors

Principle 7: ***Ensure that people are safe in and around waterways***
Performance criteria
Channel banks are not oversteepened
Channel banks are stable

Principle 8: ***Preserve cultural heritage values***
Performance criteria
Avoid the loss of indigenous cultural heritage values
Avoid the loss of non-indigenous cultural heritage values

Principle 9 (only for Group A and B creeks): ***Preserve all natural components that contribute to ecological value – particularly streamflow, water quality and flora/fauna.***
Performance criteria
Streamflow and water quality are natural
Aquatic and riparian vegetation are undisturbed and unmodified
Aquatic and riparian fauna habitat and movement corridors are retained

Schedule 18 also contains a table and maps indicating Groups A, B and C creeks and their relationship to Localities. Principle 9 is intended to guide development in the environmentally sensitive catchments (Groups A and B).

We propose that development should *not be permitted within Riparian Zones*, but *may be permitted within Riparian Buffers* if the developer can demonstrate that the development will not adversely affect the Riparian Zone and/or the waterway.

Certain development applications would be required to demonstrate how their solutions meet the performance criteria. The target applications would be developments that:

1. require an environmental impact assessment (such as a Statement of Environmental Effects under the LEP or an Environmental Impact Statement under the *Environmental Planning and Assessment Act 1979*) and which may impact on creek values; and/or
2. are proposed within a Riparian Buffer.

We propose a 'Waterway Impact Study' should be carried out in these circumstances. Depending on the nature of the development, this could either be a stand-alone study or an integral part of the environmental assessment for the development. Most of the developments captured by the change would be those in Riparian Buffers (point 2 above) because only category 3 developments require a Statement of Environmental Effects. The content of the waterway impact study would be set out in a new schedule to the LEP (Schedule 17) and would be required to demonstrate consistency with the relevant principles and performance criteria from Schedule 18.

8.2 Land Ownership

In mapping the riparian zone, existing uses and creek condition have been taken into account, so this is unlikely to constrain most forms of development. Notable exceptions are currently undeveloped areas such as the Wheeler Creek and Deep Creek catchments.

The zone is usually below the 100 year ARI flood level, in which case many developments are excluded anyway. However, some developments are compatible with flooding, but not with riparian values – such as car parks and sealed sporting fields. Again, this should have only limited impact in existing urban areas, where riparian zones tend to be narrower.

If Council accepts the need to exclude development within the riparian zone, the development rights most affected will be properties in undeveloped catchments and non-urban areas. Where land identified as Riparian Zone is privately owned, Council will need to take into consideration the extent to which the riparian zone would limit development potential of the site, if at all. Where development potential is affected, Council may need to determine whether favourable consideration be given to any development on the remainder of the site, or in extreme circumstances, whether to purchase the site, or a portion of the site, to ensure the creeks protection.

An added consideration for Council would be the desirability of acquiring developed land within riparian zones for rehabilitation. Such sites would need to have strategic value (e.g. to address a major erosion issue or to revegetate part of a wildlife corridor) to justify the expense.

Land tenure and land management arrangements raise a number of issues that are beyond the scope of this study to resolve and are proposed as matters to be addressed in Council's creek policy (section 9.1).

8.3 Design Guidelines

The following guidelines should be referred to for any proposed development or activity carried out within the Riparian Zone or Buffer:

8.3.1 LEP 2000 Design Guidelines

Design guidelines will be *amended* as required to assist with the changes recommended to the general principles and schedules (Section 8). The following *additional* Guidelines are proposed:

- on site wastewater management;
- water quality objectives (including EPA classification);
- natural channel and creek rehabilitation (reference to external sources);
- compensatory habitat (reference to external source); and
- stormwater quality interception devices
- development near creeks, riparian zones and buffers.

Water Sensitive Urban Design principles are referred to in the proposed amendments to Schedule 7. Council intends to conduct a separate project to develop a guideline for WSUD. An important constraint on WSUD in Warringah is the low infiltration capacity of soils derived from Hawkesbury Sandstone (i.e. the majority of the area). This means that some of the WSUD techniques are not applicable in many areas. In addition, caution is needed to ensure that the change in moisture content or the increase in available nutrients does not degrade natural bushland and riparian buffer areas. At this stage, there are no definitive guidelines for measures to protect bushland.

8.3.2 Operational Controls

- Some activities are having significant impacts and are inherently difficult for Council to ensure satisfactory management once development approval is granted. Examples include:
  - Filling;
  - on site wastewater treatment and disposal;
  - agriculture; and
  - landscape supplies.
- Waterway management plans will need to be prepared for many creeks. They will have limited effectiveness unless given statutory effect through the LEP.

9. Creek Policy and Management Plans

9.1 Creek policy

Council's proposed *Watercourses and Aquatic Habitat* policy should contain as a minimum:

- The creek management principles set out in section 7.1 and the accompanying performance criteria (Schedule 18 of the LEP);
- Reference to relevant LEP provisions which also are applicable to general creek management (e.g. requirements for undertaking a waterway impact study, water quality objectives);
- Operational guidelines for creek management (section 9.2.1);
- Statements of future intent (including values) for each major creek system – which may include enhancements, such as improved water quality;
- Preferred management and land tenure arrangements for riparian zones (e.g. Council, private land owner or community title);
- A timetable for the production of creek management plans ; and
- Related legislation, policies and strategies, including links and coordination mechanisms.

9.2 Operational Guidelines

9.2.1 Operational Guidelines

Operations and developments not subject to LEP 2000 for which guidelines are recommended are *[note that some are common to the LEP 2000]:*

- water quality objectives (including EPA classification);
- natural channel design and creek rehabilitation (reference to external sources);
- compensatory habitat;
- stormwater quality improvement devices (reference to external guidelines);
- works within creeks and riparian zones; and
- waterway management plans – content.

Water Sensitive Urban Design principles are also applicable to non-statutory activities – notably road design. As noted in section 8.3.1, Council intends to conduct a separate project to develop a guideline for WSUD and the scope should include public works and retrofit of established urban areas.

10. Implementation Plan

Table 10.1 shows the implementation plan and estimated total cost for each of the major creek systems, with actions divided into short (1-2 years), medium (2-5 years) and long term (5-15+ years). Land acquisition and recurrent maintenance is not included in the costs. A breakdown of indicative costs and prioritisation of each reach and activity is provided in Appendix H, with detailed costing to be developed as part of creek management plan formulation. Only outlays are shown in the table and in Appendix H. However, modest savings should arise from reduced channel erosion, sediment transport and pollutant clean up costs.

The total cost over 15+ years is estimated at $3.87 million or approximately $260,000 per annum. South Creek is proposed to consume about 30% of the total, but with much of the funding potentially coming from state government grants and subsidies. South Creek would be a high profile pilot project which, if successful, could be applied to other urban areas.

The table does not include common items in the recommendations (Section 11.2) such as LEP amendments, land declarations under SEPP 5 stormwater management plans and reserve plans of management. Specific treatments and locations are set out in Appendix B.

The activities or outcomes are intended to guide the preparation of creek management plans. Some of the rehabilitated creeks may not require creek management plans, but are included as long term (i.e. lower priority) tasks.

Table 10.1: Staged Implementation Schedule and Indicative Costing

Reach/Creek and Indicative Cost	Activities or outcomes		
	***Short term* (1-2 years)**	***Medium term* (2-5 years)**	***Long term* (5-15+ years)**
Kierans Creek (upper) **$150,000**	▪ Prepare a Creek Management Plan consistent with the Dundundra Falls Reserve plan of management ▪ Negotiate with SWC to supply sewage reticulation to the Myora road area ▪ Incentive scheme to progressively replace septic tanks with aerobic sand filtration systems ▪ Conduct a risk assessment of stormwater runoff from different land uses ▪ Consider the proposed LEP amendments in evaluating development proposals in the upper reaches	▪ Work with rural and commercial landholders (e.g. with incentive schemes, education, regulation, audit) to improve site management practices ▪ Incentives for upgrading on-site wastewater systems to effect nutrient removal	

Reach/Creek and Indicative Cost	Activities or outcomes		
	Short term (1-2 years)	*Medium term* (2-5 years)	*Long term* (5-15+ years)
Duffys Creek (upper) **$150,000**	▪ Prepare a Creek Management Plan, with particular reference to stormwater management and water sensitive design ▪ Incentive scheme to progressively replace septic tanks with aerobic sand filtration systems ▪ Conduct a risk assessment of stormwater runoff from different land uses ▪ Consider the proposed LEP amendments in evaluating development proposals in the upper reaches	▪ Work with rural and commercial landholders (e.g. with incentive schemes, education, regulation, audit) to improve site management practices ▪ Incentives for upgrading on-site wastewater systems to effect nutrient removal	
Greendale Creek (upper) **Nil**	▪ Consider the proposed LEP amendments in evaluating development proposals in the upper reaches		
Greendale Creek (lower) **$40,000**	▪ Limit further development (including impervious surfaces) within the riparian zone	▪ Investigate the costs and benefits of options to intercept and/or treat landfill leachate entering the creek.	
Dee Why Creek **$80,000**	▪ Repair erosion around the concrete creek invert by stabilising the soil and revegetating with groundcover ▪ Continue revegetating riparian areas ▪ Investigate potential pollution from Cromer industrial estate (also applicable to South Creek)	▪ Investigate the construction of an artificial wetland habitat adjacent to the creek	

Reach/Creek and Indicative Cost	Activities or outcomes		
	***Short term* (1-2 years)**	***Medium term* (2-5 years)**	***Long term* (5-15+ years)**
Brookvale Creek **$40,000**	▪ Control weeds in Allenby Park and educate landholders about garden waste management ▪ Continue weed management in the reaches below Warringah mall		
Curl Curl Creek **$100,000**	▪ Prepare a Creek Management Plan ▪ Revegetate riparian zone and buffers	▪ Investigate the performance of exiting stormwater quality controls and augment if necessary	
Manly Creek **$100,000**	▪ Continue weed management	▪ Stabilise banks and revegetate	
Burnt Bridge Creek (In cooperation with Manly Council) **$130,000**	▪ Continue implementation of erosion control and revegetation works	▪ Investigate the costs and benefits of an in stream wetland ▪ Improve the recreational and access trail network	
Bare Creek **$50,000**	▪ Undertake weed management in riparian zone ▪ Educate residents about plant selection and garden waste management ▪ Investigate sediment trapping opportunities ▪ Enforce sediment and erosion control measures for new construction	▪ Prepare a Creek Management Plan	
Frenchs Creek **$65,000**	▪ Undertake weed management in riparian zone ▪ Educate residents about plant selection and garden waste management ▪ Investigate sediment trapping opportunities	▪ Prepare a Creek Management Plan with particular attention to retro-fitting WSUD and stormwater quality control devices	

Reach/Creek and Indicative Cost	Activities or outcomes		
	Short term (1-2 years)	*Medium term (2-5 years)*	*Long term (5-15+ years)*
Carroll Creek **$245,000**	▪ Undertake weed management in riparian zone ▪ Educate residents about plant selection and garden waste management ▪ Require WSUD principles in all new development		▪ Investigate retro-fit of WSUD in existing development ▪ Install additional stormwater quality control devices
Bantry Bay Creek **$240,000**	▪ Undertake weed management in riparian zone ▪ Educate residents about plant selection and garden waste management ▪ Require WSUD principles in all new development		▪ Investigate retro-fit of WSUD in existing development ▪ Install additional stormwater quality control devices
Deep Creek (upper) **$95,000**	▪ Prepare a Creek Management Plan ▪ Progressively eliminate weed sources from the upper catchment to the National Park boundary ▪ Restrict access to vehicle and riding trails within riparian buffers ▪ Investigate causes of elevated nutrient concentrations downstream of Kimbriki Recycling and Waste Disposal Centre		

Reach/Creek and Indicative Cost	**Activities or outcomes**		
	Short term (1-2 years)	***Medium term (2-5 years)***	***Long term (5-15+ years)***
Deep Creek (lower) (In cooperation with Pittwater Council) **$25,000**	▪ Prepare a Creek Management Plan (as above) ▪ Continue revegetation around the reserve ▪ Encourage Pittwater Council to continue the program of development controls and stormwater infrastructure		
Middle Creek (upper) **$610,000**	▪ Limit catchment development on undeveloped tributaries ▪ Require WSUD in new development	▪ Prepare a Creek Management Plan (in conjunction with Snake and Oxford creeks) ▪ Recreational trail in public land from Narrabeen Lagoon to Oxford Falls ▪ Commence riparian revegetation in upper reaches (including removal and replacement of the engineered channel running through the Australian Tennis Academy with stream stabilisation measures). ▪ Educate residents about plant selection and garden waste management	▪ Riparian revegetation and weed removal in middle and lower reaches
Snake Creek / Oxford Creek **$200,000**	▪ Limit catchment development ▪ Require WSUD in new development	▪ Prepare a Creek Management Plan (in conjunction with Middle Creek) ▪ Educate residents about plant selection and garden waste management	▪ Riparian revegetation and weed removal

Reach/Creek and Indicative Cost	Activities or outcomes		
	Short term (1-2 years)	***Medium term (2-5 years)***	***Long term (5-15+ years)***
South Creek **$1,260,000**	▪ Prepare a Creek Management Plan ▪ Progressively revegetate riparian zone (upper reaches) ▪ Stabilise eroding banks in upper reaches ▪ Construct a wetland at the wheeler creek confluence ▪ Introduce at source controls (retro-fit WSUD etc) to reduce peak flows ▪ Educate residential, commercial and industrial stakeholders about at-source stormwater management ▪ Educate residents about plant selection and garden waste management	▪ Progressively revegetate riparian zone and stabilise eroding banks (middle and lower reaches) ▪ Recreational trail in public land from Narrabeen Lagoon to Beacon Hill ▪ Continue retro-fit of WSUD in catchment	▪ Continue retro-fit of WSUD in catchment
Wheeler Creek **$290,000**	▪ Strictly limit catchment development ▪ Prepare a Creek Management Plan ▪ Negotiate with property owners to revegetate disturbed riparian zones	▪ Remove weeds and sediment in lower channel near South Creek confluence ▪ Install a wetland, fishway and erosion controls at South Creek confluence	

Creeks not in the list (eg. Collaroy and minor tributaries) will also be subject to the LEP changes and continuing management by the local community groups with support from Council and the state/federal governments.

11. Conclusions and Recommendations

11.1 Conclusions

The Study has shown that virtually all of Warringah's creeks are at risk of further degradation. The level of risk varies widely as does the sensitivity of creeks to further change. One feature is common to all creeks – they flow into receiving waters that are highly valued – the four coastal lagoons and the estuaries of Sydney Harbour and the Hawkesbury River. Each of these receiving waters is under stress from pollutants conveyed by the creeks.

Just three major creeks (Deep, Wheeler and Curl Curl) are mostly unaffected by development and protection of their catchments is critical. These creeks are of high landscape and ecological value and will degrade quickly if even minor changes occur (such as weed growth, vegetation clearing or urban development).

Several creeks (such as Kierans and Snake) have development in the upper reaches, but are important because they flow into National Parks or reserves and sensitive estuarine waters. Most of these are highly modified in the urban and rural areas, but are in good condition in the National Parks. There is some evidence to suggest that this group of creeks is at the point where any increase in flows or pollutants from the catchment could result in significant deterioration in the National Park sections.

The remaining creeks flow into the coastal lagoons and catchment development has resulted in significant – and probably irreversible – changes to ecology and geomorphology. Many of these creeks – particularly close to the coast - have been subject to rehabilitation programs because people have been concerned about the degree of degradation. To some extent the two largest creeks - Middle and South – have been given less attention and the scale of work needed to rehabilitate them is now very large.

The implementation plan covers all creeks in Warringah, although some of the minor creeks are not dealt with in any detail. The plan supports the continuance of the excellent rehabilitation programs that are happening collaboratively between Council, the community and other levels of Government. However, our view is that the levels of investment in these highly modified creeks would be most cost-effective if the aims were limited to:

- Ensuring that the creeks are not a health or safety hazard to people;
- Stabilising erosion and reducing downstream sedimentation;
- Enhancing riparian habitat and minimising the further spread of weeds; and
- Providing recreational opportunities.

Greendale Creek is a good example of a rehabilitation which supports a whole range of values, while recognising that restoration aquatic and riparian ecosystems to a natural state is not possible. The key is knowing how far to go and how much to invest. For example, a more ambitious project to replace a concrete channel with a 'natural' waterway may not be as cost-effective or as beneficial as protecting an existing natural stream.

A high priority for Warringah should be protecting and managing those creeks which are of high value (Groups A and B). This may involve new mechanisms such as voluntary conservation agreements, compensatory habitat, planning constraints and additional development and operational controls. Without these mechanisms, even modest increases in development are likely to lead to a substantial decline in creek values.

We also suggest that South Creek is in need of urgent attention to address a number of issues – including flooding, erosion, sedimentation and weed growth. An integrated approach to the creek presents an opportunity to involve the community in trials of new initiatives - such as water sensitive urban design – that have application throughout Warringah.

Middle Creek is a large and diverse system, with development and past clearing scattered throughout the largely undeveloped valley. It also provides a major, untapped recreational opportunity for a walking trail from the sea, via Narrabeen Lagoon to Oxford Falls. The Middle Creek reserve covers a large part of this area, and is the largest Council-owned creek corridor in Warringah. However, a major investment is required to deal with all of the issues as part of an integrated program. The existing weed problems alone would consume Council's entire bushland rehabilitation budget for years. As an interim measure, we have recommended improved development controls and minor management intervention until Council is able to develop and implement a creek management plan.

11.2 Recommendations

Overall, we recommend that Council:

- adopts the Creek Management Study as Council policy;
- adopts the creek management principles set out in section 7.1;
- amends the LEP and design guidelines as set out in chapter 8;
- requests Planning NSW (formerly the Department of Urban Affairs and Planning) to declare riparian zones and catchments of Group A creeks as environmentally sensitive for the purposes of SEPP 5; (see figure 3.2.);
- prepares a creek policy in accordance with section 9.1;
- prepares creek management plans according to the priorities set out in Table 7.1. A suggested structure for the plans is shown in Appendix F. Implementation plans and specific actions for each reach or creek are set out in Section 10; and

- modifies the water quality monitoring program to cover upland creeks and to develop a set of water quality objectives based on knowledge of local aquatic ecosystems.

References

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Glossary

Activity – an undertaking by or on behalf of a public authority that does not require development consent under Part 4 of the *EP&A Act*. Defined in Section 110 of the *EP&A Act* and includes the erection of buildings, the carrying out of works, the use of land or of a building or work and the subdivision of land.

ANZECC – Australian and New Zealand Environment and Conservation Council.

ARI – 'Average Recurrence Interval' (standard measure of rainfall intensity).

Catchment – the area within which rainfall contributes runoff to a particular point on a waterway.

Connected Imperviousness - the proportion of impervious area directly connected to streams by pipes or lined drains.

Connectivity – the interconnection of functionally related ecological elements of a landscape so that species can move among them.

Creek - any watercourse, whether ephemeral, intermittent or perennial, whether on its natural course or altered by human interference, whether channeled or not. It also includes any drainage lines able to be identified by a linear vegetation assemblage reflective of regularly moist soil conditions or by a weed plume consistent with regularly moist soil conditions.

Waterway Impact Study – prepared for any development or activity occurring within a Riparian Zone or Buffer. May be stand alone or part of an Environmental Impact Statement, Statement of Environmental Effects or Review of Environmental Factors.

Development Consent – consent that is required for any development that is not listed in Schedules 1 or 2 of the *Warringah Local Environmental Plan 2000*. The consenting authority for the purpose of these guidelines is Warringah Council.

Designated Development – development that is in a development category identified and listed in Schedule 3 of *the Environmental Planning and Assessment Regulation 2000*.

Diversity – variety of life forms (biodiversity), natural physical features (geodiversity), water quality or hydrological regimes

Ecological Value – the natural significance of ecosystem structures and functions, expressed in terms of their quality, rarity and diversity. Significance can arise from individual biological, physical or chemical features or a combination of features.

Function (natural) – the biological, chemical and physical processes that take place within an ecosystem (e.g. carbon cycling, erosion, nutrient assimilation).

Floodplain – land that is adjacent to waterways (and includes the riparian zone) and is subject to flooding (typically at recurrence intervals of up to 100 years).

Geomorphology (fluvial) – the physical structures, processes and patterns associated with waterway systems – including landforms, soils, geology and the factors that influence them.

GPT – Gross Pollutant Trap.

Habitat – the biophysical media (such as sand and water) able to be occupied by organisms.

Health (of creeks) – the ability of a creek to maintain natural structures and functions over time, and the degree of similarity to unimpacted creeks of the same type (naturalness).

Hydrology – patterns of stream flow.

Imperviousness – the measure of a substance's inability to allow fluids to pass through.

LEP – Local Environmental Plan.

LGA – Local Government Area.

NULS – Non-Urban Lands Study.

Protected Areas – areas designated as conservational or park reserve or National Park under state or local government administration.

Riparian Zone – any land which adjoins, directly influences, or is influenced by a body of water. The width of the zone varies according to extent of riparian vegetation, flood levels, water quality, and channel form.

Riparian Buffer – an area of land which is additional to the riparian zone, necessary to protect the values and health of the riparian zone.

SEPP5 – NSW State Environmental Planning Policy NO. 5 – Housing for Older People or People with a Disability.

Structure (natural) – the site-specific biophysical characteristics of a creek system (e.g. channel form, species composition, soil, hydrology); synonymous with 'features' or 'patterns'.

Sustainability – the ability of ecosystems to maintain their natural structural and functional integrity in response to perturbations.

Water Sensitive Urban Design (WSUD) – a form of urban development which aims to enhance waterways and conserve water (e.g. by reducing peak flows and pollutants using rainwater tanks, infiltration areas, grass drainage systems, artificial wetlands).

Appendix A

Study Methodology

Warringah Council
Creek Management Study - Appendix A

Contents

List Of Tables

1. Information and Consultation

Information collected from Council, library and Internet searches and that available through the reference collections of the MWH team was collated and comprehensively reviewed. A consultation program was also undertaken to enhance the existing knowledge base and identify community issues (Table 1).

Table 1: Details of the Warringah Creek Management Study Consultation Program

Target Groups	Activity	Timing	Purpose	Outputs
Project Manager and key Council staff	Project inception meeting	On appointment	To ensure a mutual understanding of the conduct of the study and obtain information to be provided by the Council	Meeting minutes and list of actions
	Council progress and review meetings	As required	To discuss progress and emergent issues	Meeting minutes and lists of actions
Relevant sections of Council and government agencies	Workshop	On completion of review of existing information and identification of gaps in existing data	To identify issues, and obtain details of relevant policies and programs in place now and planned	List of issues for consideration, policy and program outlines and references to relevant documents
Community reference group	Workshop	On completion of review of existing information and identification of gaps in existing data	To inform key community groups of the study and identify issues of concern	List of issues raised for consideration and any responses given
Wider community	Media release	On completion of review of existing information and identification of gaps in existing data and initial workshops with Council and government agencies and community reference group	To inform of study and key issues to be addressed and to advise of the availability of a 1800 phone number for inputs	Media release, logs and notes from all calls received on the 1800 throughout study

Target Groups	Activity	Timing	Purpose	Outputs
Relevant sections of Council and government agencies	Risk Assessment Workshop	During the definition of actions required to achieve potential state	To inform of study progress and findings and identify critical issues	Critical issues for rehabilitation, remediation or restoration of reaches for examination of costs and benefits
Community reference group	Workshop	During the definition of actions required to achieve potential state	To inform of study progress and findings and identify emergent issues	List of issues for further consideration
Council, Project Manager and key staff	Presentation of draft study	On completion of draft study	To inform Council and staff of the study findings	Meeting minutes and list of issues raised for further consideration
Community reference group	Distribution of draft study to CRG members	On completion of draft study	To inform CRG of the study findings	List of issues for further consideration
Wider community	Public Advertisement and media release	On completion of draft study (One week prior to open day)	To inform of study and key findings and advise of locations of open day presentations	Media release
	Open day	As agreed with Project Officer	To present findings of the study and recommended options and strategies and to obtain community feedback	Written response forms and compilation of responses, notes from discussions with individuals
	Public advertisement and media release	At commencement of public exhibition	To inform of study and final opportunity for community input	Advertisement and media release
	Public Exhibition and brochure	As agreed with Project Officer subsequent to open day	To present findings of study, obtain community feedback and set the scene for community involvement in implementation	Poster, brochure, website material and written and telephone responses log for consideration and inclusion in an Appendix to the final report
Council, Project Manager and key staff	Discussion of comments received from community	Subsequent to public exhibition	To review comments received and agree on final amendments to report	List of changes to be made before report is finalised

The following sections detail the specific approaches adopted for the Creek Management Study.

2. Identifying Creek and Riparian Management Boundaries

It is acknowledged that while options for the management of a particular creek or reach will rely predominantly on existing and potential future values and risks, they should also be considered within the context of creek behaviour and character and the waterway's functional interaction and dependence on adjacent land. Therefore, the first step to assessing the existing characteristics of each creek was to identify creek styles and riparian management boundaries.

2.1 Creek Styles

The method used to assess creek behaviour and character in the study is a simplification of the River Styles® Framework [Note: River Styles® is a registered trademark owned by Macquarie Research Ltd and Land and Water Australia, which has been developed by Associate Professor Gary Brierley, and Ms Kirstie Fryirs, Macquarie University, Sydney NSW 2109, Australia]. The basic approach is to categorise different creeks, or reaches within a creek, according to geomorphological characteristics. The explanatory and predictive bases of the catchment-framed approach to analysis of River Styles®, and interpretation of controls and their downstream patterns provide a rigorous physical basis for river management decision making.

The Warringah Creek Management Study is the first study in which River Styles® has been adapted to act as a component of a larger study. While the basic principles of the River Styles® framework have been used in this study, certain omissions have been made on the basis that: a) They did not fit within the objectives of the study or b) they were deemed unnecessary given the timeframe for project completion.

The following components of the original River Styles® Framework were omitted from the Warringah Creek Management Study:

- Detailed proformas documenting various attributes of each River Style;
- Detailed planform maps showing the 'typical' pattern of geomorphic units that characterise each River Style;
- Valley wide cross-section surveyed for a representative reach of each River Style;
- Measurement of dimensions and geometry of representative geomorphic units for each River Style, and associated assessment of the biophysical linkages of these geomorphic units;
- Interpretation of the geomorphic processes responsible for each geomorphic unit and their associated mosaics of forms along reaches of each River Style;
- Estimation of 'Mannings n' of channel and floodplain zones;
- Measurement of bed material size (whether sand, gravel or clasts); and
- Assessment of evolutionary timeslices for each River Style, and associated interpretations of the recovery potential of differing reaches in the catchment.

Despite these limitations, the basic structure of the assessment is consistent with those adopted for River Styles® reports elsewhere. A.Prof. Gary Brierley, co-developer of the River Styles® framework, reviewed the methods adopted in this study.

Following procedures outlined in *Classification and Analysis of River Processes* (Kellerhals R, Church M and Bray D, 1976 - *Journal of the Hydraulics Division.* American Society of Engineers. Vol.102 HY7, pp 813-829.) and applied within the River Styles® framework, basic river style boundaries were determined using air photographs. In the first instance, these boundaries are based on valley setting, which defines the presence/absence, continuity and character of floodplains along river courses. Depending on whether the valley setting is confined partly confined, or alluvial, distinct arrays of River Styles may be discerned. Verification of the mapping was undertaken during field assessment of ecological and social characteristics (See Section 3). Following fieldwork each site was assessed and assigned a River Style based on valley setting, floodplain and channel characteristics, texture, and geomorphic units. The River Style boundaries identified initially were then amended where necessary and all data was entered into the project GIS data base to allow final maps to be produced. Appendix G provides a summary analysis of river styles in Warringah.

2.2 Riparian Zones and Riparian Buffers

The delineation of the riparian zone was first attempted during the field assessments (see Section 3) based on geomorphology, catchment position and the presence of plant species known to be common to riparian zone areas. When the study team was confident that the features and vegetation identified in the field constituted an accurate riparian zone boundary, riparian boundaries were noted on the catchment map.

However, as most of the sites had experienced disturbance to vegetation and channel morphology, delineation on the ground was not an accurate measure of riparian zone extent. Given these difficulties and the lack of accurate information pertaining to flood inundation lines, it was necessary to establish approximate riparian zone and buffer boundaries by examining lateral slope, vegetation density and type (using detailed stereo aerial photograph interpretation) in combination with the methodology outlined in 'Estimating the extent of riparian zones and buffers – A discussion paper' (MWH, 2001 – See Appendix D). Once this boundary was established it was checked against enlarged aerial photographs on Warringah Councils' database to ensure no obvious mistakes had been made.

[Note: Riparian zone and riparian buffer delineation is displayed on sub-catchment maps in Appendix B].

2.3 Delineating Management Units

Once creek styles and riparian buffers were identified, management units were assigned based on the following criteria in order of importance:

1. **River Styles**: Each individual River Style reach has uniform characteristics and behaviour and, therefore, provides an ideal tool on which to base the longitudinal

boundary of management units. Lateral boundaries should coincide with riparian buffers.

2. **River Condition**: This was imposed onto the River Styles template. Although an individual River Styles reach has relatively uniform characteristics and behaviour, if it exhibits varying condition, then it requires varying management. River condition was determined by comparing the relevant reach to a benchmark site in a similar catchment setting (ie: tributaries of Deep Creek and upper Wheeler Creek). The benchmark site is chosen on the basis that it is considered to be in the best condition attainable for a creek given the prevailing catchment conditions (e.g. influence of urbanisation, change to flow regime, land use change etc).
3. **Land tenure/Land use**: This was considered when assigning management units as management is effected by land ownership and land use.

3. Assessing Existing Creek Characteristics

Following a review of available information on the existing condition of creeks within the Warringah LGA, field assessments were conducted on representative reaches to assess geomorphological, ecological and social characteristics and possible threats as a basis for determining environmental values and risks.

3.1 Site selection

Using a map showing the distribution of River Styles as a template, eligible sites for field assessments were selected to ensure an even and representative spread of sites across the study area. Access was a consideration in selection of these sites. Using the SEA database at Warringah Council, each site was then examined in greater detail to confirm representativeness and collect information regarding vegetation, land tenure and the location of pits and pipes.

A total of 35 sites were selected for ecological and geomorphic examination in the field (Table 2).

Table 2: Sites Selected for Field Assessments

Catchment	Sub-Catchment	Reach	Site Location
Cowan	Kierans Creek	Kierans Creek Tributary	Aumuna Road
		Neverfail Gully	Coolowie Road
	Duffys Forest	Duffys Creek	Booralie Road
Dee Why	Dee Why Creek	Dee Why Creek	Campbell Avenue
Manly Lagoon	Burnt Bridge Creek	Burnt Bridge Creek	Corner of Eileen and Worrobil Street
		Burnt Bridge Creek Tributary	Birrima Crescent
	Manly Creek	Manly Creek	David Thomas Reserve
	Curl Curl Creek	Curl Curl Creek	Manly Warringah War Memorial Park
	Brookvale Creek	Brookvale Creek	Warringah Golf Course
			Owen Stanley Avenue
			Doulton Avenue
Middle Harbour	Bantry Bay	Northern Tributary	Forestville Park
	Carroll Creek	Carroll Creek	Merrilee Crescent
		Carroll Creek Tributary	Prahran Avenue
	Bare Creek	Bare Creek	Narabang Way
Narrabeen Lagoon	Middle Creek	Snake Creek	Corner of Morgan Road and Hillversum Crescent
		Oxford Creek	Corner of Oxford and Morgan Roads
			At Falls
		Middle Creek Tributary	Dreadnought Road

Catchment	Sub-Catchment	Reach	Site Location
		Middle Creek	Carnarvon Road
			Dreadnought Road
			Oxford Falls
			Wakehurst Parkway Bridge
			Wakehurst Parkway Side Road
	South Creek	Wheeler Creek	Maybrook Manor
			Little Willandra Road
		South Creek	Lillihina Avenue
			Willandra Road (upstream)
			Willandra Road (downstream)
			Carcoola Road
			Kirkstone Road
	Deep Creek	Deep Creek Tributary (West Branch)	South of National Park
		Deep Creek Tributary (East Branch)	
	Narrabeen Lagoon	Narrabeen Lagoon Tributary	James Wheeler Parade
Collaroy	Collaroy	ANZAC Avenue Reserve	Corner of Hendy Avenue and Kent Street

3.2 Pre-field analysis

Before the commencement of fieldwork, baseline data was collected for each site using the SEA database at Warringah Council, 1:4,000 aerial photographs and 1:10,000 topographic maps. This included:

- Approximate locations for River Styles boundaries;
- Calculation of upstream catchment area;
- Calculation of channel slope; and
- Identification of vegetation units.

3.3 Field Analysis

The following tasks were undertaken in the field:

1. Whenever practicable, River Styles boundaries were ratified in the field.

2. An assessment of geomorphic characteristics was conducted at each site to determine river character. This included examination of:

- The number of channels;
- Sinuosity;
- Lateral stability (the capacity of a river to adjust its position on the valley floor);
- Bed/bank material texture (assessed in summary classes, gravel, sand, mud);

- Instream geomorphic units (e.g. pools, runs, cascades, bars, etc); and
- Floodplain geomorphic units (e.g. levees, floodchannels).

3. An assessment was made of overall channel functioning to determine various attributes of river behaviour, this included an examination of:

- The presence and location of erosion and deposition;
- Bank height and shape;
- Channel width;
- The diversity and connectivity of geomorphic units (ie: are the geomorphic units present at the site appropriate for the valley setting and position within the catchment?);
- Riparian zone width, density and composition;
- Density and composition of other vegetation adjacent to site;
- The effect of anthropogenic structures (ie: weirs, culverts, retention basins, GPTs);
- The effects of urbanisation (ie: increased runoff, proximity to houses, modifications of channel, weed infestation etc); and
- Evidence for active channel-floodplain connectivity and interaction.

4. An assessment was made of various ecological values associated with the channel, floodplain, riparian zone and adjacent area. The following attributes were examined[*]:

- Naturalness - The degree to which the current state of a waterway reach differs from its natural state;
- Representativeness - In comparison with similar creeks in the district/region, is the creek a good example of a typical (and natural) system?;
- Diversity - The diversity of observed natural plant species/communities and records of any fauna species. (**Note: biodiversity is a very broad concept, and this narrow definition reflects the probable lack of comprehensive information**);
- Rarity - How rare or unusual are the species, communities, habitat, geomorphology, hydrology or chemistry?; and
- Special Features - Does the waterway have significant biological, chemical or physical features or processes?

5. An assessment was made of various social values associated with the waterway. The following attributes were examined:

- Landscape – Does the creek add to the scenic amenity of the area from adjacent housing or transport routes (roads, pathways)?;
- Instream Recreation – Is there evidence of the creek having value for swimming, boating, fishing or nature studies?; and

[*] These criteria are in common use in a number of ecological value methods in Australia and internationally. The method used provides reasonable assessments of each criterion based on limited data (especially for the tributaries) plus field observations. Threshold values for the classes for each criterion were set out so that objectivity was maintained and the process was repeatable.

- Offstream Recreation – Is there evidence of the area adjacent to the creek having value (where the creek enhances or supports the recreation) for walking, running, cycling, picnics or BBQs?

6. An assessment was made of the whole creek environment to determine environmental risk. The following categories were examined:

- Water quality;
- Riparian and aquatic area biodiversity;
- Adjacent natural area biodiversity;
- Weed encroachment;
- In-stream fauna health;
- Sedimentation;
- Erosion;
- Solid waste and leachates; and
- Safety.

NB: River Styles and Ecological Values pro-formas were completed for each site. This information is summarised in Appendix B.

3.4 Water Quality

In addition to the field assessments outlined above, a single water quality sampling round was conducted in late November to provide snapshot data. A total of 21 sites were selected for water quality sampling as follows:

1. Curl Curl (upper Manly) Creek, upstream of Manly Dam (Manly Dam Reserve);
2. Brookvale Creek, upstream of Warringah Mall (Allenby Park);
3. Middle Creek @ Carnarvon Drive (near Peppercorn Park, Frenchs Forest);
4. Middle Creek tributary @ Dreadnought Road (near Oxford Falls Grammar School, Oxford Falls);
5. Upper Snake Creek @ Morgan Road (near corner of Hilversum Crescent, Belrose);
6. Deep Creek tributary (East branch) @ Madang Road (Belrose);
7. Deep Creek tributary (West branch) @ Madang Road (Belrose);
8. Deep Creek tributary @ Kimbricki Road or Kamber Road (near Kimbriki Recycling and Waste Disposal Centre, Ingleside);
9. Bare Creek @ Narabang Way (Belrose);
10. Frenchs Creek @ Pringle Avenue (opposite Hews Parade, Belrose);
11. Carroll Creek tributary @ PrahRan Avenue (below GPT, Sorlie);
12. Bantry Bay tributary @ Pildra Place (near Forestville Park, Forestville);
13. Kierans Creek @ Aumuna Road (South of Larool Road, Terrey Hills);
14. Kierans Creek tributary @ Birramil Road (near swamp, Duffys Forest);

15. Kierans Creek tributary @ Kulgoa Crescent/Kulgoa Drive (Terrey Hills);
16. Neverfail Gully @ Aumuna Road (near Kinma School, Terrey Hills);
17. Wheeler Creek @ Maybrook Avenue (50m upstream of development, Cromer);
18. Wheeler Creek @ Maybrook Avenue (50m downstream of development, Cromer);
19. Duffys Creek @ Joalah Road (near Rho-ker Reserve, Duffys Forest);
20. Waterfall Gully @ Killawarra Road (Duffys Forest); and
21. Creek @ Yanderra Road (Duffys Forest – near Terrey Hills Golf Club).

A range of water parameters was measured to assess the water quality at each site. Following collection, the samples were transported to a NATA registered laboratory for analysis. Analyses were conducted by Australian Laboratory Services (ALS), Sydney on the following parameters:

- Total nitrogen;
- NOx (nitrate & nitrite);
- Total phosphorus;
- Reactive phosphorus (ortho-phosphate);
- Biological oxygen demand;
- Total suspended solids; and
- Faecal coliforms.

4. Determining Environmental Values

4.1 Current Values

The types of data collected during the field survey to assess creek characteristics facilitated assessment of current and potential environmental values. The criteria listed in Section 3.3 were used to review the data and ascribe and discuss ecological and social values, with each criterion given a rating from 1 to 5 (i.e. 1=low, 5=very high). For each site, overall values for ecology, landscape and recreation were calculated as the average rating from the respective criteria. This formed the basis for ascribing overall values for each sub-catchment (or reaches within a sub-catchment – eg. upper, middle, lower).

A desk-based assessment of cultural heritage values was also undertaken to determine, from existing records, the nature of the archaeological resource within Warringah. Refer to Appendix C for an outline of the methodology.

4.2 Desired Values

Desired future values were assessed by:

- Interviewing members of community groups involved in creek management (e.g. restoration projects);
- Reviewing Council documentation, such as LEP 2000 and plans of management for Council reserves;
- Reviewing stakeholder reports, such as stormwater management plans;
- Discussions with members of the Community Reference Group; and
- Recording community feedback to newsletters via written correspondence and comments via the free phone line.

5. Risk Assessment

Risk assessment was used to identify and characterise threats to creek values. For each sub-catchment, possible risks were identified through:

- consultation with government agencies, Council officers, the CRG and a range of other stakeholders; and
- documentation, including the LEP (future land use changes), plans of management, potential SEPP 5 and land release areas, NULS, stormwater management plans, water quality monitoring reports.

In addition, the types of data collected during the field survey to assess creek characteristics facilitated assessment of current and potential environmental risk. The criteria listed in Section 3.3 were used to review the data and ascribe and discuss environmental risks. For each criterion, the overall risk is a combination of the negative consequences (impacts) and the likelihood of occurrence, with each assigned a rating from 1 to 5 (i.e. for consequence 1=insignificant, 5=catastrophic; for likelihood 1=rare, 5=almost certain/currently occurring). The scores are multiplied and the result is proportional to the overall risk. For each site, the criterion with the highest overall risk was identified as the major threat to environmental values.

Appendix B

Sub-catchment Summaries

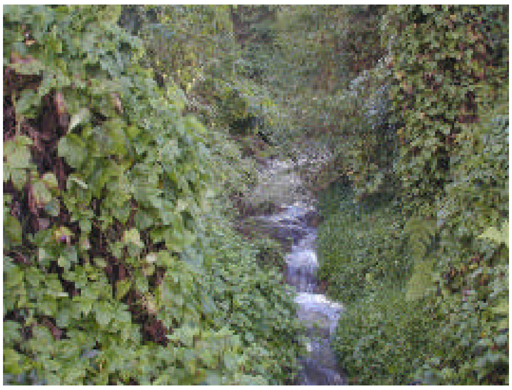
Contents

List of Figures

Appendixes

1. Kierans Creek

The main channel of Kierans Creek flows west through Ku-ring-gai National Park, with several major tributaries originating in the south-eastern areas of Terrey Hills and Duffys Forest (Figure B1.1). These reaches are characterised by steep, confined headwaters with occasional floodplain pockets (Figure B1.2). The sub-catchment (including the National Park) covers an area of approximately 1450 ha, which is < 10% impervious. The predominant land use in Terrey Hills and Duffys Forest is urban/rural and rural settlements, respectively, although significant areas of bushland still exist outside the National Park.



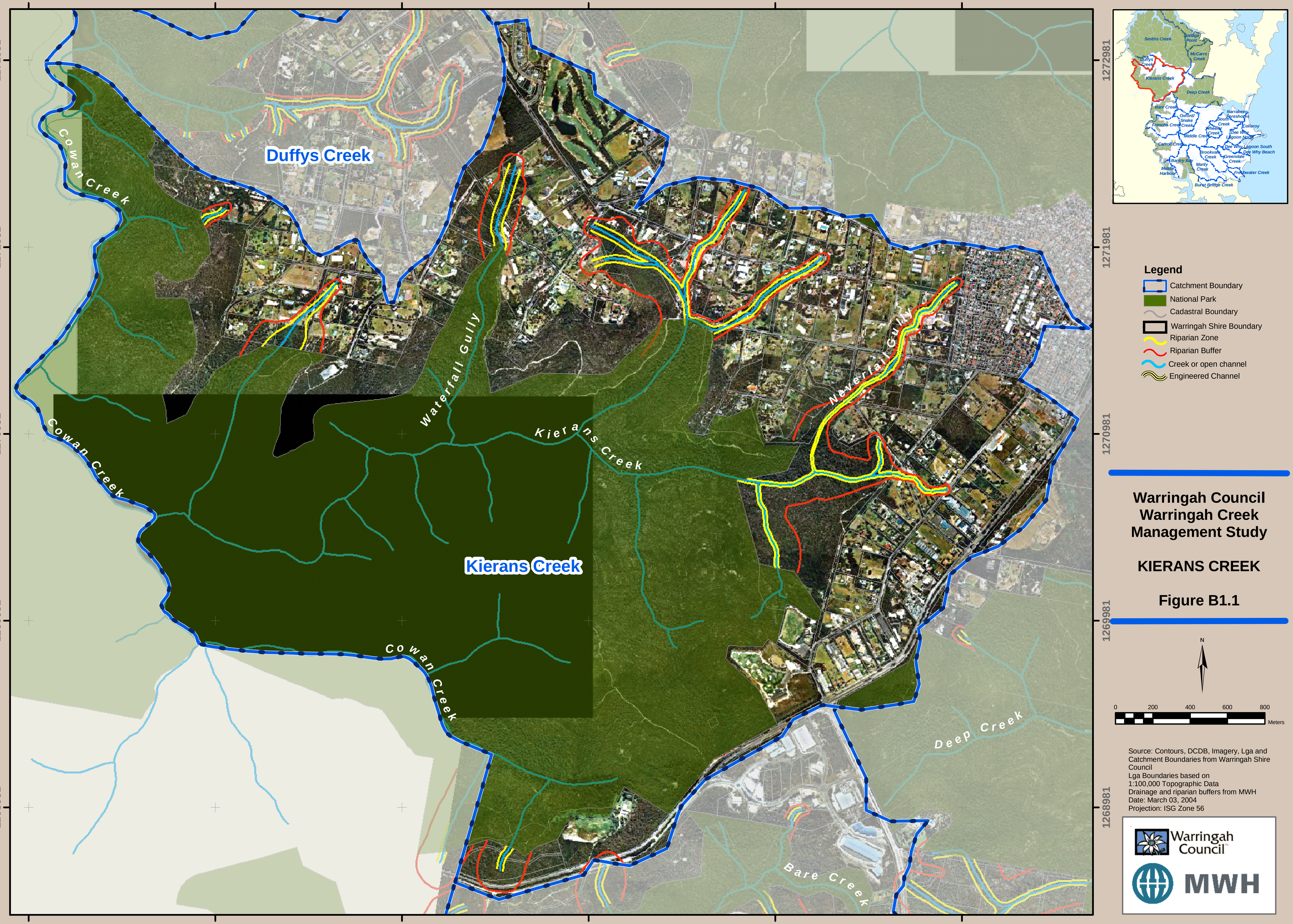
Kierans Creek near Aumuna Road

Kierans Creek near boundary of Ku-ring-gai National Park

1.1 Values (outside the National Park area)

The non-urban land within the Kierans Creek sub-catchment has previously been identified as having moderate habitat conservation value and high visual value (Warringah Council, 1998a and 1998b). Along the creek line, native species diversity, habitat value and landscape value is high immediately upstream of the National Park, with areas of good connectivity and retention of natural vegetation. There is also quality refuge habitat for native fauna affected by landscape alteration and a high potential for terrestrial species dispersal.

Ecological and landscape values decrease further upstream (adjacent to urbanised and rural-residential areas) where riparian vegetation is mostly exotic and native fauna habitat is relatively poor. Members of the Dundundra Falls Reserve community group are currently undertaking bush regeneration activities to improve this situation. Values associated with recreation are also low throughout the sub-catchment and locals have expressed the desire for safer water quality to enable swimming downstream.



Warringah Council
Warringah Creek
Management Study

KIERANS CREEK

Figure B1.1

Source: Contours, DCDB, Imagery, Lga and Catchment Boundaries from Warringah Shire Council
Lga Boundaries based on
1:100,000 Topographic Data
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council
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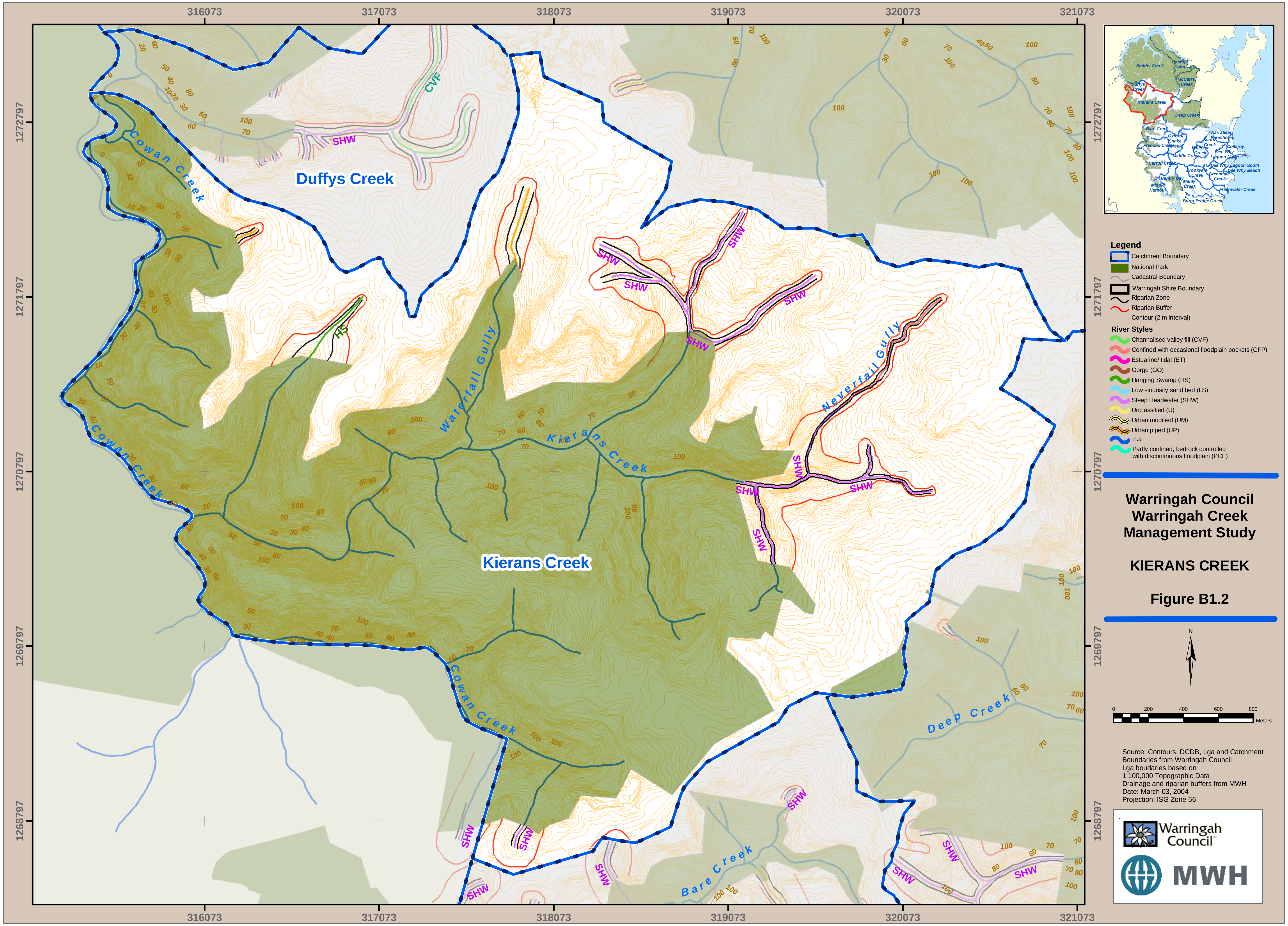
Duffys Creek
Kierans Creek
Cowan Creek
Waterfall Gully
Neverfail Gully
Deep Creek
Bare Creek
SHW
CVF
HS
Legend
Catchment Boundary
National Park
Cadastral Boundary
Warringah Shire Boundary
Riparian Zone
Riparian Buffer
Contour (2 m interval)
River Styles
Channalised valley fill (CVF)
Confined with occasional floodplain pockets (CFP)
Estuarine/ tidal (ET)
Gorge (GO)
Hanging Swamp (HS)
Low sinuosity sand bed (LS)
Steep Headwater (SHW)
Unclassified (U)
Urban modified (UM)
Urban piped (UP)
n.a
Partly confined, bedrock controlled with discontinuous floodplain (PCF)
Warringah Council
Warringah Creek
Management Study
KIERANS CREEK
Figure B1.2
0 200 400 600 800
Meters
Source: Contours, DCDB, Lga and Catchment Boundaries from Warringah Council
Lga boudaries based on
1:100,000 Topographic Data
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56
Warringah Council
MWH

1.2 Water Quality

From the water quality sampling program undertaken as part of this study, sites within the Kierans Creek sub-catchment recorded some of the highest suspended solids, total nitrogen and total phosphorus concentrations. This included the reach near Aumuna Road (which recorded the highest total nitrogen and total phosphorus concentrations of all sampling sites) and a tributary near Birramil Road. Concentrations of suspended solids and nutrients were lower downstream of Kulgoa crescent and within Neverfail and Waterfall Gullies, although guidelines for total nitrogen were still exceeded. The guideline for biologically available (i.e. dissolved) nitrogen was also exceeded at most sites, while dissolved forms of phosphorus were undetectable at all sites. Faecal coliform counts indicate that Kierans Creek is suitable for primary contact recreation, with the exception of the tributary near Birramil Road. This site also recorded a relatively high concentration of biological oxygen demand, suggesting the presence of excess organic matter.

A significant source of high pollutant concentrations within the sub-catchment is likely to be contaminated effluent from on-site wastewater systems. Many of these systems have only rudimentary treatment capability and rely on soil infiltration for removing some of the pollutants. Those that are not regularly maintained or in which the disposal area is too small can result in surface flows of effluent that can directly enter drainage lines or creeks. The risk is greatest during rain events when surface runoff and hydraulic overload of systems can occur. Older household systems in particular produce effluents of relatively poor quality.

Other sources of pollutants are stormwater runoff from the urban area of Terrey Hills and rural activities within Duffys Forest. The latter include animal husbandry, nurseries and landscape suppliers and although there is likely to be limited impact from one site, the cumulative impacts can be significant. The result can be direct passage of nutrients, organics and pathogens to creeks. This may be particularly relevant for the tributary near Birramal Road.

1.3 Risks

The Kierans Creek sub-catchment is one of the major areas of weed infestation in the Cowan catchment, due possibly to its position immediately downstream of an urban area (Cowan Stormwater Management Plan Committee, 1999). According to local community groups, the extent of the weed problem is increasing beyond control. This is particularly noticeable in upstream areas where riparian vegetation is predominantly exotic, resulting in lower native species richness and a lack of native fauna habitat.

The other main community concerns for creeks in the area are high sediment and nutrient concentrations/loads that not only result in ecosystem changes and direct loss of habitat and, but can also facilitate weed and algal growth. Particularly problems appear to arise downstream of properties where land is cleared/filled on steep slopes and animals are kept in high densities (eg. riding schools).

Without adequate controls on development and effluent release, further increases in stormwater runoff and contaminated/high nutrient discharge are certain to accompany future urbanisation. This poses a serious threat for species, habitats and communities in downstream reaches, particularly within the National Park.

1.4 Recommendations

Members of the community have expressed their desire to eradicate the weeds, control development and increase the buffer zone around Ku-ring-gai National Park. It is acknowledged that staged weed eradication will be required in the more heavily infested areas (that provide a rich seed source) to reduce the likelihood of release to downstream reaches. Although this will improve the aesthetic value of the area and protect downstream reaches in the short-term, the most effective methods to address the long-term problems are likely to be improvements in sewage treatment, stormwater quality and site uses.

The following activities are recommended for the Kierans Creek sub-catchment:

- A Creek Management Plan should be prepared that is consistent with the Dundundra Falls Reserve Plan of Management.
- Improvements in sewage treatment should be sought through negotiations with the Sydney Water Corporation (SWC) to supply sewage reticulation to unsewered areas, particularly along Myoora Road.
- To address stormwater issues, it is recommended that a risk assessment be conducted of runoff from different land uses. Audits have already been performed for land uses likely to contribute high sediment and nutrient loads to the system (i.e. riding schools, landscape suppliers and nurseries) and overall, management practices appear to be improving.
- For construction sites, adequate sediment traps need to be fitted downstream and regularly maintained, while the proposed LEP amendments should be considered in evaluating proposals for future development in the upper reaches.
- In the longer term, Council needs to work with rural and commercial landholders to improve site management practices (eg. with incentive schemes, education, regulation and audit). Incentives could also be provided for upgrading on-site wastewater treatment systems to reduce nutrient and bacterial loads (eg. progressively replace septic tanks with aerobic sand filtration systems).

2. Duffys Creek

Duffys Creek is the main waterway within the Duffys Forest area that originates outside the boundary of Ku-ring-gai National Park (Figure B2.1). These headwaters are generally steep and confined, with occasional floodplain pockets (Figure B2.2). The sub-catchment area is approximately 220 ha and although < 10% impervious, there is a potential for high sediment loads and faecal coliforms in the creek system due to the informal table drainage system and predominantly rural land use in Duffys Forest.

2.1 Values (outside the National Park area)

The habitat conservation value of non-urban land within Duffys Forest has previously been identified as moderate (Warringah Council, 1998b). Along the Creek, native species richness and fauna habitat value is moderate to high immediately upstream of the National Park, with areas of good vegetation connectivity; quality refuge habitat from altered landscapes upstream and a high potential for terrestrial species diversity. The creek's waterfall is a special feature of high ecological and scenic value.

Further upstream, the natural system has been highly modified by clearing and the importation of fill for rural residential development. As a result, connectivity is relatively poor or non-existent, while values associated with recreation are moderate.

2.2 Water Quality

The water quality sample taken downstream of Rho-ker Reserve contained elevated concentrations of total nitrogen and biological oxygen demand, while total and dissolved forms of phosphorus were undetectable. Similar results were recorded downstream of the Terrey Hills Golf Course, although the concentration of biologically available (i.e. dissolved) nitrogen was also elevated and the concentration of total nitrogen was much higher. Only the site downstream of Rho-ker Reserve may be unsuitable for secondary contact recreation, as the faecal coliform count was at the upper guideline limit.

Significant sources of pollutants within the sub-catchment are likely to be contaminated effluent from on-site wastewater systems and runoff from rural activities within Duffys Forest. The latter may be particularly relevant for the site downstream of Rho-ker reserve, which is surrounding by numerous stud farms. The results also suggest that the Terrey Hills Golf Course may be contributing high nitrogen loads to sites immediately downstream.

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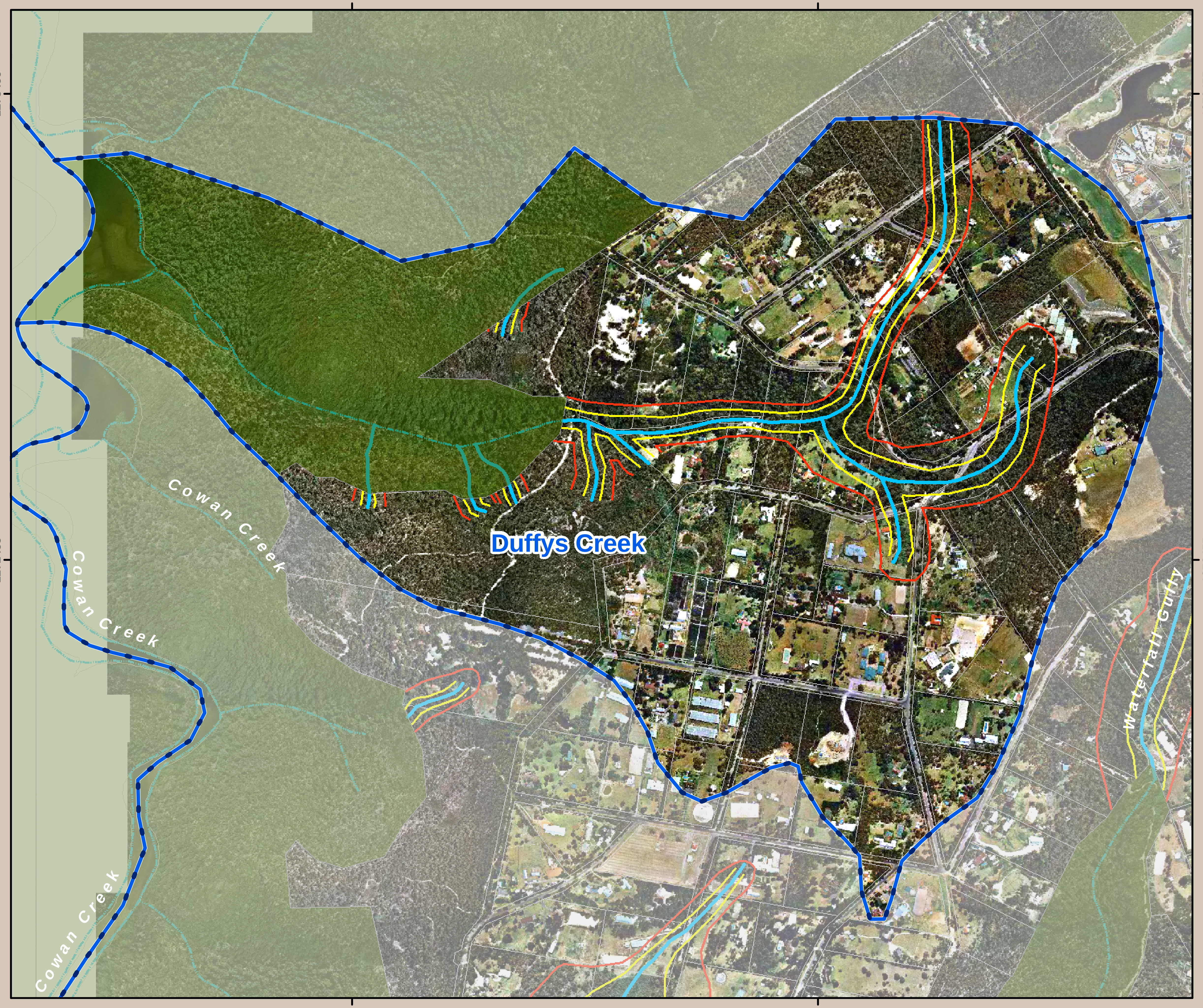

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek Management Study

DUFFYS CREEK

Figure B2.1

N

0 100 200 300 400 Meters

Source: Contours, Imagery, DCDB, LGA and Catchment Boundaries from Warringah Council
LGA Boundaries based on 1:100,000 Topographic data.
Drainage and riparian buffers from MWH
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Projection: ISG Zone 56

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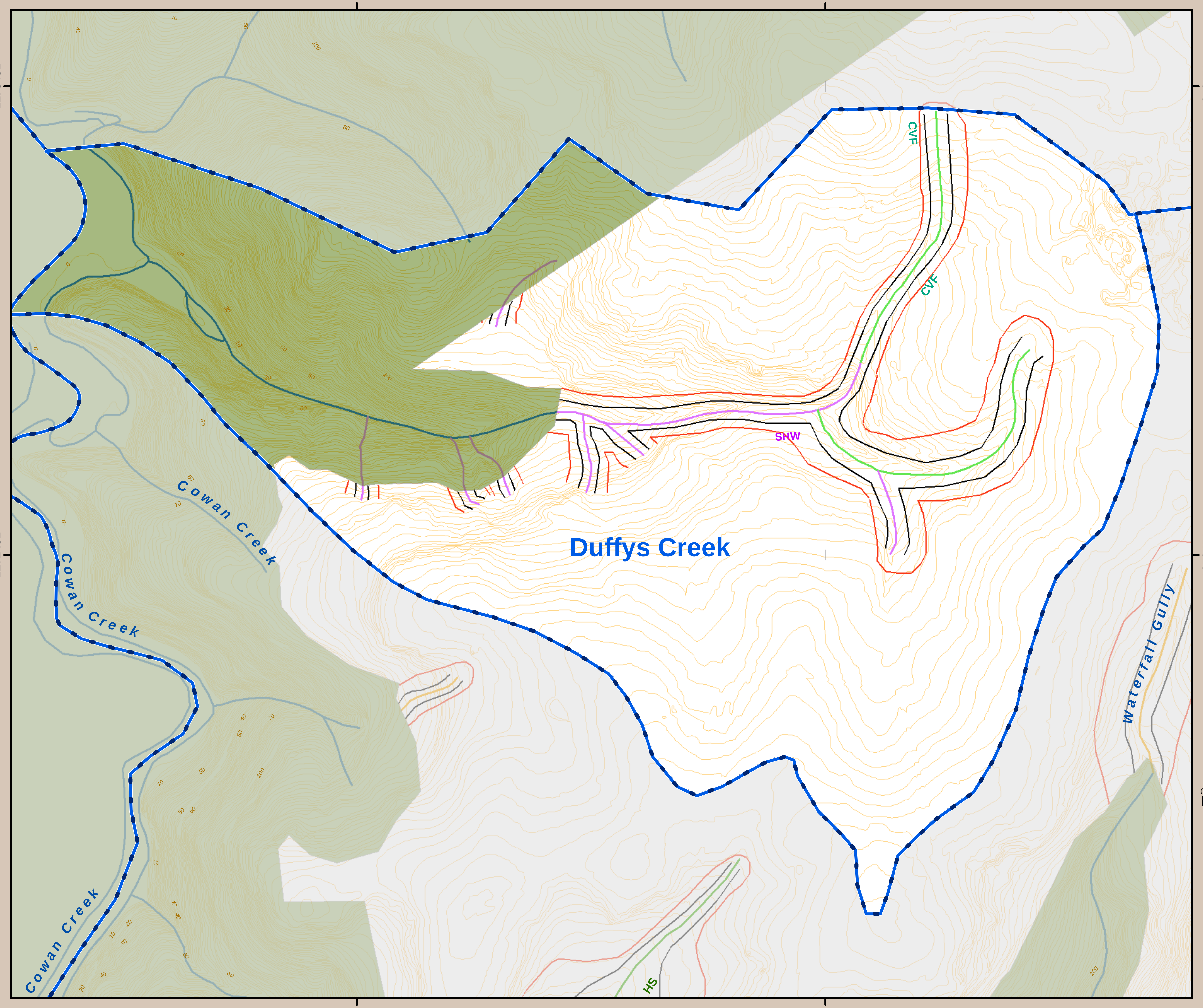

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek
Management Study

DUFFYS CREEK

Figure B2.2

N

0 100 200 300 400 Meters

Source: Contours, DCDB, LGA and Catchment Boundaries from Warringah Shire Council (Please note LGA Boundaries have been sourced from 100,000 Topographic data)
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council
MWH

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2.3 Risks

Duffys Forest is currently unsewered and runoff from rural properties (particularly where animals are kept in high densities) and the Terrey Hills Golf Club is a major concern amongst the community. In addition to water quality impacts, the informal drainage of these areas has the potential to transport weed propagates from landscaped gardens and increase sediment and nutrient loads within the creeks. The construction of weirs and dams in upstream areas has also interfered with fish passage, compromised natural habitat diversity and provided weed habitat.

Inadequate controls on future land use intensification (particularly on steep properties) and effluent release pose the major threat to the sub-catchment in terms of declining water quality and continued weed invasion. This is particularly concerning for downstream ecological communities within the National Park.

2.4 Recommendations

A new sub-division has been proposed for land previously owned by the Metropolitan Local Aboriginal Land Council (MLALC) on the western boundary of Duffys Forest (approximately 200 ha). The proposed LEP amendments should be considered in evaluating proposals for such future development, particularly in the upper reaches. In addition, members of the Duffys Forest community have suggested an amendment to the LEP to allow larger blocks (10-20 ha) to reduce the extent of land use intensification. The desirable size of allotments has not been analysed in this study, but the capacity of Duffys Creek to sustain further development is very limited and larger allotments is an important way to reduce impervious surface area.

The following activities are also recommended for the Duffys Creek sub-catchment:

- A Creek Management Plan should be prepared with particular reference to stormwater management and water sensitive urban design. A risk assessment should also be conducted of runoff from different land uses.
- Weed removal may be a realistic goal in the sub-catchment due to its limited size, although access may be an issue as many of the slopes are reasonably steep and rugged.
- An investigation into the location of weirs and dams is warranted, with respect to their impact on faunal movement and habitat diversity.
- In the longer term, Council needs to work with rural and commercial landholders to improve site management practices (eg. with incentive schemes, education, regulation and audit). Incentives could also be provided for upgrading on-site wastewater treatment systems to reduce nutrient and bacterial loads (eg. progressively replace septic tanks with aerobic sand filtration systems).

3. Greendale Creek

Greendale Creek is the main freshwater source to Curl Curl Lagoon and the Greendale Creek sub-catchment comprises the vast majority of the total Curl Curl catchment, with an area of approximately 480 ha (Figure B3.1). Apart from a natural area in the headwaters, the creek has been extensively modified (i.e. piped and channelised) following urban and industrial development in Brookvale. Downstream of the gross pollutant trap at Harbord Road, the creek flows through an alluvial floodplain within John Fisher Park before discharging into the Western section of Curl Curl Lagoon (Figure B3.2). This section has been cleared and used for landfill, with the creek channel being highly modified in the process. Land use is predominantly low-medium residential, and the sub-catchment is around 50% impervious.

Greendale Creek downstream of Harbord Road

Sediment Pond/Wetland Habitat on Greendale Creek

3.1 Values

Greendale Creek is best known in the lower reaches within John Fisher Park and immediately upstream of Curl Curl Lagoon. Though degraded by clearing, landfill and channelisation, extensive rehabilitation activities undertaken by the Curl Curl Lagoon Friends community group, state government and Council have improved recreational and scenic values, and to a lesser extent, habitat value. Upstream of the park, most of the area is within engineered channels or underground pipes. However, an important short reach occurs in the upper catchment above the former brickworks site. The riparian and catchment areas surrounding the creek have high conservation value and have been recommended for protection by community members.

3.2 Water Quality

The upper reaches of Greendale Creek are characterised by elevated concentrations of total nitrogen, dissolved nitrogen and total phosphorus, while suspended solids

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek
Management Study

GREENDALE CREEK

Figure B3.1

N

0 75 150 300 450 600
Meters

Source: Contours, Imagery, DCDB, Lga and
Cathcment boundaries from
Warringah Council;
Lga boundaries based on
1:100,000 Topographic data.
Drainage and riparian buffers from MWH
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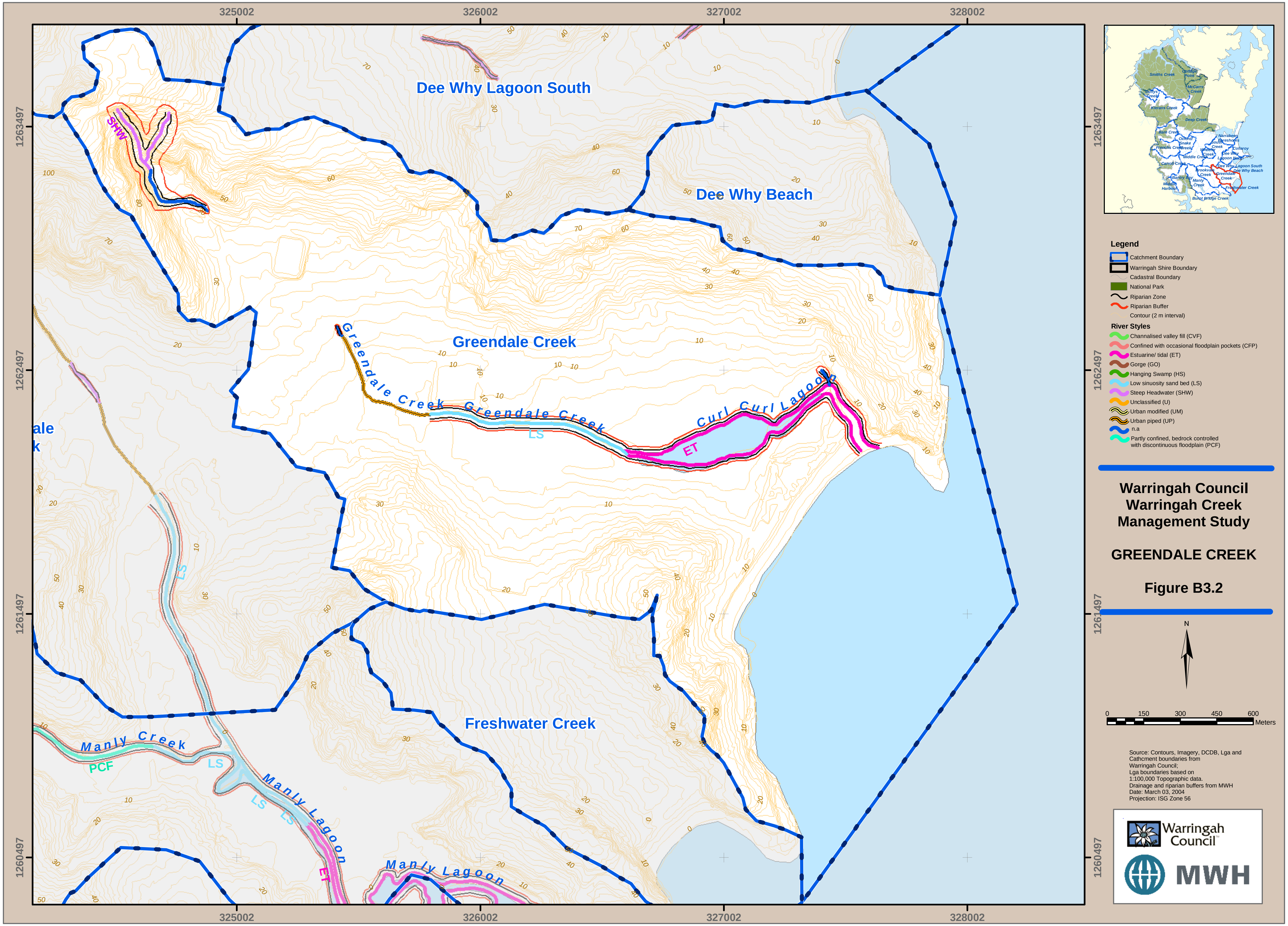

325002
326002
327002
328002
1263497
1262497
1261497
1260497
Dee Why Lagoon South
Dee Why Beach
Greendale Creek
Freshwater Creek
Greendale Creek
Curl Curl Lagoon
LS
ET
SHW
Manly Creek
PCF
Manly Lagoon
Legend
Catchment Boundary
Warringah Shire Boundary
Cadastral Boundary
National Park
Riparian Zone
Riparian Buffer
Contour (2 m interval)
River Styles
Channalised valley fill (CVF)
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Low sinuosity sand bed (LS)
Steep Headwater (SHW)
Unclassified (U)
Urban modified (UM)
Urban piped (UP)
n.a
Partly confined, bedrock controlled with discontinuous floodplain (PCF)
Warringah Council
Warringah Creek
Management Study
GREENDALE CREEK
Figure B3.2
N
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Meters
Source: Contours, Imagery, DCDB, Lga and Cathcment boundaries from Warringah Council;
Lga boundaries based on 1:100,000 Topographic data.
Drainage and riparian buffers from MWH
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MWH
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concentrations are relatively low (Laxton, 2000). Concentrations of suspended solids, total nitrogen and total phosphorus increase downstream of Harbord Road, although dissolved nitrogen levels decrease (Laxton, 2000). Dissolved phosphorus concentrations are below the recommended guidelines in both the upper and lower sections (Laxton, 2000). Faecal coliform counts suggest that the Creek is suitable for secondary contact recreation.

The most likely source of pollutants within the sub-catchment is stormwater runoff from the urban and industrial areas within Brookvale. However, the infiltration of leachate from previous landfill sites downstream of Harbord Road may be contributing to higher pollutant concentrations within the lower reaches.

3.3 Risks

The major environmental issue associated with Greendale Creek is poor water quality resulting from inadequate stormwater treatment. For example, whilst the majority of stormwater runoff from adjacent playing fields and the predominantly impervious urban and industrial areas upstream is directed into the system (approximately 35 stormwater pipes are known to discharge into the creek) water quality improvement devices currently serve less than 50% of the sub-catchment (Warringah Council, 2000e). In addition, leachate from former landfill areas surrounding John Fisher Park has infiltrated the groundwater system, while the landfill areas themselves have decreased the quality of habitat for native wildlife.

Although the system is already highly degraded and the consequence of future risks is considered low, continuing contamination from inadequately treated stormwater and landfill leachate would nullify rehabilitation efforts and may eventually destroy important habitats within Curl Curl Lagoon itself.

Another threat is the proposed development of the brickworks site downstream of the high ecological value areas in the upper catchment. Specific concerns are edge effects and weed encroachment into the natural areas, as well as water quality downstream.

3.4 Recommendations

Continuing rehabilitation activities, including the re-introduction of native grasses, is desirable, while recognising that the high level of resources applied in the recent past may be reduced as the main focus becomes maintenance. Improvements in stormwater treatment, particularly the introduction of source controls in the upper catchment and more intensive maintenance of existing GPT(s), will also be required if revegetation strategies are to coincide with improvements in water quality.

The following activities are also recommended for the Greendale Creek sub-catchment:

- Development of the upper catchment should be strictly controlled to protect the small natural area that remains. This will include consideration of the proposed LEP amendments in evaluating development proposals in the upper reaches;

- Further development in the lower catchment (including impervious surfaces) should be limited within the riparian zone. In addition, investigations should be conducted into the costs and benefits of options to intercept and/or treat landfill leachate entering the creek downstream.

4. Dee Why Creek

The Dee Why Creek sub-catchment (also known as the Dee Why Valley or the Dee Why Lagoon North sub-catchment) covers an area of approximately 300 ha and is over 50% impervious. The non-tidal section of Dee Why Creek has been modified by residential development, while downstream of Pittwater Road, the system flows through a Wildlife Refuge before discharging into the western side of Dee Why Lagoon (Figures B4.1 and B4.2). Most of the main channel has been cleared and channelised with only a small area of wetland and a short natural reach remaining. Numerous water quality improvement devices are located within the sub-catchment, including an in-stream gross pollutant trap at Campbell Avenue.

Dee Why Creek concrete channel below Cambell Avenue

Dee Why catchment revegetation, Fisher Road

4.1 Values

Dee Why Creek (upstream of Pittwater Road) has very low ecological value, with no retention of native riparian species and little habitat availability. The highest ecological values are associated with the short reach downstream of Pittwater Road and the wetland. The sub-catchment as a whole has potential as an important wildlife corridor, linking the coastal areas of Dee Why and the Collaroy Plateau with Garigal National Park in the North, via the Dee Why Valley/South Creek system (Clouston report, 1996). Recreational and landscape values are moderate in the lower reaches where the concrete channel is limited to the invert and the surrounding banks are partially treed.

4.2 Water Quality

The upper reaches of Dee Why Creek are characterised by elevated concentrations of total nitrogen, total phosphorus and dissolved phosphorus (Laxton, 2000). Suspended solids concentrations are also high relative to other sub-catchments, while the

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Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek Management Study

DEE WHY LAGOON NORTH

Figure B4.1

N

0 50 100 200 300 400 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Please note that Lga boundaries have been sourced from 1:100,000 Topographic data.
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council
MWH

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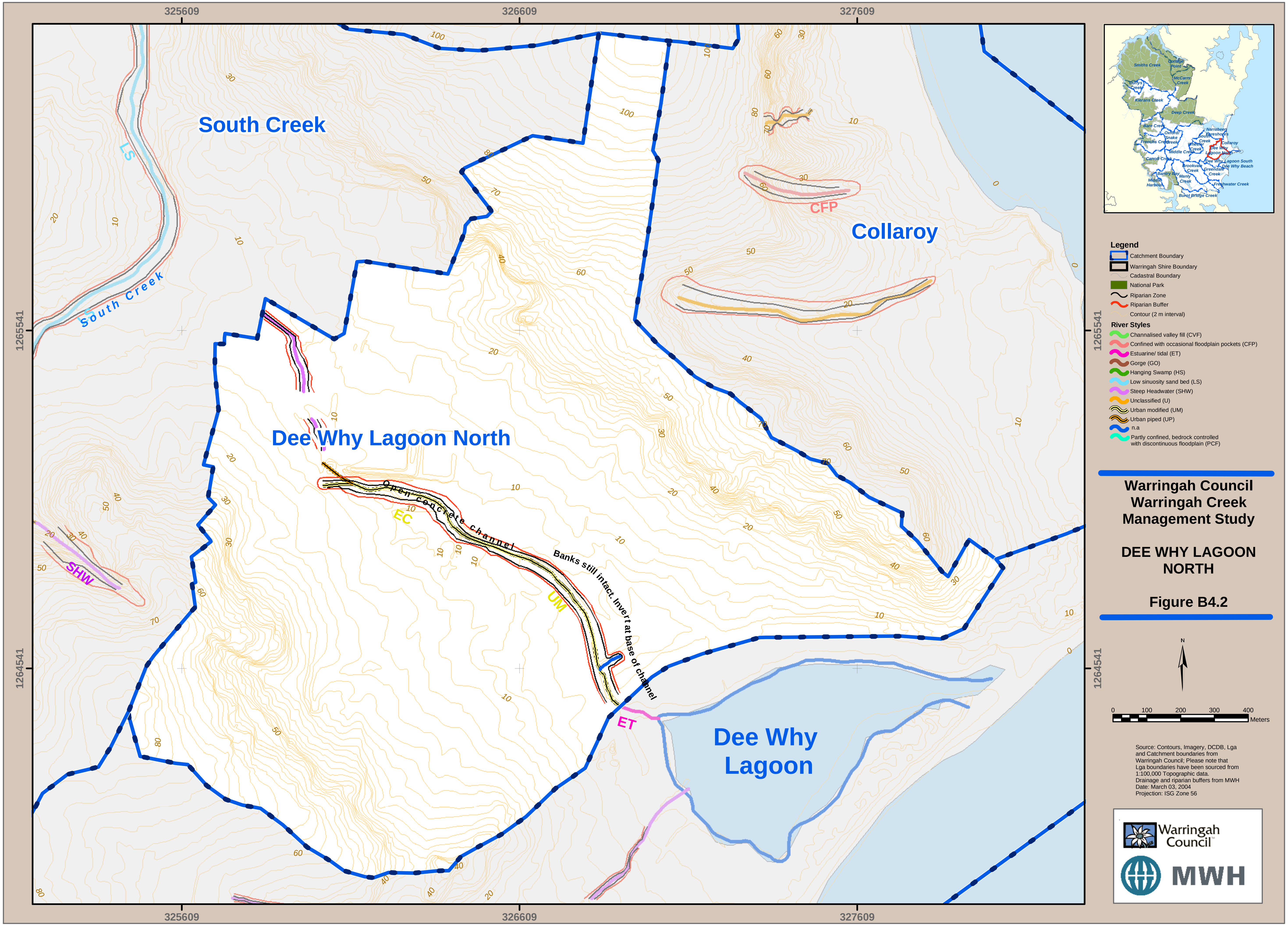

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concentration of dissolved nitrogen is below the recommended guidelines (Laxton, 2000). Further downstream, concentrations of suspended solids and total and dissolved phosphorus decrease, while total and dissolved nitrogen levels increase (Laxton, 2000). Faecal coliform counts suggest that the Creek is suitable for secondary contact recreation.

Stormwater runoff from surrounding urban areas, particularly the Cromer industrial estate, is likely to be a major source of pollutants within the sub-catchment.

4.3 Risks

The main risks to the creek are weed encroachment in the wetland and sediment deposition into the lower reaches. The concrete invert downstream of Cambell Avenue is eroding at the edges and current maintenance practice is to replace the soil. However, this is not a long-term solution. As a result, higher flow velocities and volumes due to the high imperviousness of the sub-catchment and channel itself will continue to deposit high loads of sediment and nutrients into the system, which eventually passes through a wildlife refuge and important habitats within Dee Why Lagoon.

4.4 Recommendations

Current community rehabilitation activities (such as those undertaken by Ozgreen, the Friends of Dee Why wetlands and the Heron Place Bushcare group) seek to improve the habitat and landscape value within the riparian zone and floodplain. Native regeneration should be encouraged within the riparian zone, in conjunction with weed control.

The following activities are also recommended for the Dee Why Creek sub-catchment:

- erosion around the concrete creek invert should be repaired by stabilising the soil and revegetating with groundcover;
- the construction of an artificial wetland habitat adjacent to the creek near Heron Place should be considered; and
- potential pollution sources from the Cromer industrial estate should be investigated.

Suggestions have also been made to rehabilitate the channelised parts of the creek. However, removal of the concrete channel upstream of Cambell Avenue would be a major exercise and could divert considerable resources from higher priority catchments. Removal of the invert downstream of Cambell Avenue would be less resource intensive and could address the erosion problem at the same time.

As an interim measure, local erosion control and riparian revegetation in this reach is the main priority.

5. Brookvale Creek

The total area of the Brookvale Creek sub-catchment is approximately 450 ha. The steep headwaters tributaries flow through remnants of natural bushland within Allenby Park while immediately downstream of the parklands, the system has been modified (i.e. piped and channelised) as a result of industrial and commercial development to the east of Old Pittwater Road, including the Warringah Mall Shopping complex. Further downstream within the Warringah Golf Course, the main channel flows through an alluvial floodplain before joining Manly Creek immediately upstream of Passmore Reserve. The combined system eventually discharges into the north-western section of Manly Lagoon (Figures B5.1 and B5.2). The sub-catchment is over 40% impervious.

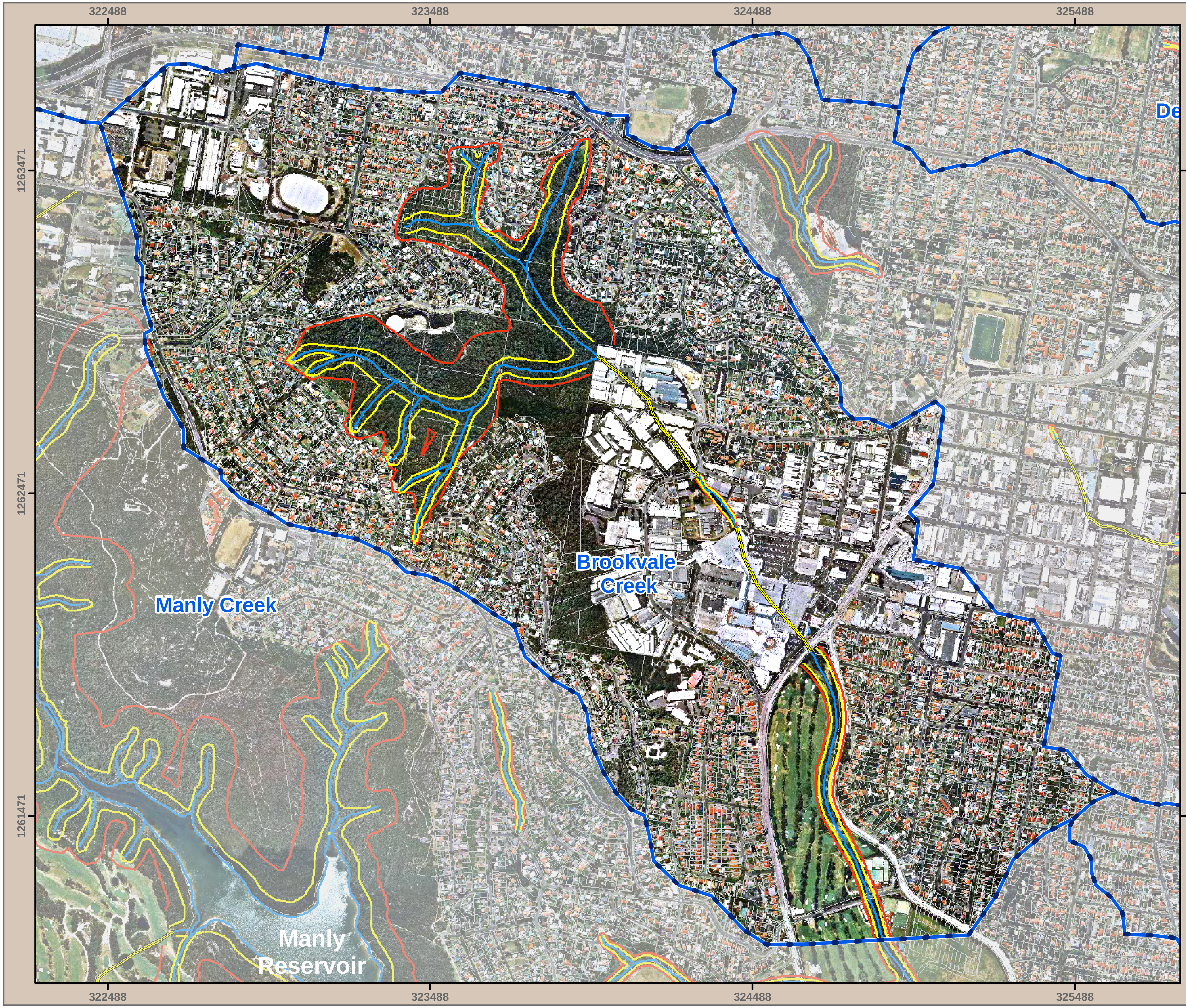
5.1 Values

Although the sub-catchment is over 40% impervious, high ecological values have been retained in the reaches upstream of the industrial/commercial district with the immediate natural catchment remaining largely intact. Allenby Park has been previously described as a natural buffer to the surrounding residential development, with significant scenic, environmental and biodiversity values and a range of habitats such as Coachwood dominated rainforest along the boulder-lined creeks (Warringah Council, 2000a). These upper reaches of Brookvale Creek contain good examples of natural, moist creek line gully vegetation of the district, with moderate to high connectivity, continuity and habitat quality in the riparian zone and floodplain. As a result, native species richness and diversity is moderate to high and there is reasonable potential for dispersal of native terrestrial fauna species. Special features include waterfalls and rock overhangs, which provide high landscape value for the local community (Warringah Council, 2000a).

Within Warringah Golf Course, vegetation connectivity and availability of refuge habitat is low and there is currently poor potential for dispersal of native terrestrial fauna species. However, these aspects are likely to improve over time as recent rehabilitation activities continue. For example, native species richness has already increased and weeds are considered to be largely under control. Early signs suggest that the creek line vegetation is a good example of successful restoration of a highly degraded system.

5.2 Water Quality

Despite the high ecological and landscape value of the upper reaches of Brookvale Creek, water quality samples taken within Allenby Park exceeded the recommended guidelines for all nutrient forms. In particular, the concentration of dissolved phosphorus was the highest of all sites sampled during the study. The faecal coliform count was also the highest recorded and suggests that the upper reaches are unsuitable



Legend

- Adjacent Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek
Management Study

BROOKVALE CREEK

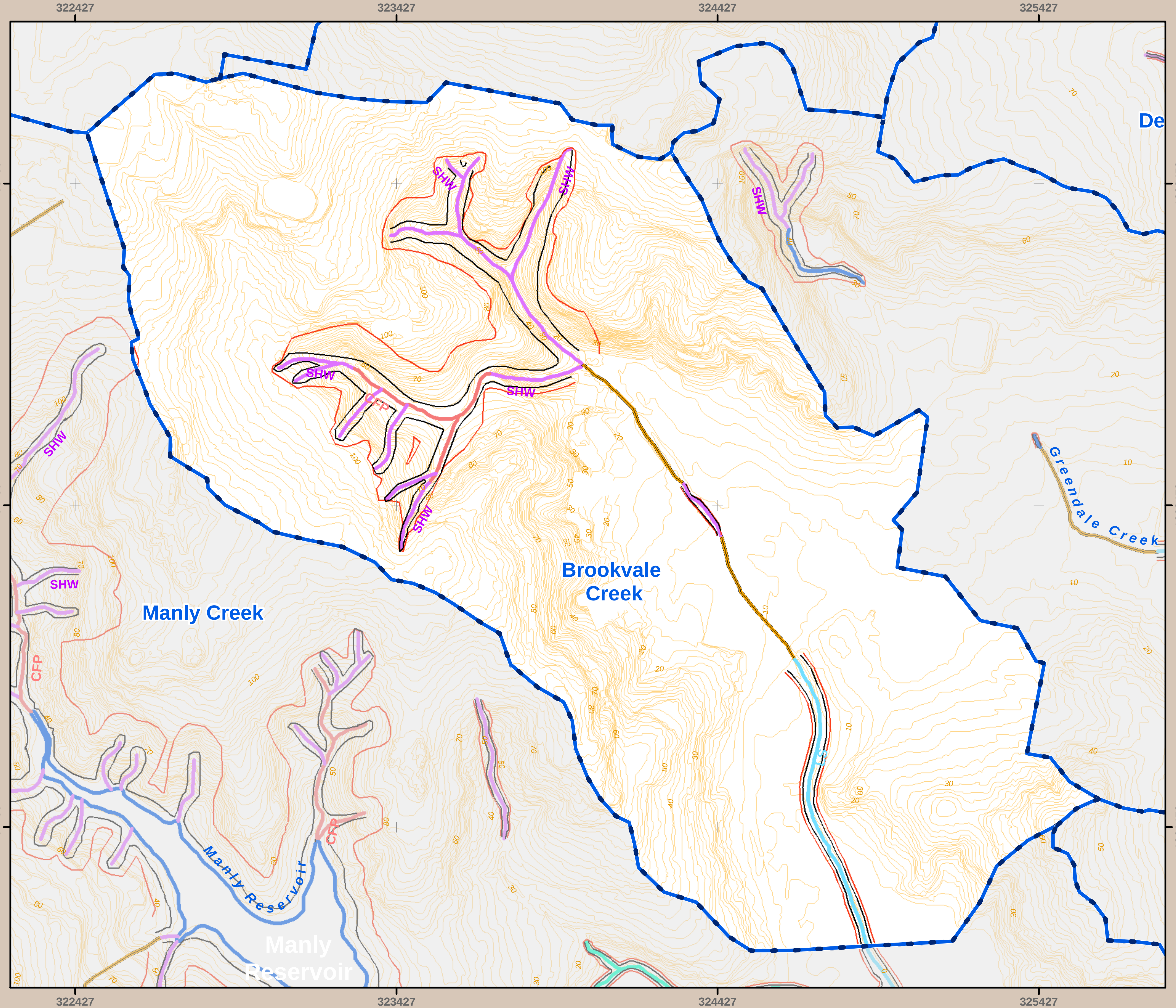
Figure B5.1

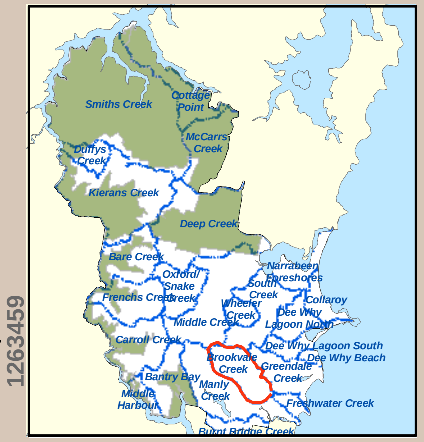
N

0 125 250 375 500 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 Topographic data. Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council
MWH





Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek
Management Study

BROOKVALE CREEK

Figure B5.2

N

0 125 250 375 500 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries may have some minor misalignments. Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council

MWH

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for secondary contact recreation. The concentration of biological oxygen demand was also relatively high, although suspended solids levels were low. Monitoring results recorded by Laxton (2000) indicate that the concentration of all parameters are typically lower downstream within the Golf Course, although total and dissolved nitrogen and total phosphorus levels still exceed recommended guidelines.

Likely sources of pollutants within the sub-catchment are stormwater runoff from residential and industrial areas within Beacon Hill, Allambie Heights, Brookvale and North Manly. Major sources of faecal contamination would include domestic animal waste in residential areas and other wildlife within the parklands. The results suggest that the bushland surrounding the upper reaches provides little attenuation or trapping of pollutants.

5.3 Risks

Within Allenby Park, weed invasion is very minor and confined to specific areas. However, if these weeds are not controlled, the extent of infestation will gradually increase and the existing values of the natural system would eventually be lost. Urban nutrient enrichment (i.e. runoff and garden-refuse dumping) and alterations to hydrology are also major risks, particularly in relation to rainforest vegetation communities adjacent to the creek lines within Allenby Park (Warringah Council, 2000a). The reintroduction of weeds from unrestored sections also poses a threat to areas revegetated within Warringah Golf Course.

5.4 Recommendations

Several reaches within Allenby Park are considered excellent candidates for community projects. In particular, complete weed eradication may be a possibility at these sites due to the minor extent of current infestations. This should be coupled with a community education program to prevent the escape of exotic garden species into the natural system. Adequate maintenance of these upper reaches is required to prevent weed re-invasion in downstream reaches that are already being managed (i.e. Warringah Golf Course).

6. Manly Creek

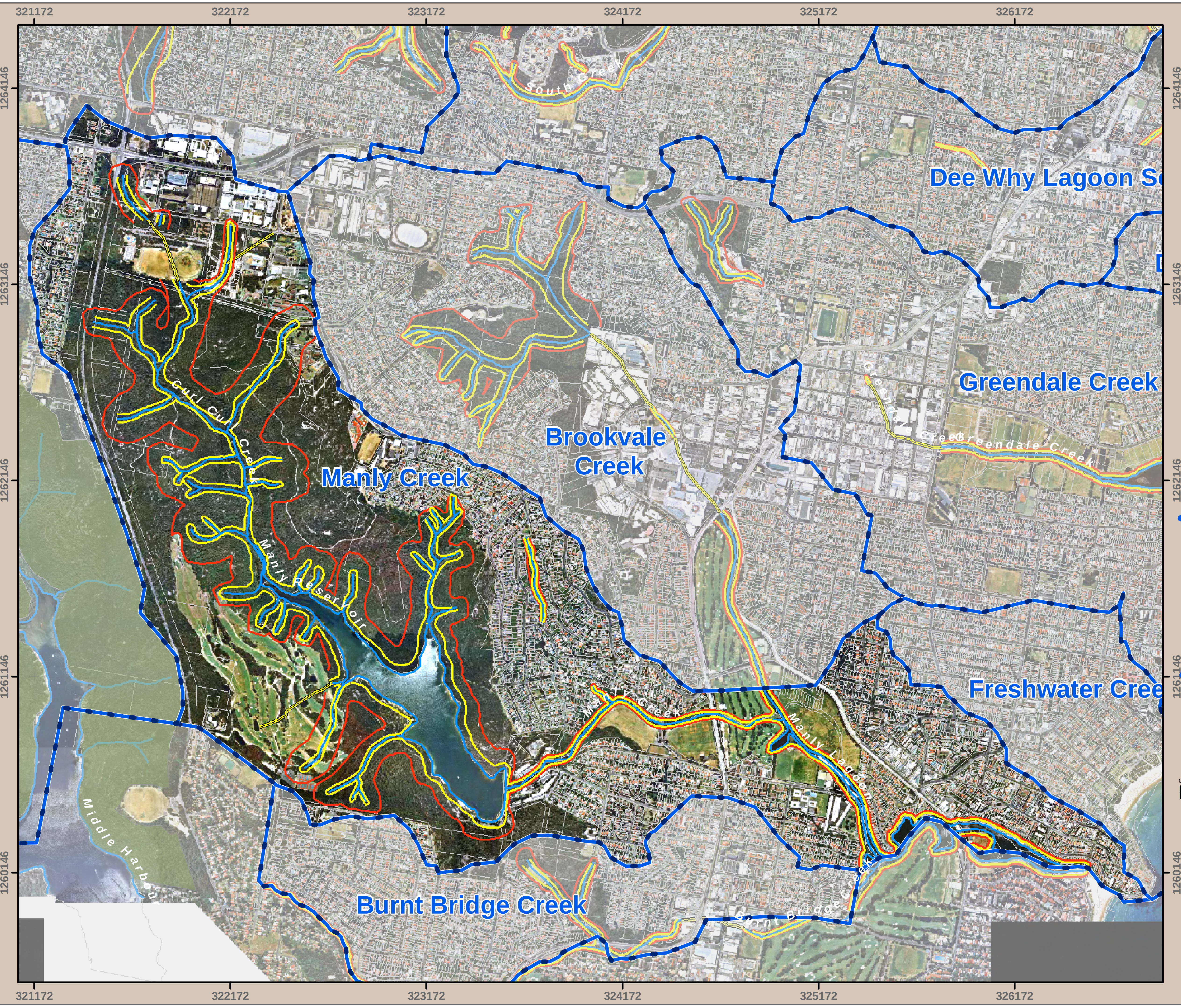
The Manly Creek sub-catchment covers an area of approximately 810 ha. Upstream of Manly Dam, steep headwaters tributaries in the north-western corner of the Manly Dam Reserve flow through natural bushland into the main stream (known as Curl Curl Creek) which feeds into Manly Reservoir. The section downstream of the Manly Dam (known as Manly Creek) flows through a bedrock controlled, discontinuous floodplain, surrounded by parkland and residential development, before flowing under the Condamine Street Bridge and adjoining Brookvale Creek immediately upstream of Passmore Reserve (Figures B6.1 and B6.2). The catchments surrounding the upper and lower reaches are less than 10% impervious and over 30% impervious, respectively. Major users of the creek's water include research laboratories and Warringah Golf Course.

Waterfall on Curl Curl Creek

6.1 Values

Manly Dam Reserve covers approximately 375 ha of which 78% is bushland (Nelson Consulting Pty Ltd, 1998). This provides a high level of connectivity of natural vegetation in the floodplain and riparian zone of Curl Curl Creek and reasonable habitat for dispersal of native terrestrial fauna species. Geomorphic diversity is also very high, providing a wide range of habitats and supporting excellent native species richness. Curl Curl Creek and its tributaries also provide high landscape and passive recreation value to the area.

Below Manly Dam, the sub-catchment is over 30% impervious, with little retention of natural land uses. Despite impacts of urban runoff and nutrient loads, important natural features still exist, such as significant areas of natural bushland immediately downstream of the dam wall, the McComb Hill area, and along the creek to the 'Mermaid Pool'. Council has recently prepared a restoration plan for the Mermaid Pool (2003), which includes analysis of the associated values.



Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek
Management Study

MANLY CREEK

Figure B6.1

N

0 175 350 525 700 875 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment Boundaries from Warringah Council; Please note that Lga boundaries have been sourced from 1:100,000 Topographic Data.
Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56

Warringah Council
MWH

MARCH 04, 2004
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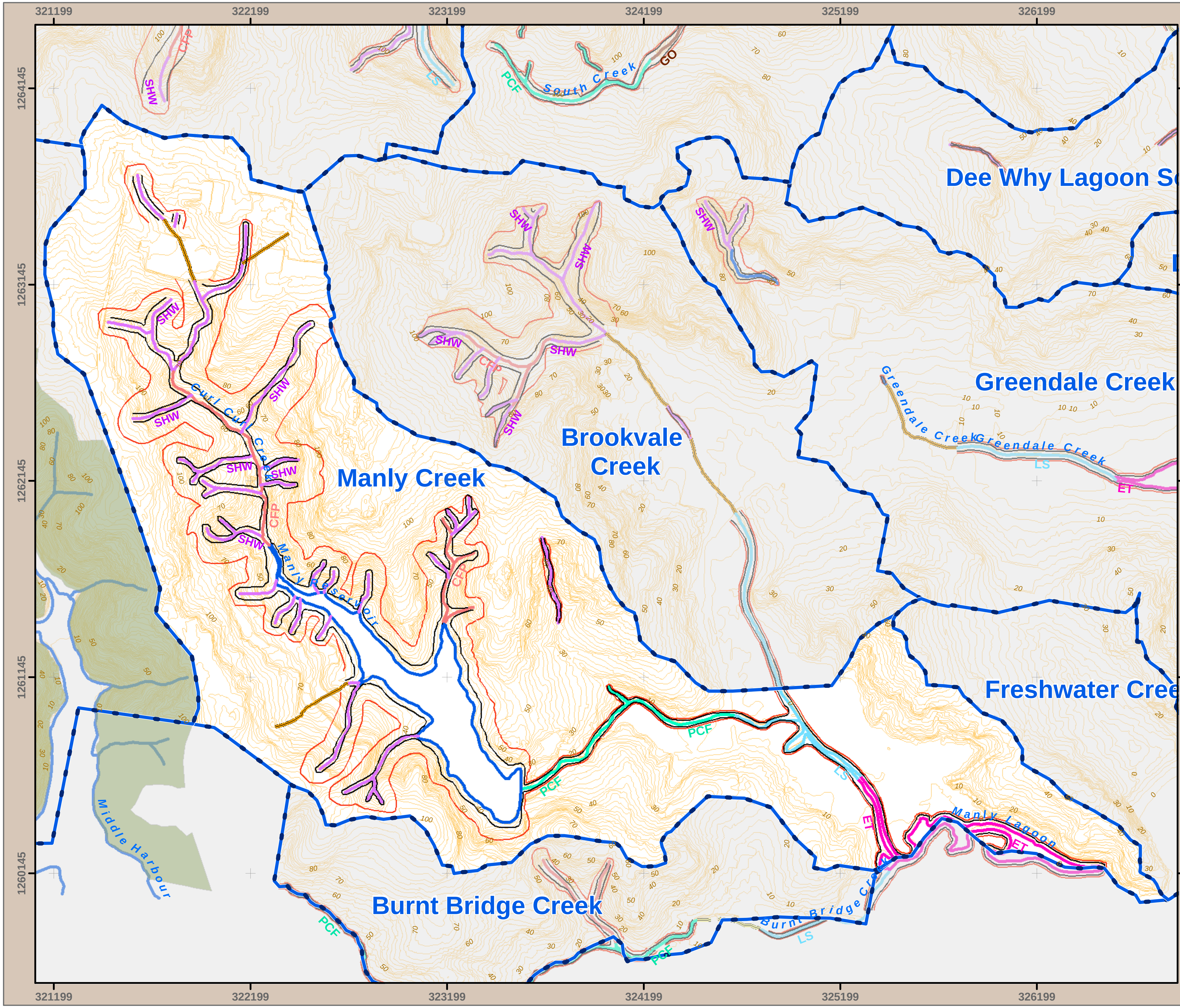

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek Management Study

MANLY CREEK

Figure B6.2

N

0 200 400 600 800 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment Boundaries from Warringah Council;
Lga boundaries based on 1:100,000 Topographic Data.
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council
MWH

MARCH 03, 2004
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The removal of vegetation from the floodplain and riparian surfaces adjacent to Manly Creek have resulted in channel incision, limited dispersal opportunities and refuge habitat for native species and low native species richness. Opportunities still exist for recreation, although landscape value is low relative to upstream reaches. Within Warringah Golf Course, these aspects are likely to improve over time as recent rehabilitation activities continue.

6.2 Water Quality

Water quality results from the present study and Laxton (2000) indicate that both Curl Curl Creek and Manly Creek have elevated concentrations of total and dissolved nitrogen, while concentrations of suspended solids are relatively low. The concentration of total phosphorus also exceeds the recommended guideline in Manly Creek.

Likely sources of pollutants within the sub-catchment are stormwater runoff from residential areas within Allambie Heights and Manly Vale and open spaces along the creek line. The surprisingly high pollutant concentrations within Curl Curl Creek may be reflecting upper catchment fertiliser use or polluted groundwater and suggest that the bushland surrounding the upper reaches provides little attenuation or trapping of pollutants.

6.3 Risks

The major threat to the high naturalness of the Curl Curl Creek system is new invasions and continuing reinvasion and expansion of existing weed species. Runoff from existing and future development in the catchment surrounding the Reserve (including expansion of the Wakehurst Golf Course) also presents a risk to water quality and natural flow conditions in these relatively pristine upper reaches. Stream connectivity has also been affected by the installation of a major stormwater treatment facility associated with a new subdivision abutting the Manly Dam Reserve.

Water quality, pollution and weeds are the main environmental issues for the community downstream of Manly Dam (Warringah Council, 2001a). Furthermore, environmental flows are in a much altered state, while excess runoff rates from the predominantly urban catchment surrounding this area pose another major threat to the remnant natural features within the Manly Creek system, due to ongoing channel erosion and sedimentation downstream.

6.4 Recommendations

Curl Curl Creek is an excellent candidate for rehabilitation, particularly with the current abundance of exotics. This will require frequent maintenance so that weeds can be removed before they establish and endemic natives could be introduced so they colonise before the exotics have a chance to take hold. Community activities would be facilitated by these straightforward management requirements, and the easy access to the site (i.e. existing walking tracks). While rehabilitation activities could also encompass the entire creek downstream of Manly Dam, such works would be very expensive due to the size and condition of the channel and would improve landscape more than ecology. Nonetheless, current community efforts, such as that aimed at rehabilitating the riparian zone of the 'mermaid pool', should continue.

The following activities are also recommended for the Curl Curl/Manly Creek sub-catchment:

- A Creek Management Plan should be prepared;
- The performance of existing stormwater quality controls should be investigated and augmented or modified if necessary, particularly in the upper catchment;
- Weed management should continue along the lower reaches and address the upper reaches of Manly Creek; and
- Banks along the creek line should be progressively stabilised and revegetated to prevent release of excess sediment into downstream reaches already being managed (i.e. Warringah Golf Course).

7. Burnt Bridge Creek

Forming part of the boundary between Warringah and Manly LGAs, the area of the Burnt Bridge Creek sub-catchment within Warringah is approximately 170 ha. The Creek is predominantly a bedrock controlled, discontinuous floodplain system, originating at North Balgowlah and eventually discharging into the Western corner of Manly Lagoon, adjacent to the Manly Golf Course. The main tributary on the Warringah (Northern) side is a confined system draining the playing fields to the South of Manly Vale Primary School (Figures B7.1 and B7.2). The sub-catchment is over 50% impervious, consisting predominantly of low-medium density residential properties.

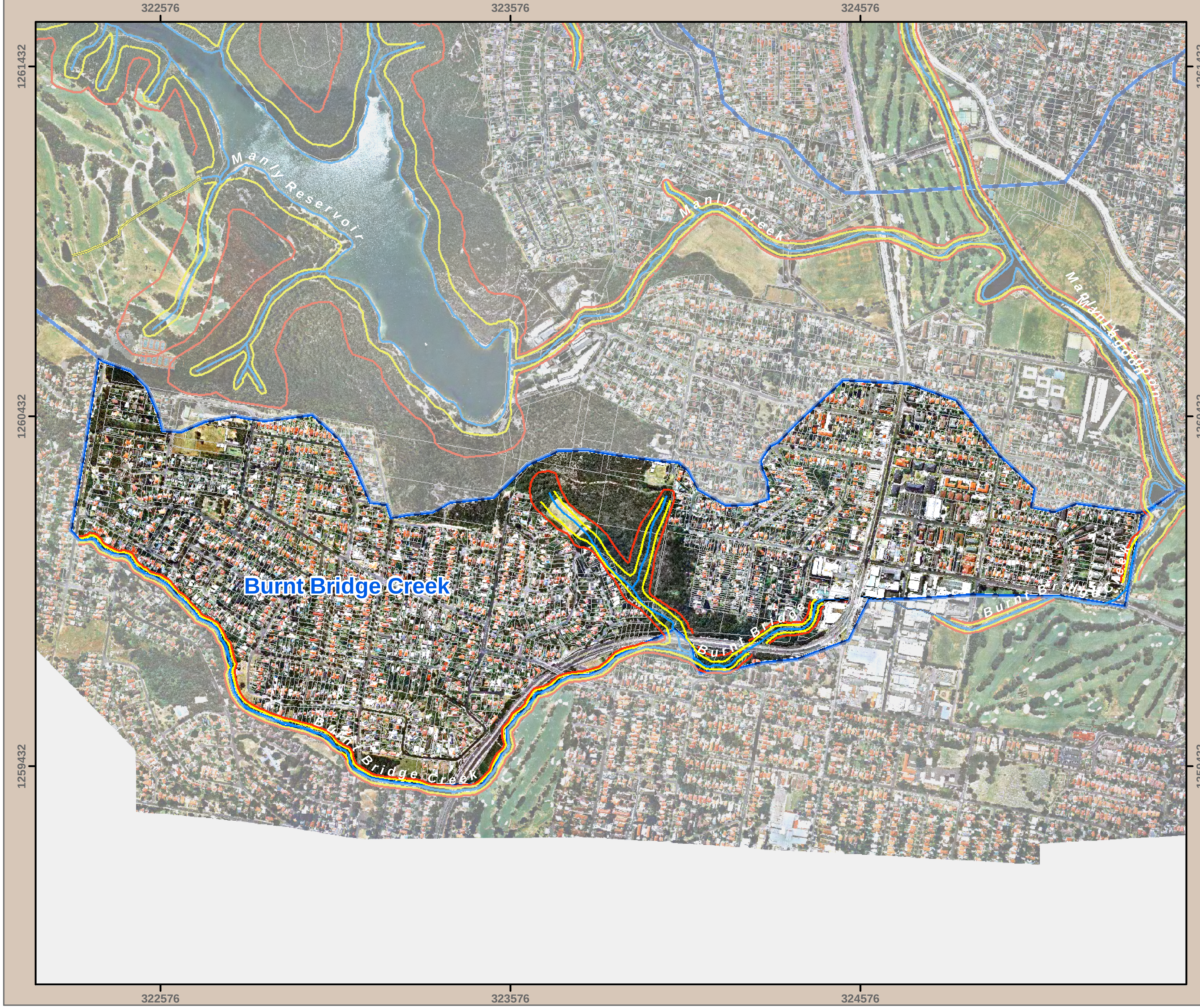
Erosion control along Burnt Bridge Creek

Section of Burnt Bridge Creek yet to be rehabilitated

7.1 Values

A recent fauna survey conducted by White (2001) found that the natural condition of Burnt Bridge Creek has been substantially changed and biodiversity has decreased as a result of catchment development. This is particularly so for native terrestrial mammals and appears to be largely due to predation by foxes, cats and dogs (White, 2001). The Ecology Lab (2001) also found that tall heath and fresh water wetlands may once have been part of the corridor but are no longer represented and of the 20 species of macrophyte recorded, only six were native (i.e. *Juncus usitatus, Potomogeton* sp., *Persicaria* sp., *Persicaria decipiens, Rumex* spp. and *Typha* sp.). In a previous stream assessment conducted by the NSW DLWC (1999), areas of bank erosion were identified in the upper and middle reaches of the creek, *'mainly due to undercutting or gullying caused by overland flow of water'*. This has resulted in sediment deposition throughout the creek, particularly where in-stream structures have reduced flow velocities (NSW DLWC 1999).

Despite the limited retention of natural catchment land use, a recent rehabilitation program has been highly successful in re-establishing the native riparian zone and floodplain vegetation along many, previously degraded sections along the upper reaches



Legend

- Adjacent Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek
Management Study

BURNT BRIDGE CREEK

Figure B7.1

N

0 62.5 125 250 375 500 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Please note that Lga boundaries have been sourced from 1:100,000 Topographic data.
Drainage and riparian buffers from MWH
Date: March 21, 2002
Projection: ISG Zone 56

MARCH 03, 2004
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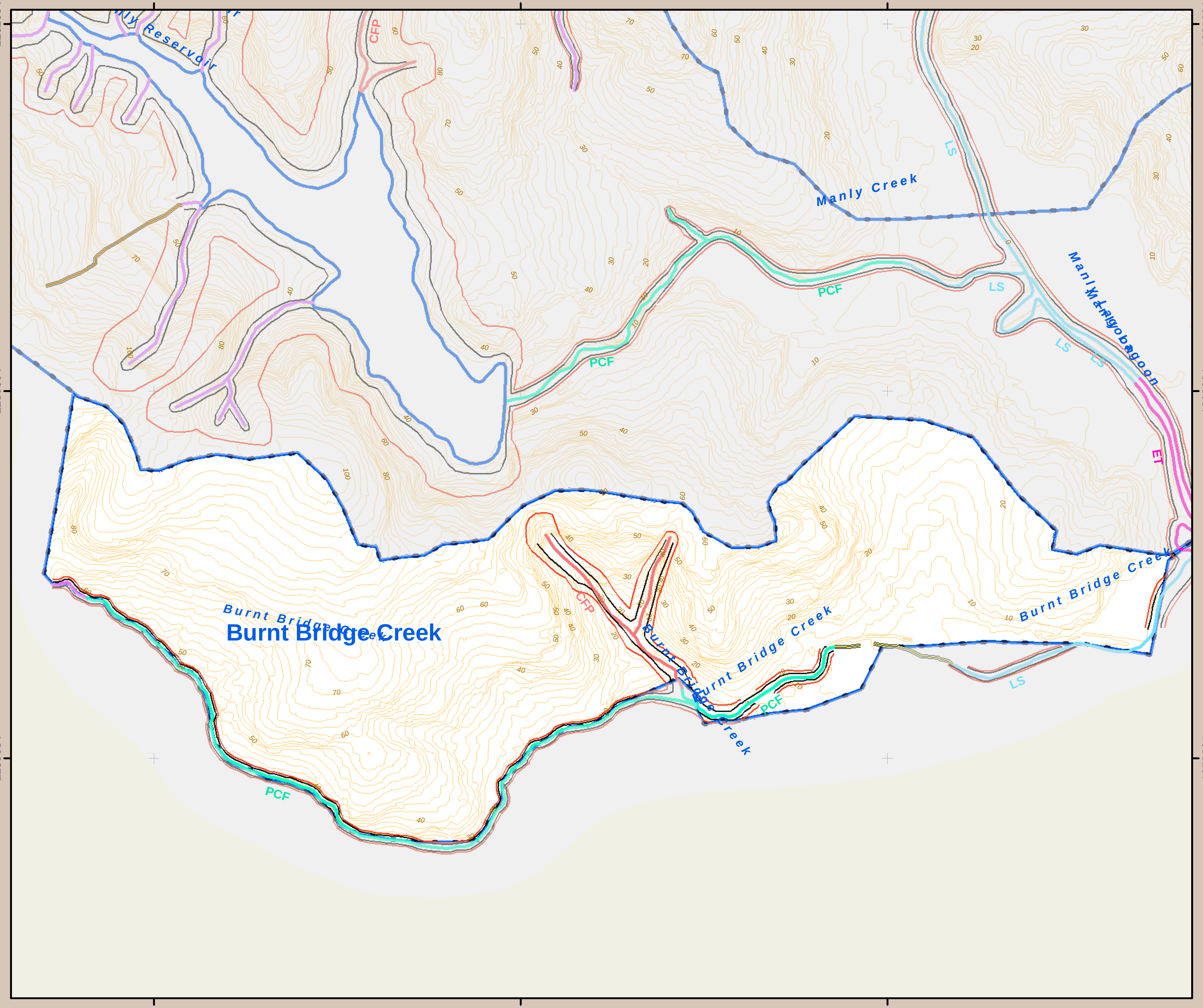

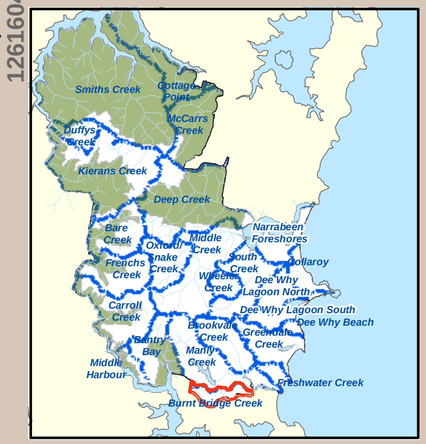

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek Management Study

BURNT BRIDGE CREEK

Figure B7.2

N

0 125 250 375 500 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Please note that Lga boundaries have been sourced from 1:100,000 Topographic data.
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council
MWH

MARCH 03, 2004
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of the creek. Although canopy cover remains patchy, successfully revegetated areas display higher native species richness and diversity. White (2001) identified a number of fauna habitats within the creek corridor, including open woodland, shrubland, flowing creek line, pools and sandstone exposures, while recorded fauna species included two native fish (Striped Gudgeon and Short-finned Eel), two species of lizard, one species of frog and 17 bird species. Landscape values have also improved and overall, the partially completed project is an excellent model for rehabilitating a highly degraded system. In areas yet to be restored native species richness and diversity is relatively poor, although some areas provide habitat for dispersal and refuge of native fauna.

The creek becomes progressively less natural downstream and the lower reaches are artificially channelised and armoured. Riparian vegetation is dominated by weeds (notably Coral Tree, Privet and Ludwigia) and riparian zone widths tend to be narrower, shrinking from an average of 10m in the upper reaches to 0m in the lower reaches. However, The Ecology Lab (2001), found fish diversity and abundance to be greatest downstream at a site within Manly Golf Course. Macrophyte cover and diversity were also found to be greatest at this site, although a fish barrier upstream or the sampling method may have been responsible for the observed lack of fish at upstream sites. Following a pesticide kill, dead eels and striped gudgeons were observed at the upstream sites.

Thirty nine families of macroinvertebrates were collected as part of the survey, and various statistical analysis indicated that the upper and lower reaches had distinct assemblages (The Ecology Lab, 2001). Sites were found to be in 'fair' to 'very poor' condition (based on SIGNAL indices). The rehabilitated upper reaches had better fauna assemblages than those downstream, but in the absence of reference sites, the differences could not be attributed to the rehabilitation.

7.2 Water Quality

The Ecology Lab (2001) found that conditions for supporting aquatic life were less than desirable in Burnt Bridge Creek, with low dissolved oxygen and elevated turbidity levels recorded at most sites sampled. The most common macroinvertebrate families collected during the survey were 'considered tolerant to pollution and disturbance' (e.g. chironomids) which the authors speculated may have been due to both chronic (stormwater runoff) and/or acute (e.g. pesticide spills) pollution. Results obtained by Laxton (2000) indicate that the downstream reaches of the creek also contain elevated concentrations of total and dissolved nitrogen and total phosphorus, although suspended solids levels are low and the creek is suitable for secondary contact recreation.

7.3 Risks

The reintroduction of weeds from unrestored sections poses the most serious threat to areas revegetated with native species. There is also the potential for water quality to decline if nutrient rich runoff from the surrounding land use, such as Balgowlah Golf Course, nearby houses, parkland and bicycle paths, is not sufficiently controlled.

Depending on the stage of restoration, erosion of steeper banks may also result from the removal of weedy vegetation before vegetation becomes re-established. However, consistent maintenance has so far reduced this risk.

7.4 Recommendations

Continued rehabilitation, weed eradication and erosion control along the entire creek line will be the most effective method for improving overall stream health, provided that maintenance of restored section remains consistent. This will require a high level of cooperation between Warringah and Manly Council in order to complement each other's work. Highest priority should be given to reaches with the potential to contribute large amounts of weed propagates to the system.

Further recommendations include:

- Investigating the costs and benefits of an in-stream wetland. Recreation of wetlands is identified in the rehabilitation plan as a priority and White (2001) suggested that heath could be re-established in a few locations in the middle reaches.; and
- improving the recreational and access trail network.

According to White (2001), 'controlled replanting' is needed to restore fauna habitat and control weeds. Buffer plantings of 'hardy, native, non-invasive and easy to maintain' species should be provided for to limit the edge effects of urban areas. Artificial ground shelter is also required for fauna habitat, unless natural debris is allowed to accumulate (White, 2001).

The recommendations of White (2001) and the draft rehabilitation plan (AWT, 1998) are consistent with the approaches taken in the Warringah Creeks Study, but are able to provide a higher level of detail. The value of continuing the Burnt Bridge Creek rehabilitation lies mostly in terms of it being an excellent model for other similar programs.

8. Bare Creek

The Bare Creek sub-catchment covers an area of approximately 550 ha in the north-western corner of Belrose. The main channel flows west through Garigal National Park, while the steep headwaters originate to the North of the sub-catchment, immediately South of Mona Vale Road (Figures B8.1 and B8.2). Major land uses throughout Belrose include the Austlink Business Park, low-medium residential development, non-urban bushland (outside the National Park) and the Belrose Waste Management Facility. The sub-catchment is around 10% impervious.

8.1 Values (outside the National Park area)

Upstream of the National Park, certain areas within the Bare Creek system are typical of upper catchment streamside communities of the district. The tributaries immediately upstream of the National Park are in very good condition (relative to other systems in the Middle Harbour catchment), with high continuity and diversity of natural vegetation, very high native species richness and diversity, and excellent habitat for dispersal and refuge of native fauna species. Landscape values are also high.

A 10 ha site owned by NSW Waste Services on the north-eastern side of the Belrose Waste Management Facility also contains pristine bushland including hanging swamp.

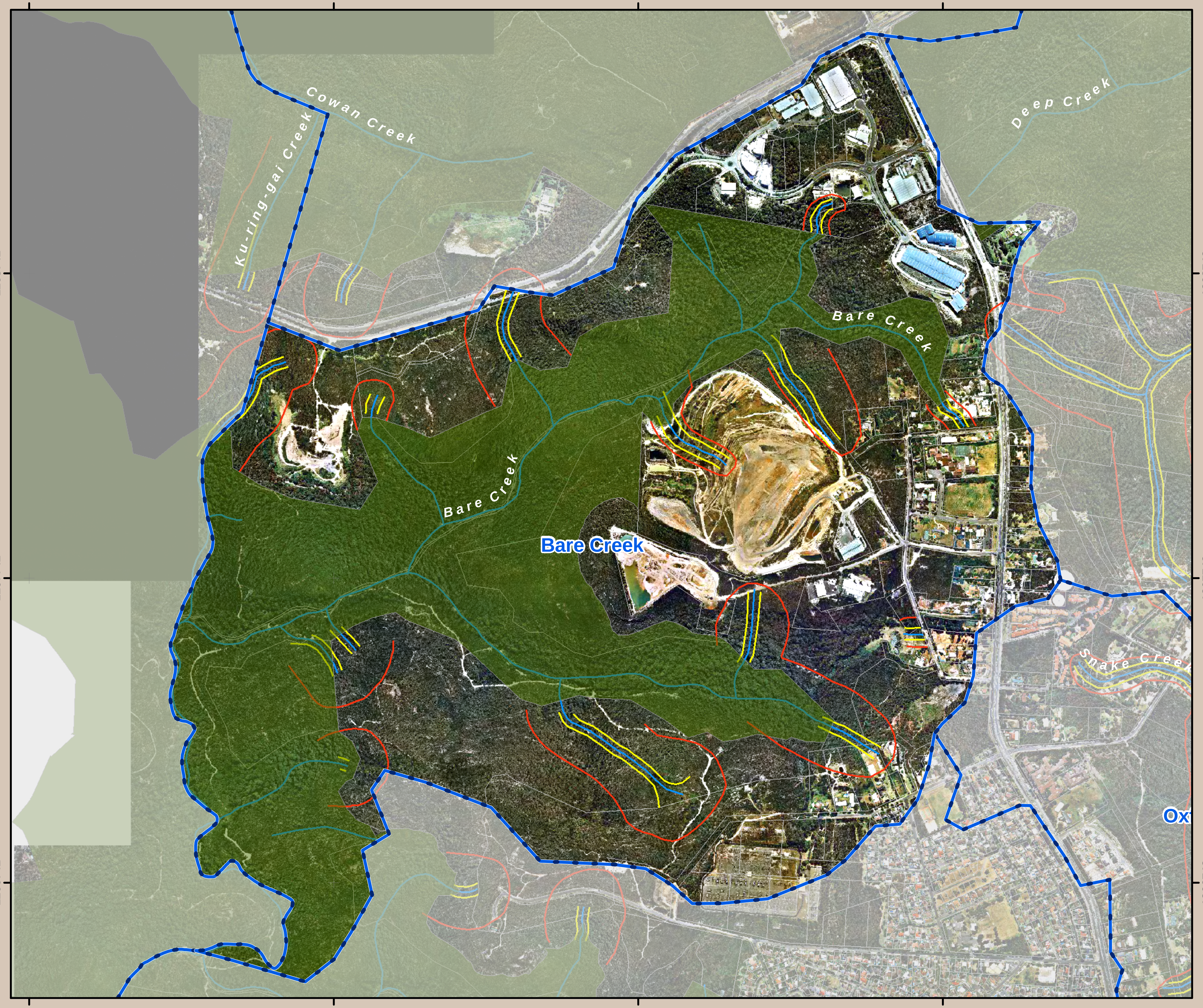
8.2 Water Quality

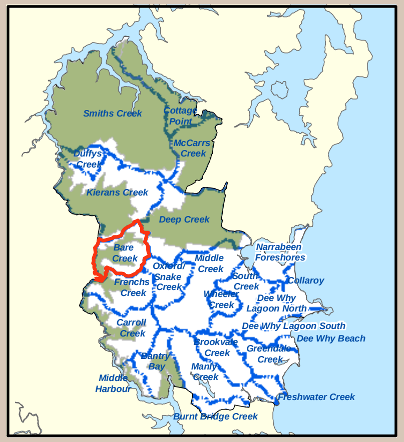
Samples taken near Narabang Way exceeded the recommended guidelines for total and dissolved nitrogen. Concentrations of total and dissolved phosphorus and biological oxygen demand were undetectable and suspended solids were low relative to other sub-catchments in the study area.

Although the catchment is only 10% impervious, likely pollutant sources would still include stormwater runoff from developing industrial and residential areas and associated construction sites.

8.3 Risks

Due to the high levels of naturalness, representativeness and diversity in the Bare Creek sub-catchment, minor changes in catchment practices could present a significant risk to stream integrity. The main long-term threat will be an increase in catchment imperviousness associated with the expansion of the industrial/commercial zone in the northern corner. Without adequate design considerations, this will increase runoff rates, which could import higher nutrient and sediment loads to the system.





Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek
Management Study

BARE CREEK

Figure B8.1

N

0 125 250 375 500
Meters

Source: Contours, DCDB, Lga and Catchment Boundaries from Warringah Council;
Please note that Lga Boundaries have been sourced from 1:100,000 Topographic data
Drainage and riparian buffers from MWH
Date: March 21, 2002
Projection: ISG Zone 56

Warringah Council
MWH

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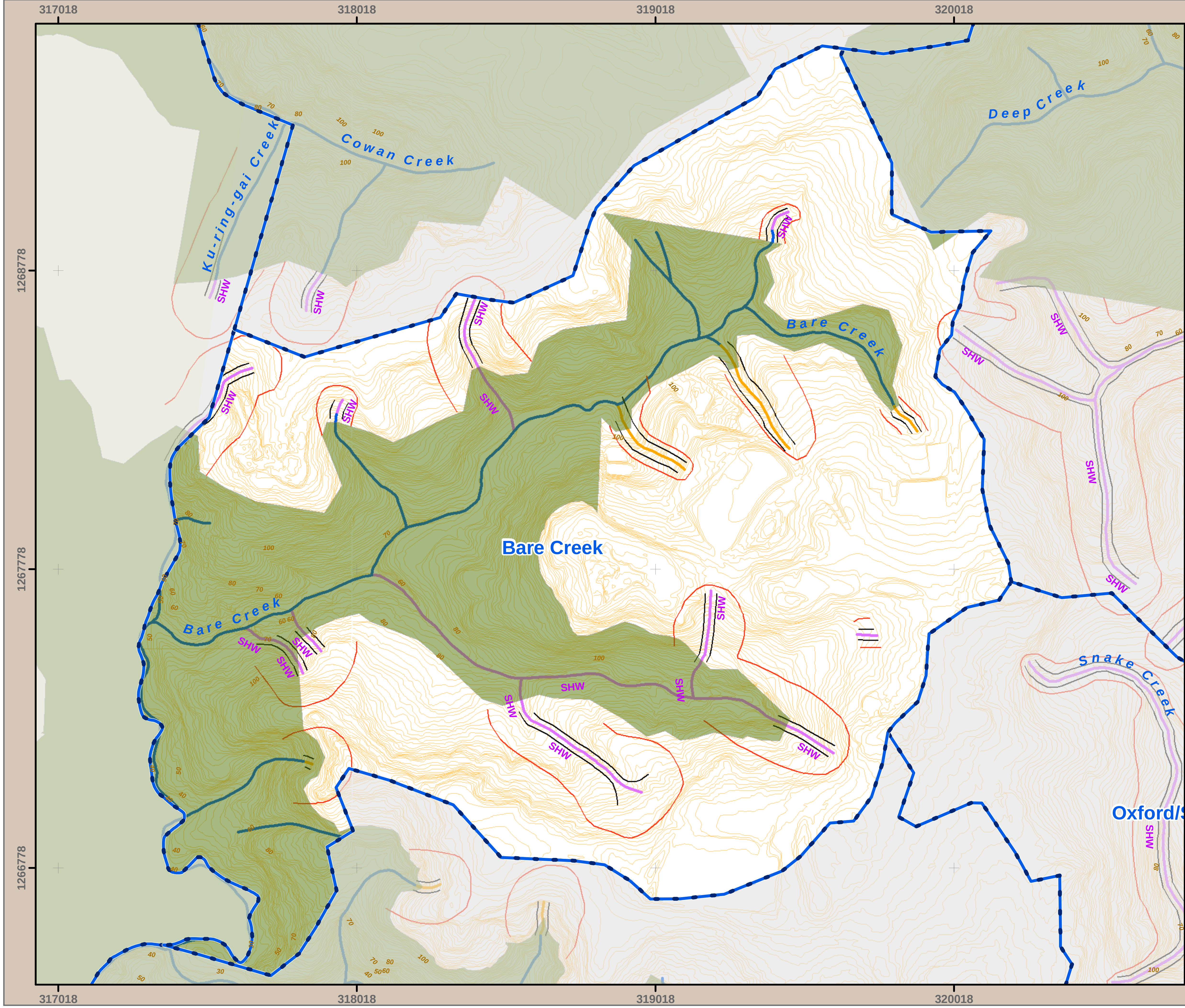

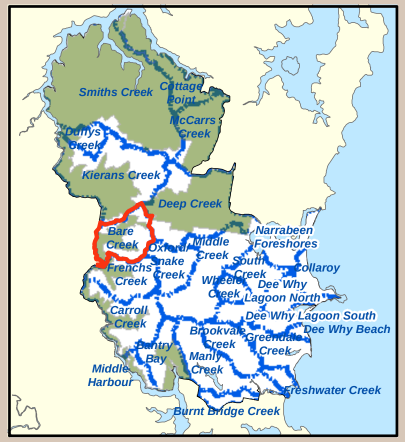

Legend

- Catchment Boundary
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- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
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- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council Warringah Creek Management Study

BARE CREEK

Figure B8.2

N

0 125 250 375 500 Meters

Source: Contours, DCDB, Lga and Catchment Boundaries from Warringah Council;
Please note that Lga Boundaries have been sourced from 1:100,000 Topographic data
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council™

MWH

MARCH 03, 2004
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In the short term, construction stage impacts will be the most significant threats to the system. For example, during the field surveys, a temporary detention basin was situated immediately downstream of a construction site on Narabang Way. Although this appeared to be playing a vital role in terms of sediment and gross pollutant capture, it was holding a large volume of water and may have been affecting the amount of flow reaching the channel. This, in turn, may have been reducing the channel's ability to transport the sediment introduced by unprotected tributaries draining the industrial and commercial area to the north.

8.4 Recommendations

The limited extent of existing development within the Bare Creek catchment presents an opportunity to implement a number of activities before this high value system becomes significantly degraded. In the short term, these include:

- undertaking a weed management program in the riparian zone;
- educating residents about the importance of plant selection and garden waste management in minimising weed proliferation downstream;
- investigating sediment trapping opportunities for tributaries draining developing areas; and
- enforcing sediment and erosion control measures for new construction sites.

In the medium term; a Creek Management Plan should also be prepared. In addition, developing areas will need to be consistently monitored for weeds as colonisation is facilitated by ongoing disturbance.

9. Frenchs Creek and Carroll Creek

The Frenchs Creek and Carroll Creek sub-catchments cover approximately 550 ha and 760 ha, respectively. For both systems, the main channel flows west through Garigal National Park, while the steep headwaters originate to the East of the sub-catchment, within the urban area of Frenchs Forest (Figures B9.1 and B9.2, and B10.1 and B10.2, respectively). Despite large areas of bushland associated with the National Park, the sub-catchments are both over 30% impervious.

9.1 Values (outside the National Park area)

Frenchs Forest is dominated by low-medium density residential development, with limited retention of the natural catchment. However, immediately upstream of the National Park, high native species richness occurs in reaches from both systems, with reasonable connectivity and quality habitat for dispersal and refuge (eg. downstream of the waterfall to the South of Prahran Avenue). Reaches further upstream are more heavily influenced by urban modification and are characterised by low native species richness, sparse natural vegetation and relatively unsuitable habitat for dispersal and refuge. These areas are highly manicured with natural riparian vegetation largely replaced by planted exotics. Values associated with landscape and recreation are generally low throughout the majority of both creek systems (outside the National Park).

9.2 Water Quality

The water quality sample taken from Carroll Creek downstream of the GPT at Prahran Avenue recorded the highest dissolved nitrogen concentration of all sites sampled as part of the Study's program, while the concentration of total nitrogen was second only to Kierans Creek downstream of Aumuna Road. Concentrations of both nitrogen forms were lower from Frenchs Creek at Pringle Avenue, although still high relative to other sub-catchments. Concentrations of suspended solids recorded from both sites were also relatively high, as were the concentrations of total and dissolved phosphorus at Pringle Avenue. Concentrations of both phosphorus forms were undetectable at Prahran Avenue and concentrations of biological oxygen demand were undetectable at both sites.

Due to the limited retention of natural catchment land use upstream of the National Park, the likely source of pollutants within both sub-catchments is runoff from the urban areas of Frenchs Forest.

MARCH 03, 2004
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Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek Management Study

FRENCHS CREEK

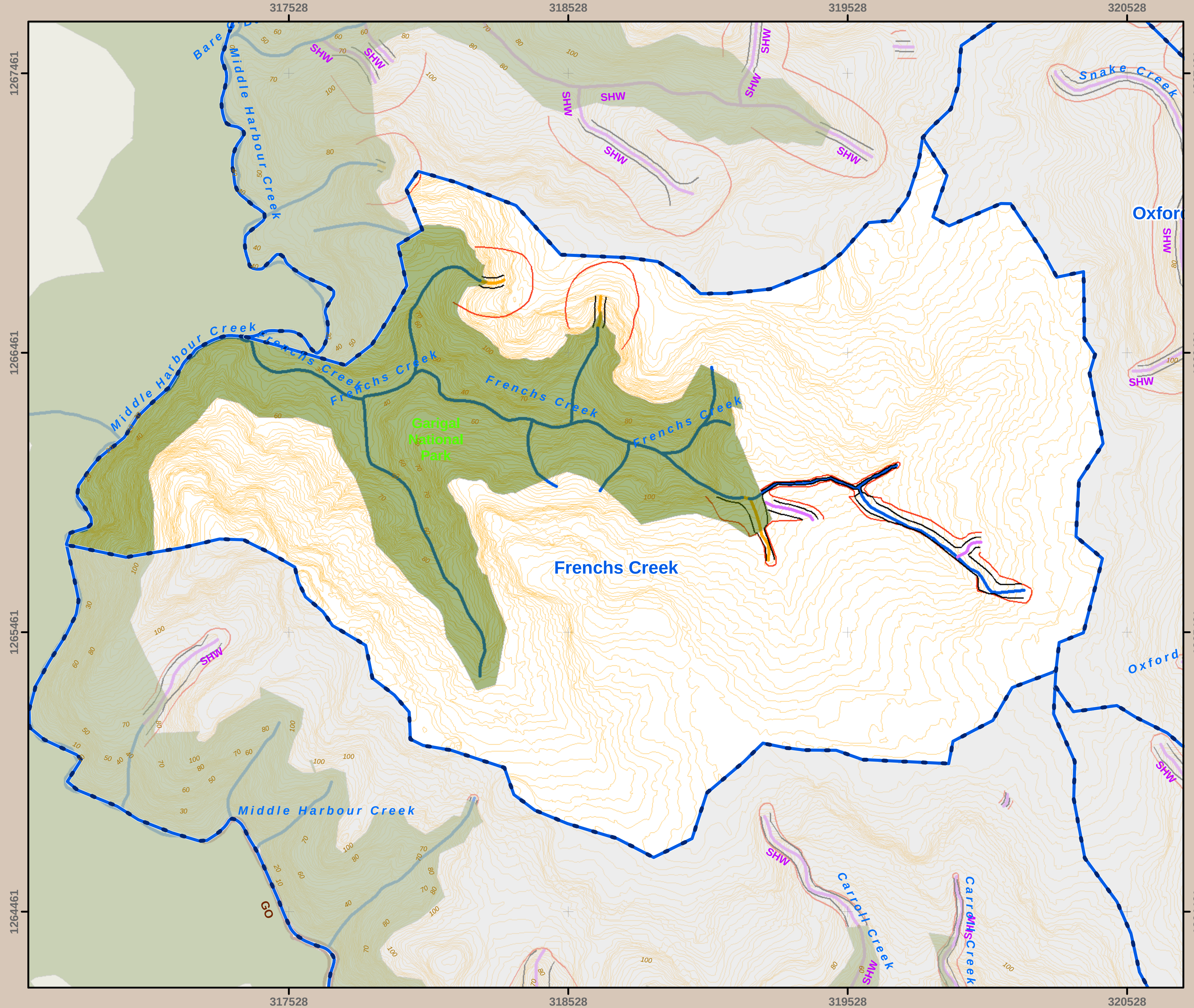
Figure B9.1

N

0 150 300 450 600 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment Boundaries from Warringah Council; Please note Lga Boundaries have been sourced from 1:100,000 Topographic data.
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council
MWH



Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council Warringah Creek Management Study

FRENCHS CREEK

Figure B9.2

N

0 150 300 450 600 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment Boundaries from Warringah Council; Please note Lga Boundaries have been sourced from 1:100,000 Topographic data.
Drainage and riparian buffers from MWH
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Warringah Council
MWH

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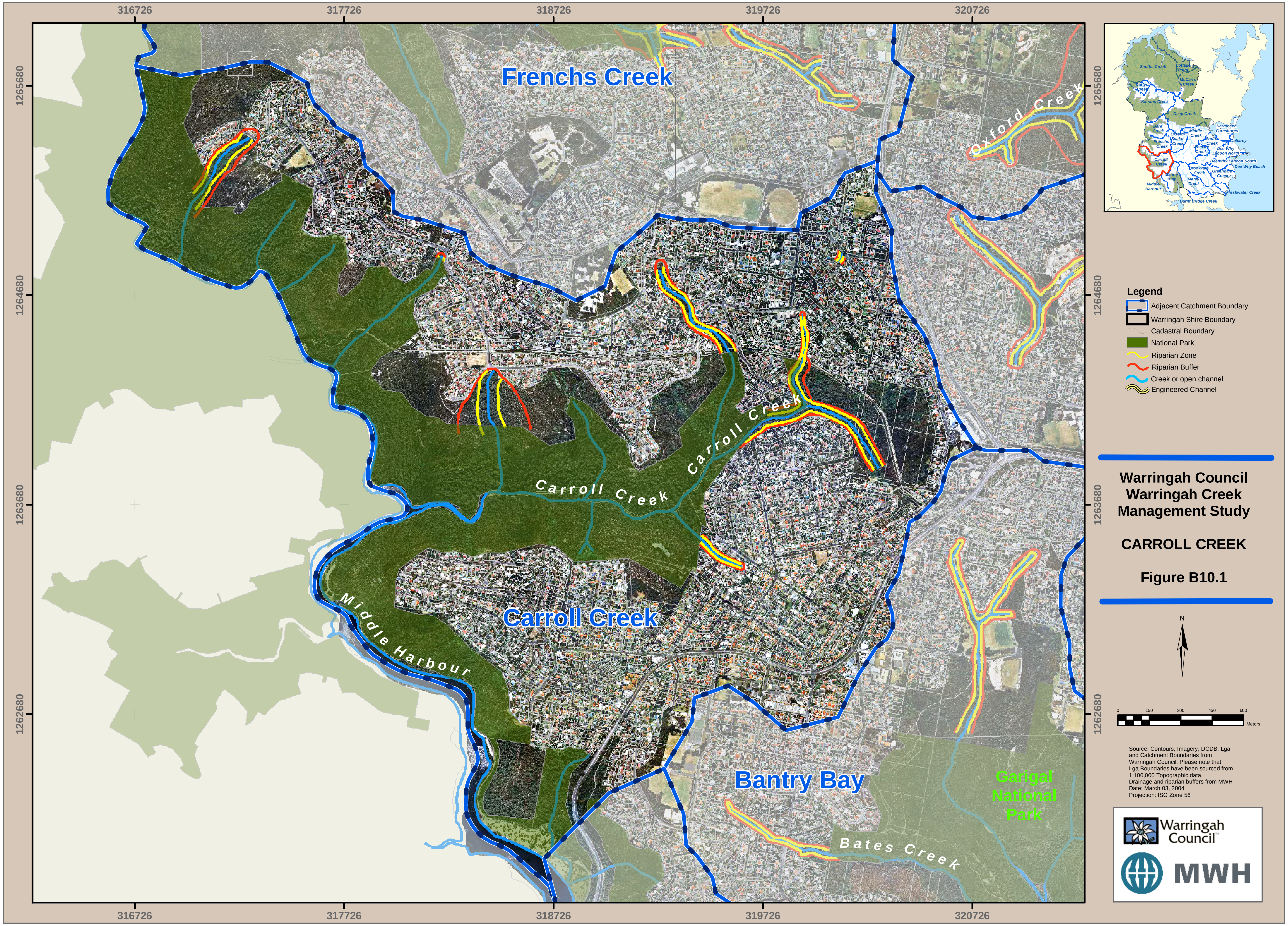
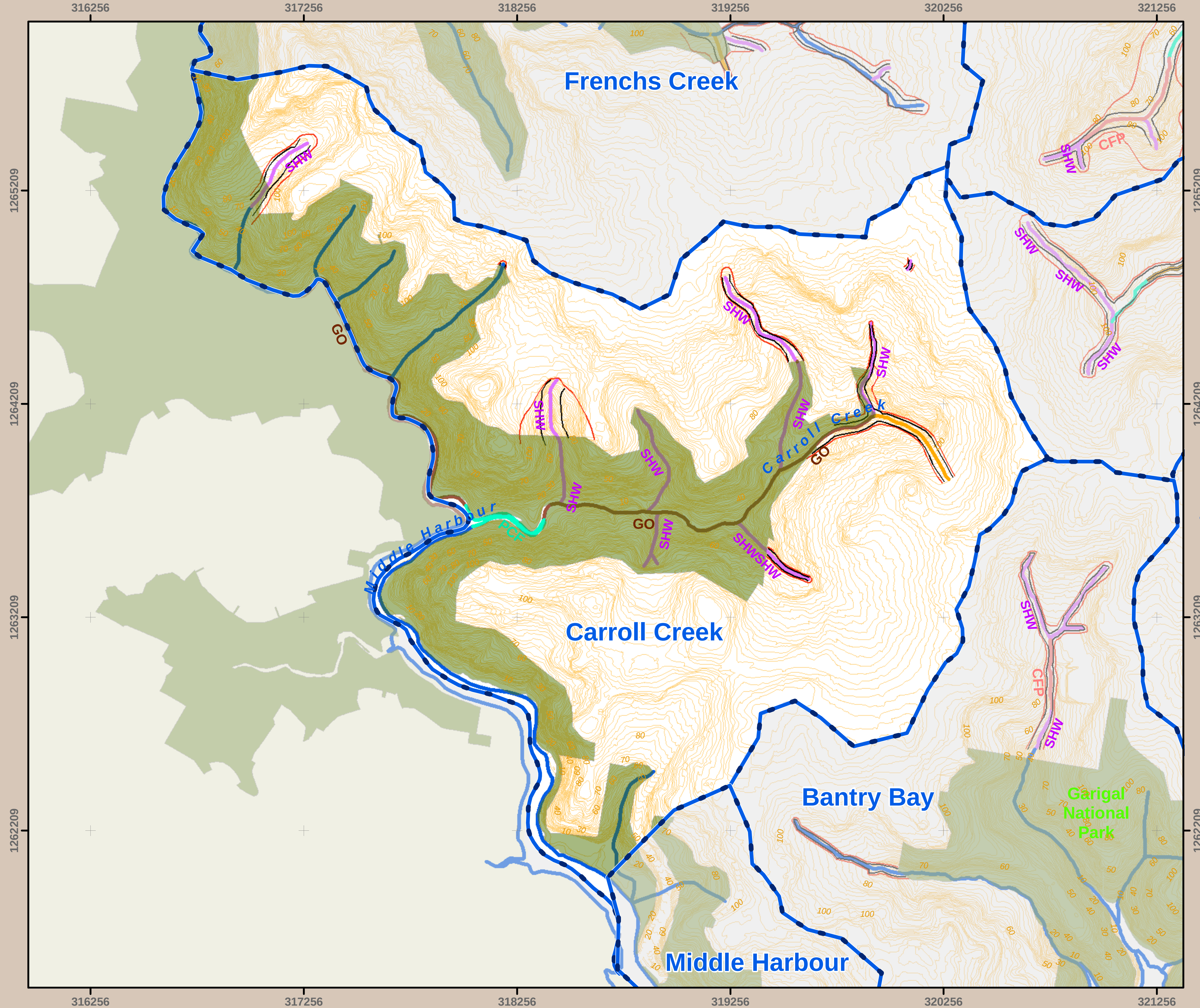

316726
317726
318726
319726
320726
1265680
1264680
1263680
1262680
Frenchs Creek
Oxford Creek
Carroll Creek
Carroll Creek
Carroll Creek
Middle Harbour
Bantry Bay
Bates Creek
Garigal National Park
Legend
Adjacent Catchment Boundary
Warringah Shire Boundary
Cadastral Boundary
National Park
Riparian Zone
Riparian Buffer
Creek or open channel
Engineered Channel
Warringah Council
Warringah Creek
Management Study
CARROLL CREEK
Figure B10.1
N
0
150
300
450
600
Meters
Source: Contours, Imagery, DCDB, Lga
and Catchment Boundaries from
Warringah Council; Please note that
Lga Boundaries have been sourced from
1:100,000 Topographic data.
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56
Warringah Council
MWH



Legend

- Adjacent Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek Management Study

CARROLL CREEK

Figure B10.2

N

0 200 400 600 800 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment Boundaries from Warringah Council; Please note that Lga Boundaries have been sourced from 1:100,000 Topographic data.
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council
MWH

9.3 Risks

The ongoing processes contributing to the degraded state of the upstream reaches within the Frenchs Creek and Carroll Creek sub-catchments threaten the areas of remnant native habitat that currently retain relatively high natural values. These processes include weed encroachment (through both uncontrolled invasions and deliberate cultivation of exotics) and polluted runoff from the urban catchment. Eventual replacement of native species by exotic or non-local species will occur as the extent of quality habitat becomes more unsuitable for natural regeneration.

9.4 Recommendations

While the local community already maintains some areas, a more comprehensive management approach is required to improve degraded reaches along Frenchs Creek and Carroll Creek to a level that minimises the risk to natural habitats. This would include the following actions:

- undertaking a weed management program in the riparian zone of both systems;
- educating residents in both sub-catchments about residential plant selection and garden waste management to contain the spread of weed propagules;
- investigating sediment trapping opportunities;
- requiring WSUD principles in all new development within the short term; and
- preparation of Creek Management Plans in the medium to long term, with particular attention to retrofitting WSUD and installing additional stormwater quality control devices.

10. Bantry Bay

The area of the Bantry Bay sub-catchment (within Warringah) is approximately 500 ha. The main tributaries on the Warringah (northern) side are characterised by steep, confined headwaters, with occasional floodplain pockets. These systems drain the residential areas of Forestville, before running through Garigal National Park and discharging into Bantry Bay (Figures B11.1 and B11.2). The sub-catchment (including the National Park) is over 20% impervious.

10.1 Values (outside the National Park area)

Upstream of the National Park, the land surrounding the Bantry Bay tributary systems has been extensively cleared for housing and parkland. As a result, the sparse natural vegetation within the floodplain and riparian zone is highly disturbed and discontinuous and is a poor representation of the native creek line vegetation typical of the district. Native species richness is low, with a high number and abundance of exotic species. Habitat is of better quality in specific areas (eg. downstream of the GPT on the South side of Currie Road), which provide refuges and opportunities for dispersal of native fauna. Certain riparian vegetation communities (i.e. Duffys Forest) could be highly significant. The creeks still provide moderate landscape value to the local community, despite the generally low level of naturalness.

10.2 Water Quality

Despite the highly disturbed nature of the sub-catchment, samples taken near Forestville Park were low in all pollutants measured, relative to other reaches within the study area, although concentrations of total and dissolved nitrogen still exceeded recommended guidelines. Concentrations of both forms of phosphorus and biological oxygen demand were undetectable.

The most likely sources of elevated nitrogen levels within the sub-catchment are runoff from urban areas and residential parkland.

10.3 Risks

Similar to most other urbanised catchments, declining water quality, pollution and weeds are the main environmental issues for the community. The presence of rare or significant biotic features is limited and any existing native species are threatened by these processes, as well as ongoing bank erosion caused by excess runoff rates. This is a significant problem for those areas providing higher quality habitat.

319057
320057
321057
322057
1263330
1262330
1261330
1260330
Carroll Creek
Bantry Bay
Middle Harbour
Bates Creek
Garigal National Park
Curl Curl Creek
Manly Reservoir
Legend
Catchment Boundary
Warringah Shire Boundary
Cadastral Boundary
National Park
Riparian Zone
Riparian Buffer
Creek or open channel
Engineered Channel
N
0 75 150 300 450 600 Meters
Warringah Council
Warringah Creek Management Study
BANTRY BAY
Figure B11.1
Source: Contours, Imagery, DCDB, Lga and Catchment Boundaries from Warringah Council; Please note that Lga Boundaries have been sourced from 1:100,000 Topographic Data.
Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56
Warringah Council
MWH
MARCH 03 2004
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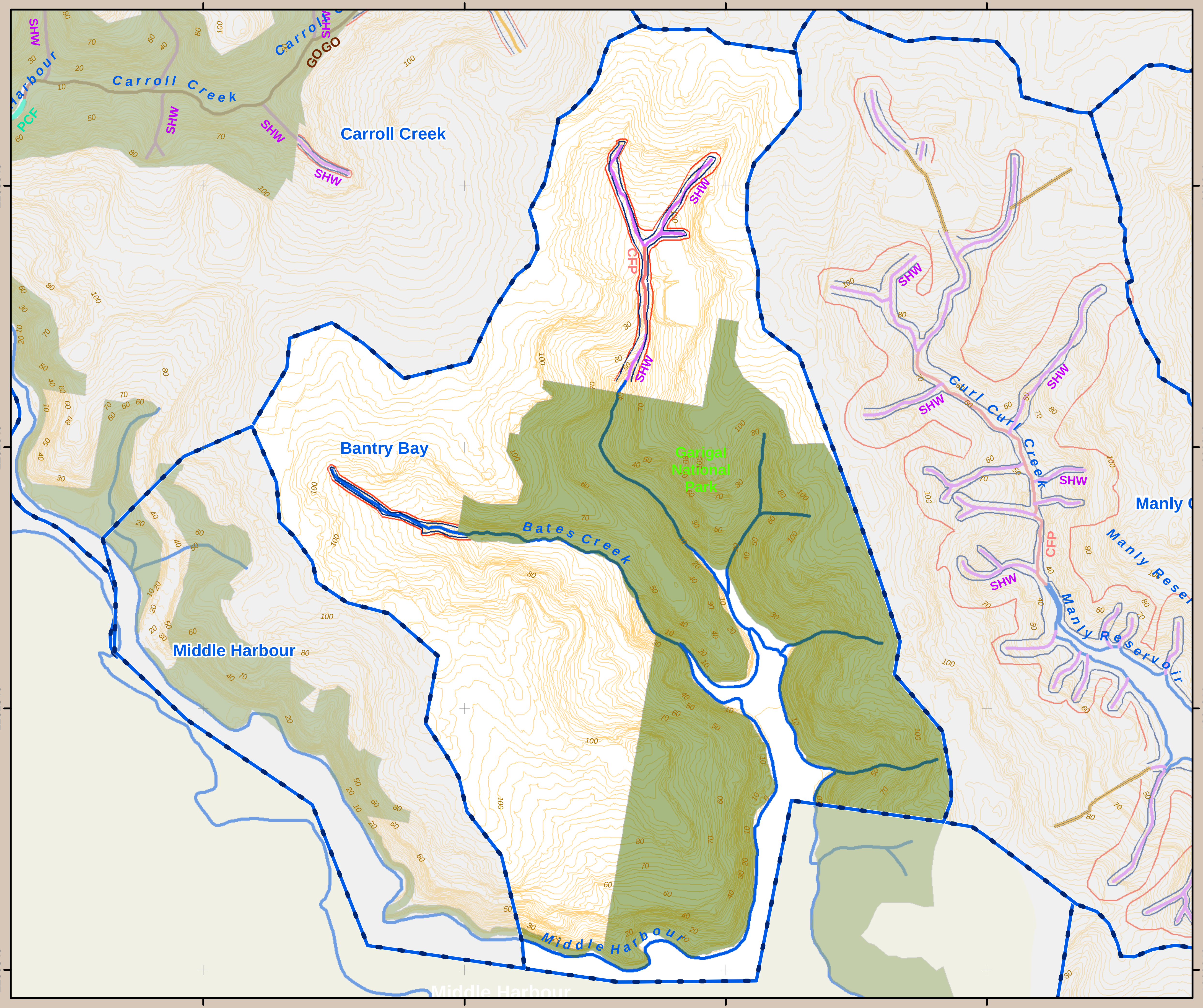

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek Management Study

BANTRY BAY

Figure B11.2

N

0 75 150 300 450 600 Meters

Source: Contours, Imagery, DCDB,
Lga and Catchment Boundaries from
Warringah Council; Please note that
Lga Boundaries have been sourced from
1:100,000 Topographic Data.
Drainage and riparian buffers from MWH
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10.4 Recommendations

As the tributaries flow into a National Park, weed eradication and bank stabilisation are considered a priority. In particular, education about residential plant selection and garden waste management is desirable. For example, native vegetation could be planted to replace exotics, with changes in mowing and weed control practices to allow natural regrowth. This would not only protect the natural areas downstream, but would also improve overall habitat value and native species diversity/richness upstream of the National Park, particularly in the riparian zone. As for Frenchs and Carroll Creeks, WSUD principles should be required in all new development in the short term, while in the longer term, the retrofitting of WSUD in existing development and the installation of additional stormwater quality improvement devices should be investigated.

11. Deep Creek

The Deep Creek sub-catchment (within Warringah) is approximately 1360 ha. The majority of the sub-catchment is contained within Garigal National Park. Most of the land outside the Park boundary surrounds the steep headwaters of several tributaries originating to the North of the Middle Creek sub-catchment (Figures B12.1 and B12.2). These areas are predominantly non-urban and the only significant areas of developed land within the sub-catchment occupy the north-western corner, near Terrey Hills. As a result, less than 5% of the catchment is impervious.

11.1 Values (outside the National Park area)

The Deep Creek tributaries below the south-western boundary of Garigal National Park are in the best overall condition of any creeks within the study area. All ecological and landscape indicators are considered to be of very high value, due to total retention of natural catchment land uses and the extensive natural bushland setting. The plant community is highly representative of a natural riparian community in dry sclerophyll forest in the local district, with very minor disturbance or modification and practically no exotic weeds present. Habitat quality and availability, native species richness, cover and abundance, and vegetation connectivity are all excellent. In addition, the area has potential koala habitat (i.e. SEPP44 listed Grey Gums) and suitable habitat for the threatened Red-crowned Toadlet.

The lower reaches also have high ecological and landscape values and are an important recreation reserve at the fringe of Narrabeen Lagoon. The Save Deep Creek community group is currently undertaking rehabilitation activities along these reaches.

11.2 Water Quality

Water quality samples taken from the south-western tributaries of Deep Creek at Madang Road recorded some of the lowest overall pollutant concentrations of any creeks within the study area. Concentrations of dissolved nitrogen, total and dissolved phosphorus, biological oxygen demand, suspended solids and faecal coliforms were undetectable or very low, while the concentration of total nitrogen recorded from the east branch was one of only two samples to be below the recommended guideline.

Concentrations of both forms of nitrogen were slightly higher than the guidelines downstream of Kimbriki Recycling and Waste Disposal Centre, although still relatively low in comparison with other creeks. This site also recorded one of the highest concentrations of biological oxygen demand, suggesting that runoff from the tip may be contributing organic material to the system. The faecal coliform count suggests that this location is only suitable for secondary contact recreation.

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council Warringah Creek Management Study

DEEP CREEK

Figure B12.1

N

0 200 400 600 800 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment Boundaries from Warringah Council; Please note that Lga Boundaries have been sourced from 1:100000 Topographic data.
Drainage and riparian buffers from MWH
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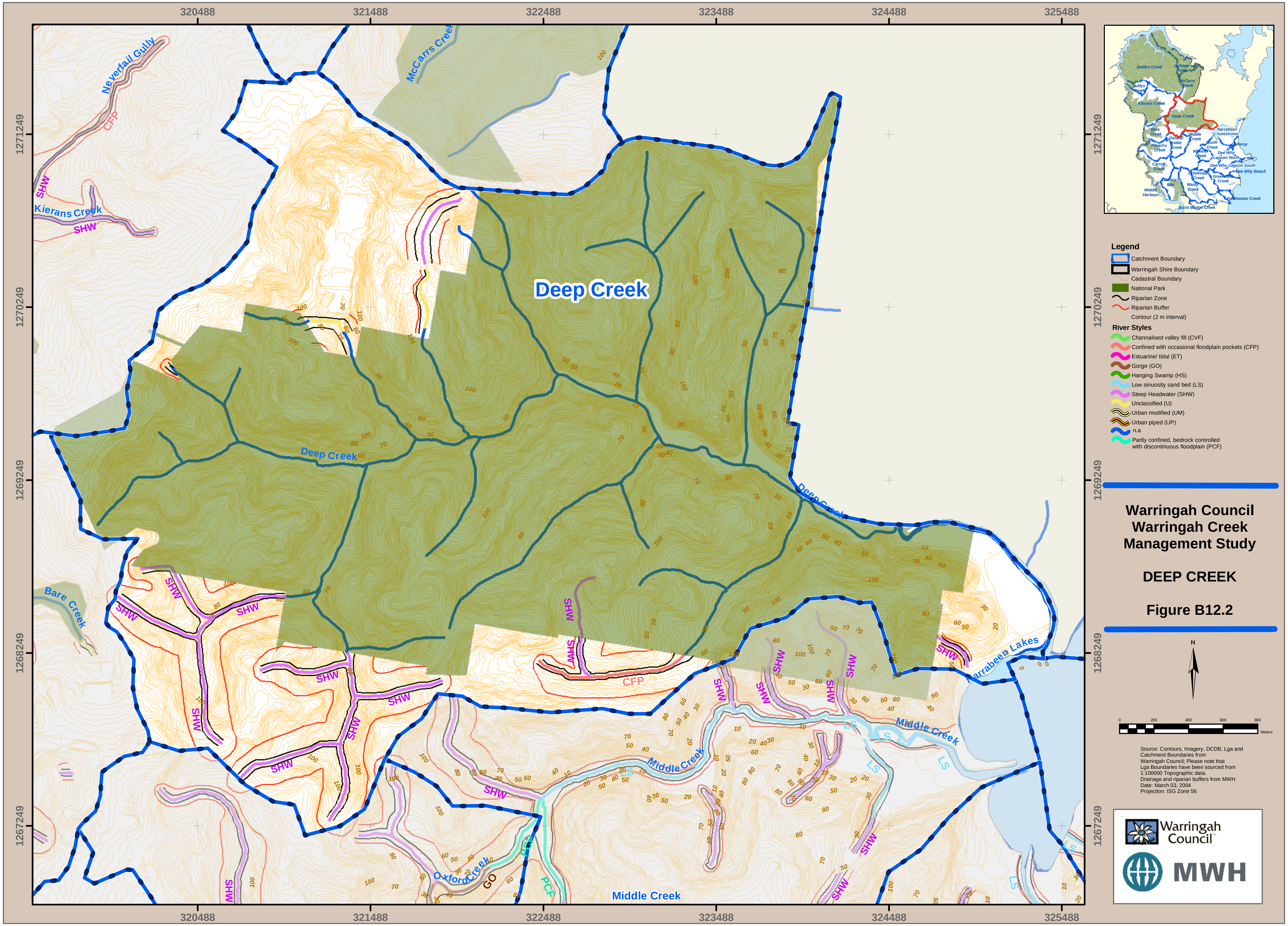


Warringah Council
Warringah Creek Management Study

DEEP CREEK

Figure B12.2

Long term results indicate that concentrations of total and dissolved nitrogen and total phosphorus are also slightly elevated immediately upstream of Narrabeen Lagoon (Laxton, 2000). The likely source of these pollutants is runoff from the urbanised areas within the Pittwater LGA, rather than the protected areas of National Park within Warringah.

11.3 Risks

While the system is not considered to be under high or immediate risk, the importation of weed propagates by recreational users of the bushland, which includes vehicles, bushwalkers, horses and trail bikes has already occurred and is evident along track edges. If left unchecked, this could eventually have a devastating impact on the naturalness, diversity, representativeness and rare and special features of the system, due to displacement of characteristic vegetation and habitat loss. Deterioration of the unpaved access tracks is also of concern, with the potential for increased erosion and sediment transport.

The most significant future threat is conversion of the non-urban lands surrounding the south-western tributaries to more intensive uses – whether rural, semi-urban or urban. The effects of minor increases in sediment and nutrient loads on the existing natural systems are likely to cause major changes in ecosystem integrity.

The lower (tidal) reaches in the Deep Creek Reserve are not part of the study area, but are showing signs of sedimentation and nutrient enrichment. Community groups, such as the Save Deep Creek Group, are primarily concerned with weed control in these downstream reaches.

11.4 Recommendations

The protection of the upper catchment of Deep Creek from rural or urban development is paramount and as a minium, the non-urban lands should be designated as environmentally sensitive. Extending protected area status through public acquisition of the lands should be the long-term aim.

In the short term, the following activities are recommended for the Deep Creek sub-catchment:

- Preparation of a creek management plan that focuses on the protection of natural areas, and considers the transport of sediments, nutrients and weed propagules from the entire system into Narrabeen Lagoon;
- Progressively eliminate weed sources from the upper catchment to the National Park boundary. In particular, vehicle and riding trail access should be restricted within the riparian buffer and signage introduced to educate track users about weed management;
- Continue the revegetation activities undertaken by community groups in the lower reaches; and

- Investigate the causes of elevated pollutant concentrations downstream of Kimbriki Recycling and Waste Disposal Centre.

As the major source of weed propagules, nutrients and sediment is likely to be from the developed areas within the Pittwater LGA, Pittwater Council also needs to be encouraged to continue the program of development controls and stormwater improvement to ensure effective results.

12. Middle Creek

The Middle Creek sub-catchment drains an area of approximately 1030 ha. The main channel originates from two main tributaries within the residential areas of Frenchs Forest (East of Forest Way) and Beacon Hill (West of Golden Grove Park). These upstream reaches are characterised by steep, confined headwaters, which combine immediately downstream of the Oxford Falls Grammar School to form a system of gorges and bedrock, controlled, discontinuous floodplains. Middle Creek is joined by Oxford Creek within the Oxford Falls Recreation Reserve, adjacent to the Wakehurst Parkway. The combined system (Middle Creek) then flows East through an alluvial floodplain before eventually discharging into the western side of Narrabeen Lagoon, adjacent to the NSW Academy of Sport (Figures B13.1 and B13.2). The entire sub-catchment is around 20% impervious.

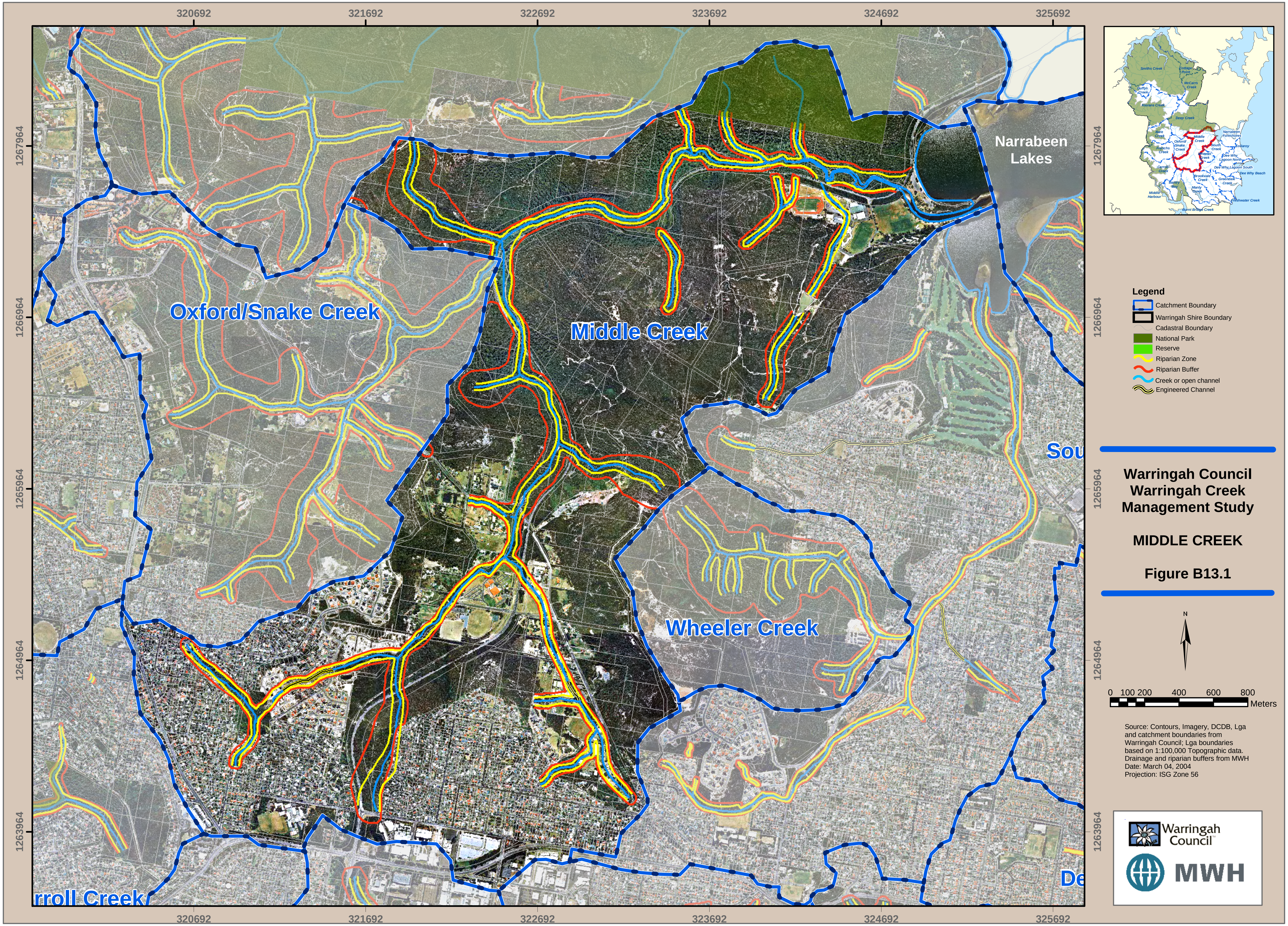
Upper Middle Creek

Middle Creek at Oxford Falls

12.1 Values

The headwaters of Middle Creek are surrounded by urban development, although some native vegetation has been retained on the floodplain and in the riparian zone. In particular, minor replanting and bush regeneration activities in Frenchs Forest have removed exotics and enhanced connectivity and representativeness of remnant robust native species, which is likely to result in improved availability of natural habitat and higher native species richness. However, in the majority of upstream areas (where these activities are not in place), ecological values have been lost through urban encroachment.

Downstream of Oxford Falls Road, predominant land use shifts from urban and large lot residential settlements, to significant areas of natural bushland and open space. Ecological values are generally high along these mid-reaches, with excellent examples of native riparian and floodplain vegetation, characterised by good connectivity and high species richness. This provides habitat for dispersal and refuge of native fauna and high recreational and landscape value.



Warringah Council
Warringah Creek
Management Study

MIDDLE CREEK

Figure B13.1

Source: Contours, Imagery, DCDB, Lga and catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 Topographic data.
Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56

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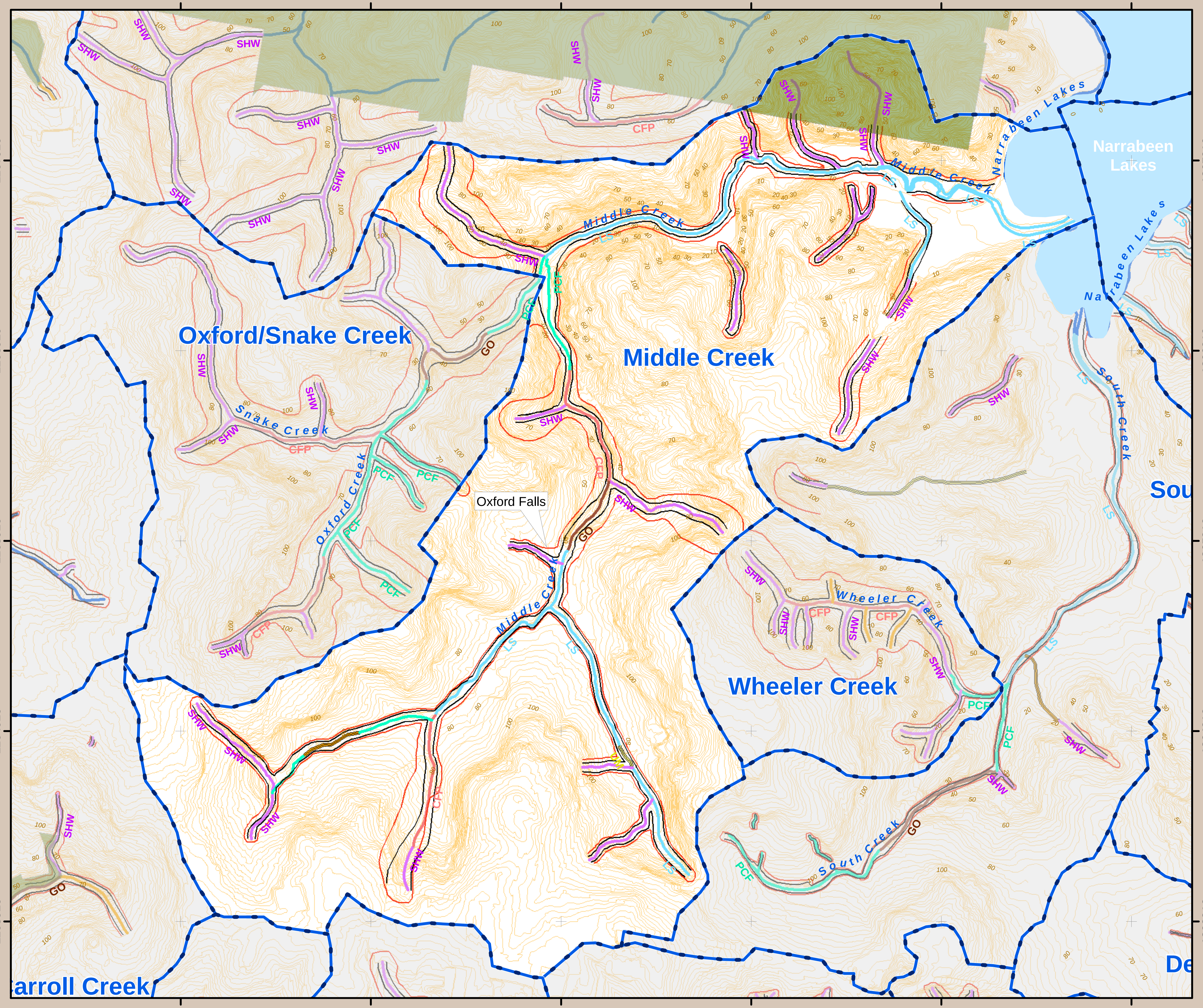

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Reserve
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council Warringah Creek Management Study

MIDDLE CREEK

Figure B13.2

N

0 200 400 600 800 Meters

Source: Contours, Imagery, DCDB, Lga and catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 Topographic data. Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56

Habitat of moderate ecological value still exists along the downstream reaches of Middle Creek, although this is compromised by the high level of weed invasion due partly to past land use practices in the floodplain.

12.2 Water Quality

Water quality samples taken from the upper reaches of Middle Creek as part of the present study indicate that, upstream of Oxford Falls Road, the system contains relatively high concentrations of suspended solids. Concentrations of total and dissolved nitrogen were slightly higher than the recommended guidelines, although low relative to some other creeks surrounded by urban development. Concentrations of both phosphorus forms and biological oxygen demand were also relatively low or undetectable. Similar results were obtained by Laxton (2000) in both the upper and lower reaches of Middle Creek as part of a longer term study, although the concentration of suspended solids appears to be relatively low most of the time. That study also found that the lower reaches could be suitable for primary contact recreation, although only secondary contact activities were recommended for the upper reaches.

The likely source of elevated pollutant levels in the upper reaches is runoff from urban development within the suburbs of Frenchs Forest and Oxford Falls. Similar results obtained downstream suggest that concentrations do not appear to be attenuated by in-stream processes.

12.3 Risks

Within the urbanised areas of the sub-catchment, the interruption of the riparian zone and increases in imperviousness have led to weed infestation, bank erosion and altered local flow conditions. While these processes threaten the value of rehabilitated areas within the upper reaches, the most significant problems will occur if large amounts of weed propagules, sediments and pollutants continue to be transported further downstream into more natural areas. For example, the continuing presence of less robust native species along the mid-stream reaches would be eliminated if degradation were to occur. Risks to the most downstream sections are considered relatively insignificant due to the vast extent of current weed infestation and limited environmental value.

12.4 Recommendations

In the short term, it is recommended that further development within the Middle Creek catchment be limited on undeveloped tributaries and any approved developments should require the incorporation of WSUD principles. While it is acknowledged that limited, cost-effective, ecological benefits are to be gained from attempting rehabilitation at the more seriously degraded sites within the sub-catchment (particularly downstream), weed removal, riparian revegetation and bank stabilisation strategies will eventually be required to reduce weed propagule and sediment supply to the creek channel and Narrabeen Lagoon. Such activities should commence in upper reaches where either rehabilitation activities are already occurring, some reasonable natural habitat or other important features still exist, or high values exist immediately downstream. For example, the engineered channel running through the Australian Tennis Academy (upstream of Wearden Road) is of an inadequate size for existing flows and should be removed and replaced with appropriate stream stabilisation measures (eg. sandstone boulders and revegetation such as exists downstream). In addition, flooding often occurs along Middle Creek forcing the closure of Wakehurst Parkway and any rehabilitation works in the lower reaches would need to consider this in the design.

Other medium to long-term recommendations include:

- Preparation of a creek management plan in conjunction with Snake and Oxford Creeks (see Section 13);
- Educating residents about plant selection and garden waste management; and
- Considering the construction of a recreational trail in public land from Narrabeen Lagoon to Oxford Falls to improve recreational values associated with the system and provide access for rehabilitation.

13. Oxford Creek

The Oxford Creek sub-catchment drains an area of approximately 420 ha. The main stream originates from two major tributaries (Snake Creek and Oxford Creek) within the rural area of Belrose and the residential area of Frenchs Forest (East of Forest Way). These steep, confined headwaters join immediately downstream of the Telstra and Optus Satellite Earth Station to form a system of gorges and bedrock, controlled, discontinuous floodplains. The creek joins Middle Creek within the Oxford Falls Recreation Reserve, adjacent to the Wakehurst Parkway (Figures B14.1 and B14.2). The sub-catchment is predominantly non-urban and between 10-15% impervious.

Weed infestation along Oxford Creek

Waterfall on Oxford Creek

13.1 Values

Environmental values vary between reaches within the sub-catchment, owing mostly to the varied extent of weed infestation and proximity to areas cleared for agricultural purposes. High landscape value and fine examples of native streamside vegetation of the area can be observed in the vicinity of the waterfall on Oxford Creek at the upstream end of the Middle Creek Recreation Reserve, with good connectivity, composition, abundance and diversity. This provides natural habitat for native fauna, which accommodates high species richness and abundance. The potential for dispersal of terrestrial native species and refuge habitat is also generally high.

Environmental values are relatively poor in areas where natural catchment land use has been lost, such as the eastern side of the channel at the corner of Oxford and Morgan Roads which has been cleared for agriculture.

13.2 Water Quality

With the exception of the upper tributaries of Deep Creek, samples taken from upper Snake Creek (downstream of the retirement village) contained the best overall water

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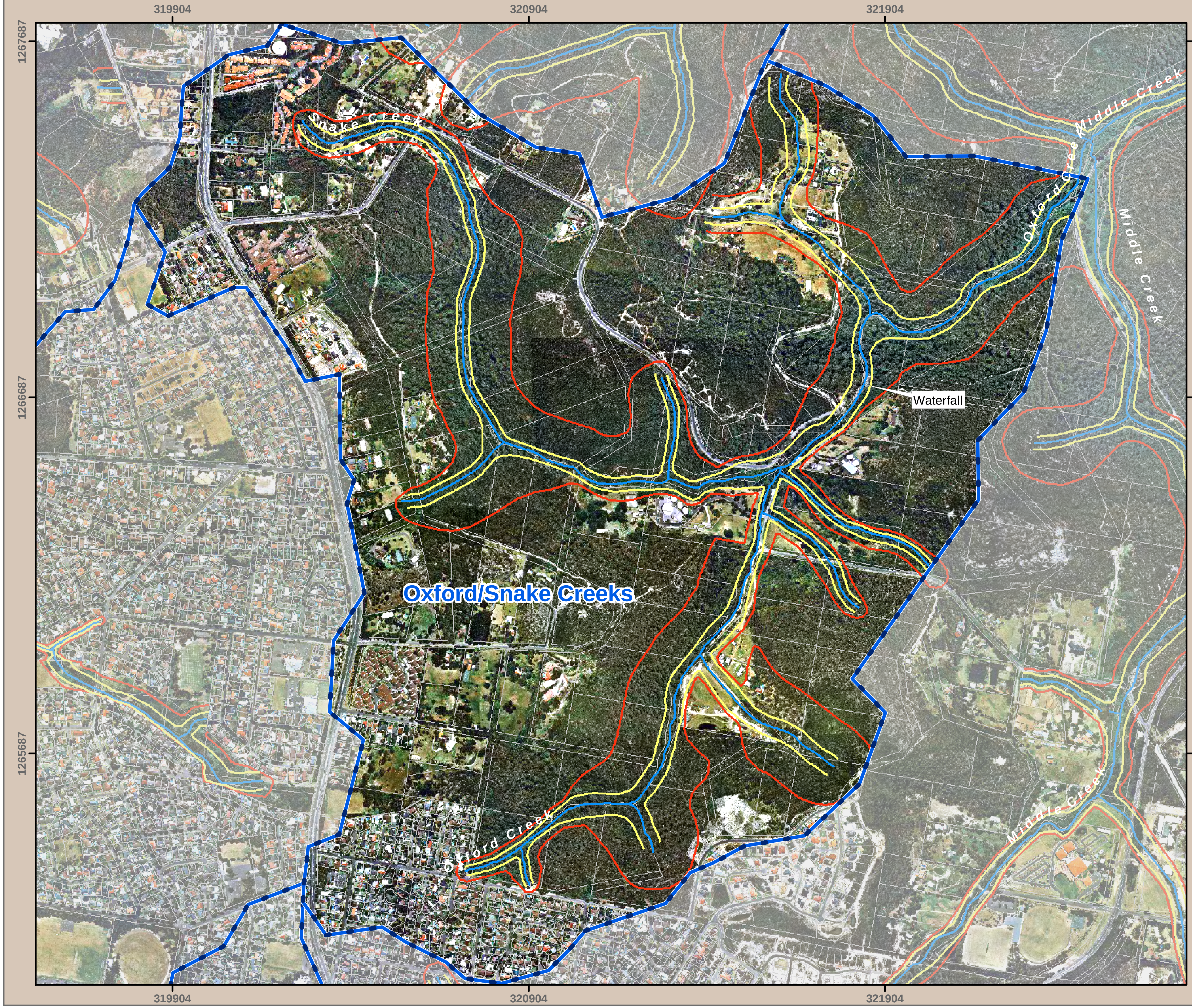

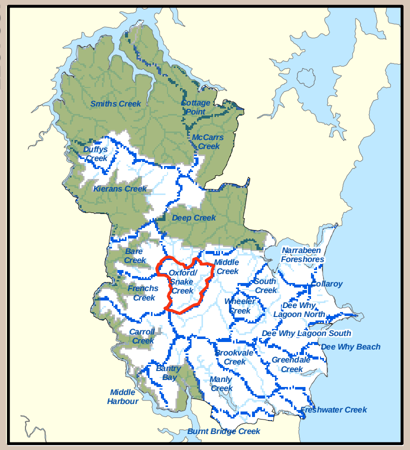

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek Management Study

OXFORD/SNAKE CREEKS

Figure B14.1

N

0 50 100 200 300 400 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 Topographic data. Drainage and riparian buffers from MWH
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Warringah Council

MWH

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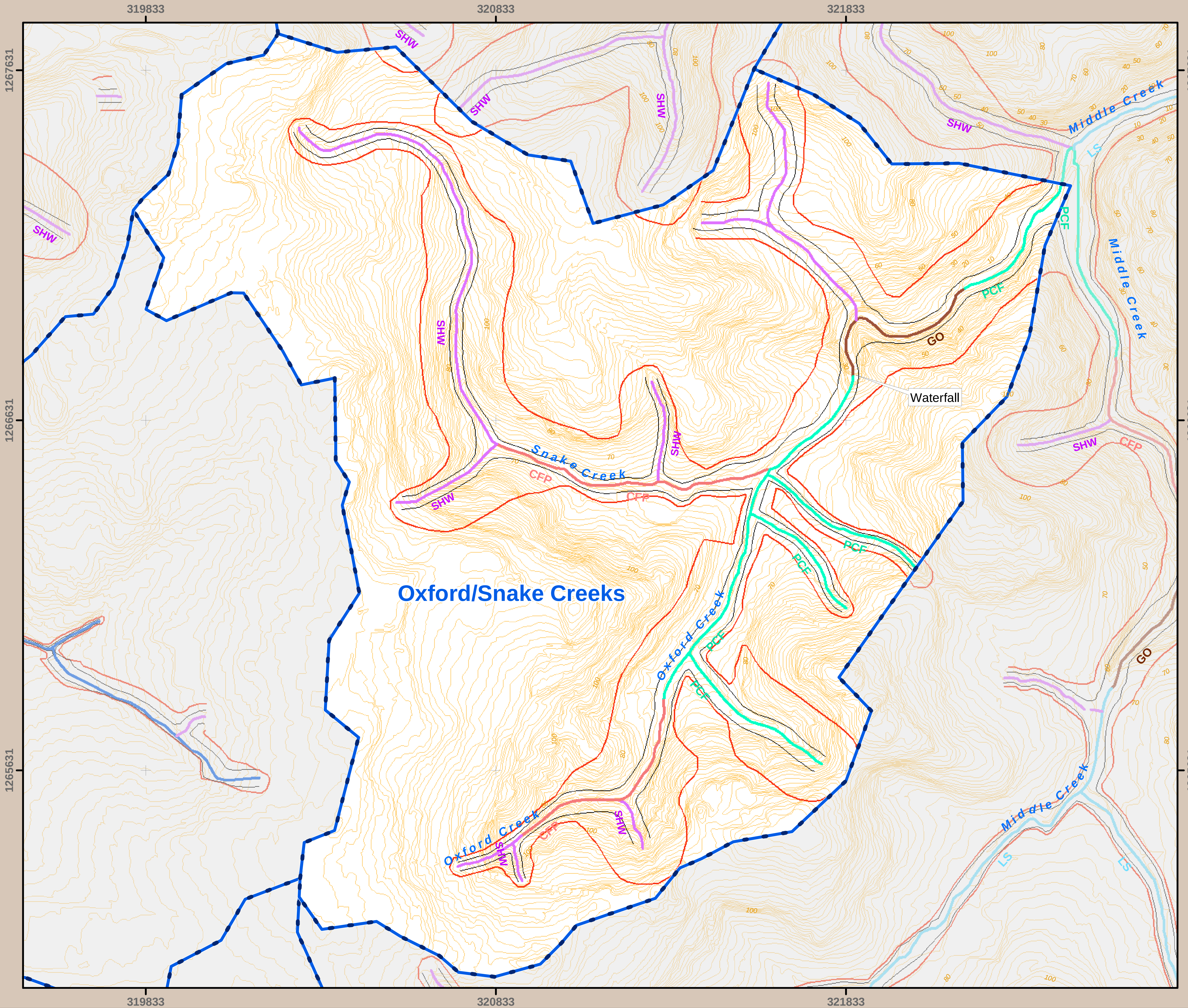


Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek
Management Study

OXFORD/SNAKE CREEKS

Figure B14.2

0 100 200 300 400 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 Topographic data. Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56

Warringah Council
MWH

quality of all creeks within the study area. In particular, the site had the clearest water (i.e. the concentration of suspended solids was the lowest recorded) and the only parameter with a concentration above the recommended guideline was dissolved nitrogen. All other pollutants were undetectable or very low.

13.3 Risks

Whilst runoff from agricultural properties may impact on water quality and the transport of weed propagules from degraded areas may lead to invasion of pristine areas in the long-term, the most significant risk to the sub-catchment as a whole is future urbanisation. This is a sensitive issue for the community because under the current LEP, much of the non-urban land on the fringe of existing residential districts is prone to future development. Already the extension of a retirement village above the headwaters of Snake Creek has been proposed while a major residential development has been approved in the watershed between Oxford and Snake Creeks (Perentie and Dawes Roads). Without appropriate management, such developments not only contribute additional sediments, nutrients and weed propagules to the system, but the increase in imperviousness and removal of natural buffers act as catalysts for existing processes of degradation.

13.4 Recommendations

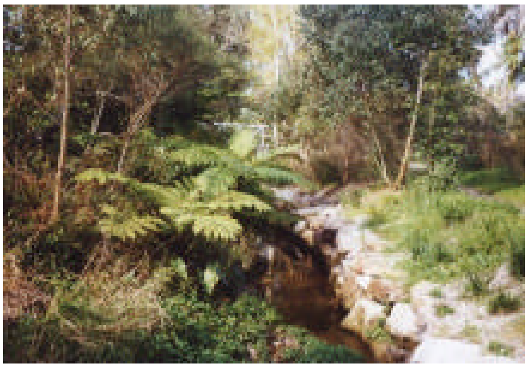
The limited extent of existing development in the Oxford Creek sub-catchment provides an excellent opportunity for innovative approaches to environmental management, including the incorporation of WSUD principles into any future residential estates and the installation of sediment control measure downstream of development sites. In the longer term, the following activities are recommended:

- Preparation of a creek management plan in conjunction with Middle Creek;
- Educating residents about plant selection and garden waste management; and
- Riparian revegetation and weed removal in degraded areas.

Such activities will help to ensure adequate management of the system before irreversible damage occurs.

14. South Creek

The South Creek sub-catchment covers an area of approximately 600 ha. From its headwaters at Beacon Hill, South Creek flows through a bedrock controlled, discontinuous floodplain before adjoining its major tributary, Wheeler Creek, at Narraweena. The system then changes to an alluvial floodplain and eventually flows into the South-Western corner of Narrabeen Lagoon, adjacent to Cromer Golf Course (Figures B15.1 and B15.2). The total length of the main stream is approximately 5km. The majority of the subcatchment is urbanised, particularly to the South and East of the main channel, and is over 40% impervious.



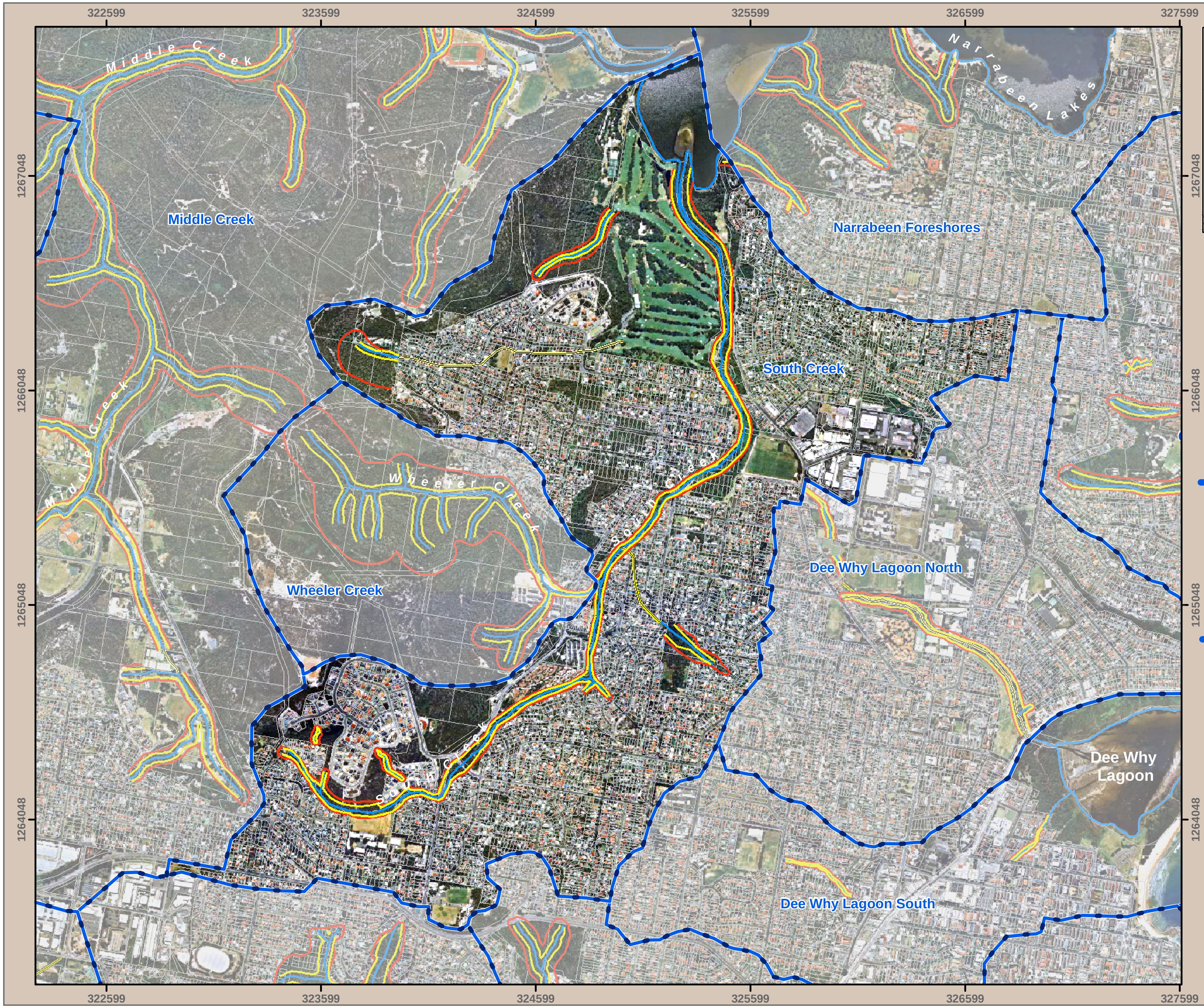
Upper South Creek near Beacon Hill High School

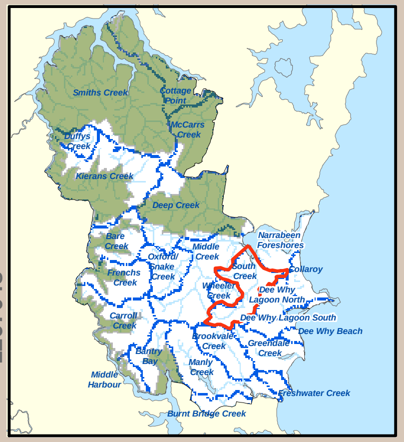
Lower South Creek at Cromer

14.1 Values

Only a small percentage of the South Creek sub-catchment is natural bushland and riparian vegetation has largely been replaced by mown grassland. However, the channel itself has not been modified, apart from several road crossings, an in-stream Gross Pollutant Trap and rock reinforcement of eroding banks. The geomorphology of the channel is of high value because it represents a once common stream type that is now rare in urban areas.

The open space corridor present for the majority of the length of the creek is considered to have moderate to high environmental value as a core habitat and potentially important wildlife corridor, linking the Dee Why Valley to the East with Garigal National Park to the North (Clouston, 1996; Warringah Council, 1998b). Previous reports also suggest that the headwaters within Red Hill are potential habitat for two vulnerable frog species (Smith, 1998 – Appendix C in Red Hill report) and regionally significant communities of Swamp Mahogany exist near the entrance to Narrabeen Lagoon (LandArc Landscape, 2000). Natural catchment land use has been partially retained in these upper reaches with some remnant stands of native vegetation, although the riparian zone is discontinuous due to interruptions by mowing and manicuring.





Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek Management Study

SOUTH CREEK

Figure B15.1

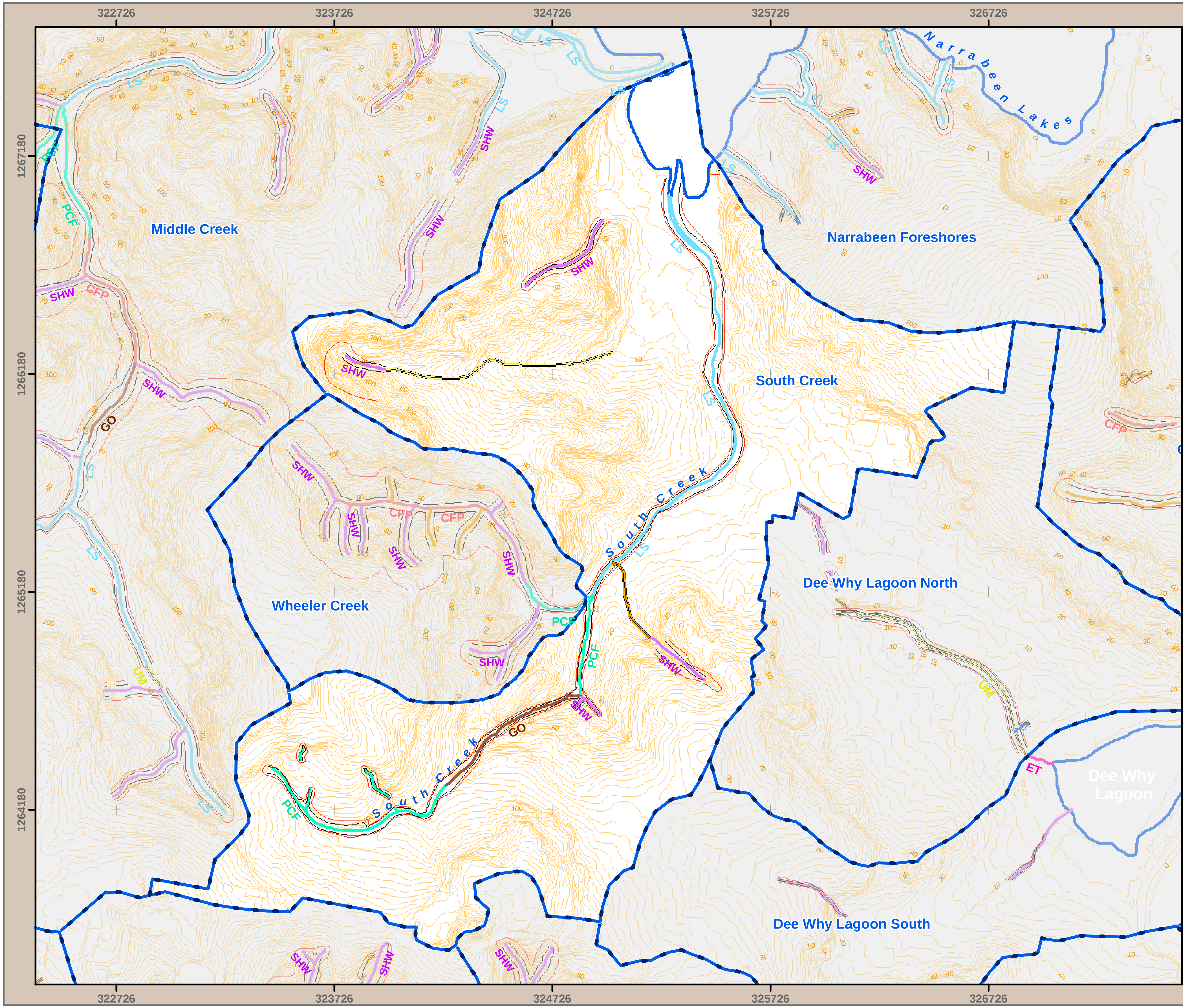
N

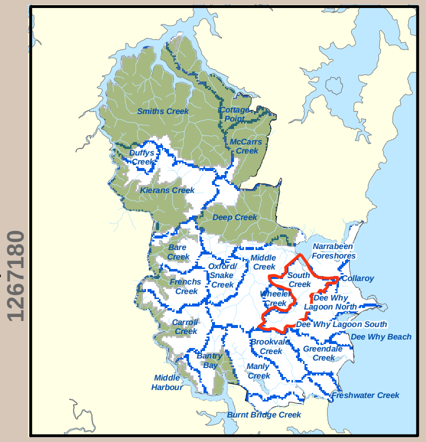
0 150 300 450 600 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 topographic data.
Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56

MARCH 04, 2004
\\PROJECTS\831-00007\GIS\SALL_EWARRINGAHSOUTH_A3P.MXD

Produced in ArcMap 8 by MWH Environmental Division





Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek Management Study

SOUTH CREEK

Figure B15.2

N

0 150 300 450 600 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 topographic data. Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56

Warringah Council
MWH

MARCH 04, 2004
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High continuity can be observed in some mid-stream sections, with high species richness associated with fine examples of moist forest. However, the riparian zone has been overrun by exotics in places, leading to very low habitat availability, poor native species richness and low landscape value. Recreational value is also generally low, although there is potential for recreational linkages between Jamieson Park and the Western shoreline of Narrabeen Lagoon through to Garigal National Park (LandArc Landscape, 2000).

14.2 Water Quality

Long-term monitoring results obtained by Laxton (2000) indicate that the upper and lower reaches of South Creek have similar water quality, with concentrations of total and dissolved nitrogen and total phosphorus all exceeding recommended guidelines. The results also indicate that, within the Warringah LGA, South Creek contributes the worst water quality to Narrabeen lagoon, although pollutant levels are low relative to most other creeks within highly urbanised sub-catchments of the study area. Faecal coliform counts suggest that the upper reaches are suitable for primary contact recreation, while only secondary contact activities are recommended further downstream.

The most likely pollutant source is runoff from adjacent urban areas within Cromer, Narraweena and Beacon Hill. As for Middle Creek, similar results obtained upstream and downstream suggest that concentrations do not appear to be attenuated by in-stream processes.

14.3 Risks

The South Creek Catchment and riparian zone have been extensively modified. Extensive loss of the riparian canopy along South Creek has facilitated weed invasion and increased bank erosion and downstream sedimentation, while higher sub-catchment imperviousness has also led to bank erosion and increased pollutant loads. These processes pose a serious threat to the few natural ecological and landscape features remaining along the creek line.

14.4 Recommendations

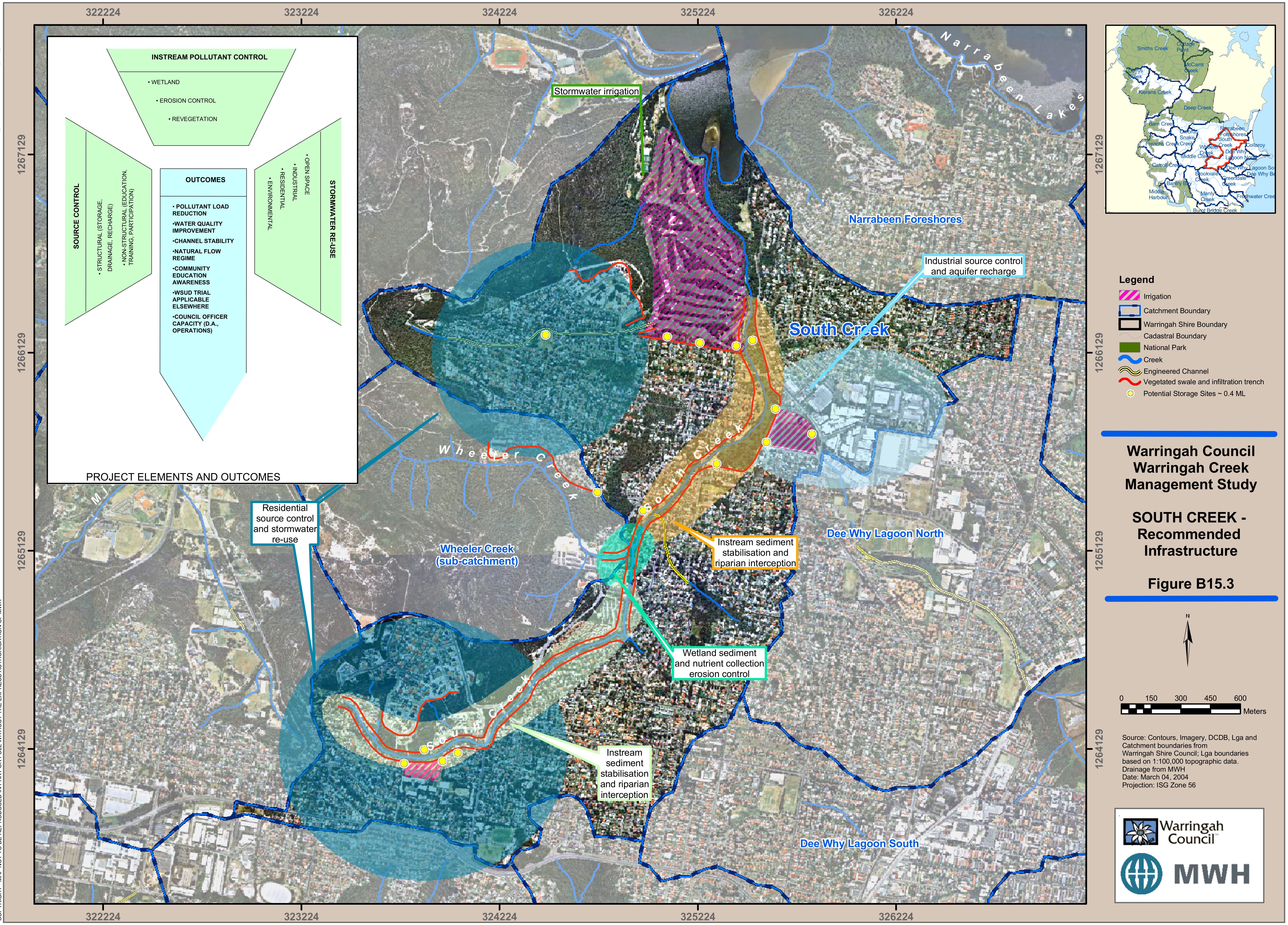
Whilst channel erosion and local flooding will continue to threaten the system, increases in peak flows have widened and incised the creek in some areas and bank stabilisation works and revegetation may therefore not be viable in the long term. Channel widening to accommodate the flows is also not desirable because it would encroach on public lands and private properties. Consequently, in stream works need to be augmented with controls on future development and catchment works to decouple drainage systems.

Specific recommendations are to:

- Prepare a creek management plan;

- Educate residents about plant selection and garden waste management and educate residential, commercial and industrial landholders about at0source stormwater management;
- Introduce water sensitive urban design practices to future developments to prevent further increases in peak flows and sediment transport;
- Investigate opportunities for 'retrofitting' source controls into upper catchment areas. This may include detention and infiltration basins, household storage tanks and swale drainage (note: there may also be opportunities for re-use of stored or re-charged water which may help to defray costs);
- Continue the staged program of erosion control, weeding and revegetation, generally from upstream to downstream over the next several years. The reaches upstream of the Wheeler creek confluence have higher environmental values and weed and erosion problems are less complex to manage;
- Remove sediment from the channel and construct an artificial wetland at the confluence of South and Wheeler Creeks. This can be combined with erosion control works and weed removal in the Wheeler Creek channel to stabilise erosion of the western bank; and
- Provide a track and encourage pedestrian access along the length of the creek corridor from Narrabeen Lagoon to Beacon Hill.

A major rehabilitation program was proposed as part of a 2002 Stormwater Trust grant application (see Figure B15.3). Though the application was not successful, there was strong community support for the concept and the Trust has asked that a future application be made with a more staged approach. The grant application can serve as a guide for the proposed Creek Management Plan.



322224
323224
324224
325224
326224
1267129
1266129
1265129
1264129
INSTREAM POLLUTANT CONTROL
• WETLAND
• EROSION CONTROL
• REVEGETATION
SOURCE CONTROL
• STRUCTURAL (STORAGE, DRAINAGE, RECHARGE)
• NON-STRUCTURAL (EDUCATION, TRAINING, PARTICIPATION)
OUTCOMES
• POLLUTANT LOAD REDUCTION
•WATER QUALITY IMPROVEMENT
•CHANNEL STABILITY
•NATURAL FLOW REGIME
•COMMUNITY EDUCATION AWARENESS
•WSUD TRIAL APPLICABLE ELSEWHERE
•COUNCIL OFFICER CAPACITY (D.A., OPERATIONS)
STORMWATER RE-USE
• OPEN SPACE
• INDUSTRIAL
• RESIDENTIAL
• ENVIRONMENTAL
PROJECT ELEMENTS AND OUTCOMES
Stormwater irrigation
Narrabeen Lakes
Narrabeen Foreshores
Industrial source control and aquifer recharge
South Creek
Wheeler Creek
South Creek
Residential source control and stormwater re-use
Instream sediment stabilisation and riparian interception
Wheeler Creek (sub-catchment)
Dee Why Lagoon North
Wetland sediment and nutrient collection erosion control
Instream sediment stabilisation and riparian interception
Dee Why Lagoon South
Legend
Irrigation
Catchment Boundary
Warringah Shire Boundary
Cadastral Boundary
National Park
Creek
Engineered Channel
Vegetated swale and infiltration trench
Potential Storage Sites ~ 0.4 ML
Warringah Council
Warringah Creek
Management Study
SOUTH CREEK -
Recommended
Infrastructure
Figure B15.3
N
0 150 300 450 600
Meters
Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Shire Council; Lga boundaries based on 1:100,000 topographic data.
Drainage from MWH
Date: March 04, 2004
Projection: ISG Zone 56
Warringah Council
MWH

15. Wheeler Creek

Wheeler Creek is the major tributary of South Creek, running east from Cromer Heights to the confluence at Narraweena (Figure B16.1). The system is characterised by steep, confined headwaters with occasional floodplain pockets (Figure B16.2). The sub-catchment covers an area of approximately 160 ha. Unlike South Creek, the Wheeler Creek sub-catchment is dominated by non-urban land and is less than 10 % impervious.

Wheeler Creek upstream from development

Wheeler Creek near South Creek Confluence

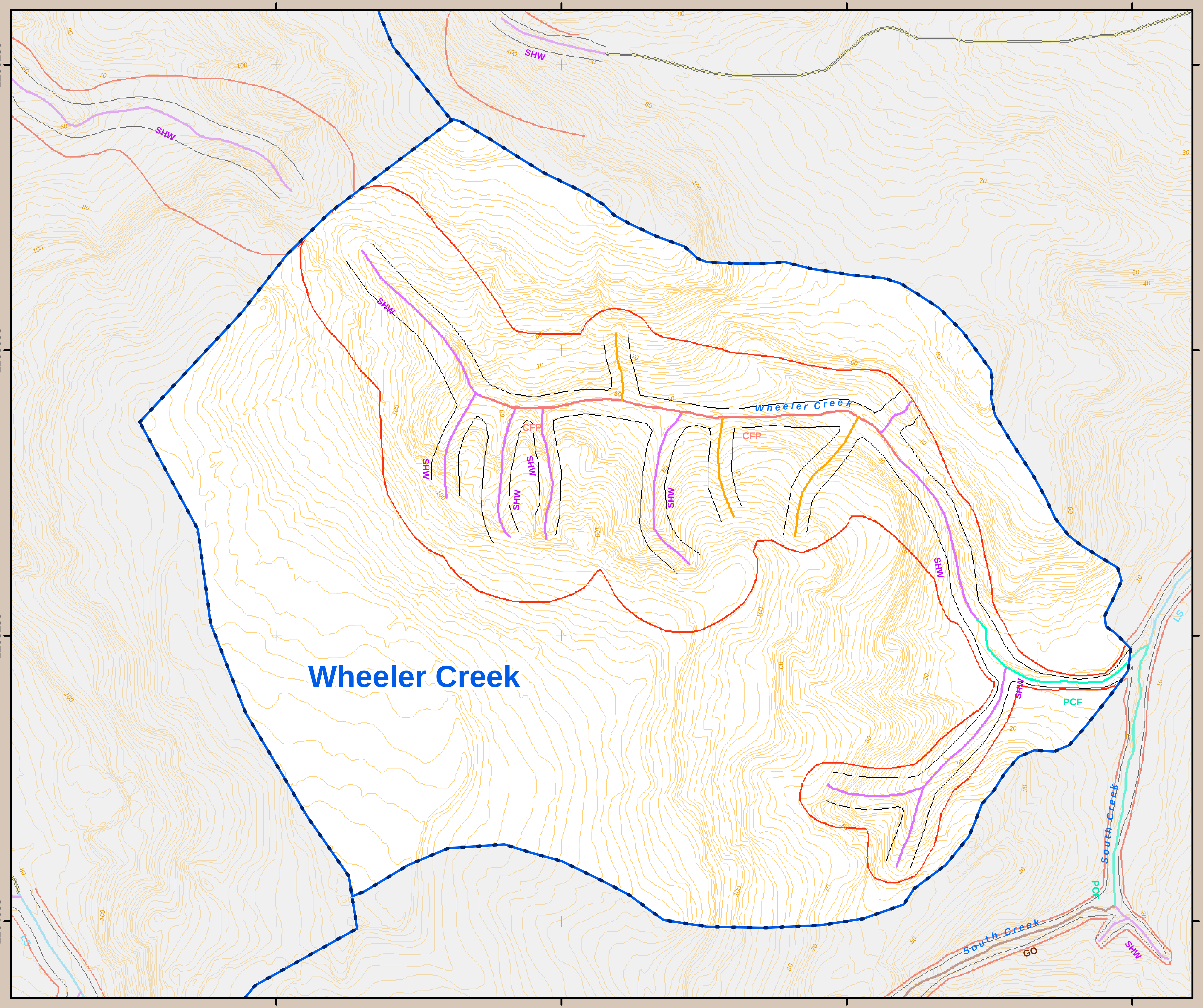
15.1 Values

Although natural catchment land use has been altered in Cromer Heights, the majority of the Wheeler Creek sub-catchment is characterised by natural vegetation with a very high degree of continuity, canopy cover, native species richness and community composition. This provides excellent potential for dispersal and refuge for native fauna. The creek itself also provides habitat for a number of important species, including the endangered Red-crowned toadlet, *Pseudophyrne australis* and Giant Burrowing Frog, *Heleioporous australis* (NPA NSW, 2001). The upper and middle reaches are also fine examples of creeks with high Dry Sclerophyll and riparian native species diversity that is only compromised by development on the northern side. In addition, the creek valley has significant cultural heritage values and is actively used for recreation.

As the creek approaches the confluence with South Creek, natural catchment land use is lost with almost entire removal of native creek line vegetation and associated value as a result of recent development. Community members have therefore indicated a strong preference to protect the creek's values and to rehabilitate degraded tributaries and the lower reaches. The National Park Association has already coordinated two biodiversity surveys and tributary rehabilitation.

MARCH 04, 2004

Produced in ArcMap 8 by MWH Environmental Division



Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek
Management Study

WHEELER CREEK

Figure B16.2

N

0 75 150 225 300 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 Topographic data. Drainage and riparian buffers from MWH
Date:March 04, 2004
Projection: ISG Zone 56

Warringah Council

MWH

MARCH 04, 2004
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Produced in ArcMap 8 by MWH Environmental Division

15.2 Water Quality

Samples taken immediately upstream and downstream of development at Maybrook Avenue suggest that altered land use in Cromer Heights appears to have had no significant impact on water quality in the upper reaches. For both sites, concentrations of total and dissolved oxygen were only just above the recommended guidelines, while concentrations of total and dissolved phosphorus and biological oxygen demand were below detection limits. Surprisingly, suspended solids concentrations were high relative to most other sites sampled within the study area. The source of the material is unknown, although it is unlikely to be from human influences.

Sampling undertaken by Laxton (2000) immediately upstream of Little Willandra Road suggests that suspended solids concentrations within the system are typically lower in the long-term. However, these results also indicate that concentrations of total and dissolved nitrogen and total phosphorus are typically higher. Unlike the upper reaches, however, these higher levels may be influenced by runoff from developed (residential) areas in the lower catchment.

15.3 Risks

Recent clearing and associated development in the lower reaches of the creek has demonstrably increased the risk of weed invasion and polluted runoff entering the natural areas further south. The consequences of these disturbances are all ready evident, particularly near the South Creek confluence. Casual observation of these degraded lower reaches provides a graphic illustration of the potential fate of the remainder of this rare example of a natural creek so close to urban areas.

The major threat in future is the potential for large-scale SEPP5 developments in the currently untouched catchment areas. Even with riparian buffers and inclusion of WSUD and strict development controls, it is likely that the integrity of the creek would be significantly and irreversibly damaged. Without rehabilitation of the lower creek, changes in natural flow conditions, poor connectivity of riparian vegetation and barriers to fish passage may result in the isolation of the upper system and prevent important interactions with the South Creek and Narrabeen Lagoon systems.

15.4 Recommendations

It is recommended that future development be strictly limited within the Wheeler Creek sub-catchment. A Creek Management Plan is also recommended to provide for rehabilitation of the lower reaches, in conjunction with protection of the remaining catchment. This would involve negotiation with property owners to revegetate disturbed riparian zones and re-routing stormwater pipes currently emptying into the channel via bio-retention systems to reduce sediment loads. Erosion control works and a weed and sediment removal program will also be required, while the installation of a wetland (with provision for fish passage) would help to capture nutrients and sediments, without compromising connectivity.

16. Narrabeen Foreshores

The Narrabeen Foreshores sub-catchment encompasses the small pocket of land between the mouth of South Creek and the northern edge of the Collaroy Plateau. This covers an area of approximately 270 ha, which is drained by a number of independent waterways originating in the vicinity of the War Veterans Home at Wheeler Heights and flowing through Jamieson Park before entering into the southern edge of Narrabeen Lagoon (Figure B17.1). The system is characterised by steep headwaters and alluvial floodplains (Figure B17.2). The sub-catchment is over 40% impervious and is a combination of residential development to the south and open space/bushland to the north.

16.1 Values

The only retention of natural ecological features within the Narrabeen Foreshores sub-catchment occurs within specific areas of Jamieson Park. While the majority of the reserve is covered by dense, weedy vegetation, expanses of native bushland still exist, including numerous Swamp Mahoganies (a significant winter flowering species for native fauna) and relict communities of threatened Sydney Coastal Estuary Swamp Forest. There is also some potential for dispersal of native terrestrial species, although poor refuge for native fauna (except for those tolerant of degraded environments) exists in the creek line areas themselves. Landscape and recreational value is considered to be moderate-high in these areas, although the latter may be attributed to the proximity of the Lagoon, rather than the creek environment.

16.2 Risks

While runoff from urban areas is an ongoing risk to water quality, the main threat to existing fauna habitat is recent disturbance, such as expansion of existing development on the fringe of the park and progressive degradation of adjacent bushland through weed infestation. These will ultimately lead to complete replacement of remnant native communities with exotics due to a lack of regeneration opportunities. In particular, rarity values are at risk from long-term loss of species indicative of the threatened swamp forest complex.

16.3 Recommendations

Exotic vegetation needs to be managed in the reserve to prevent encroachment into adjacent bushland in relatively good condition. Threatened native communities warrant specific protection against weed infestation and future development to ensure adequate opportunities for regeneration.

Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council Warringah Creek Management Study

NARRABEEN FORESHORES

Figure B17.1

N

0 150 300 450 600 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 Topographic data. Drainage and riparian buffers from MWH
Date: March 04, 2004
Projection: ISG Zone 56

MARCH 04, 2004
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MARCH 04, 2004
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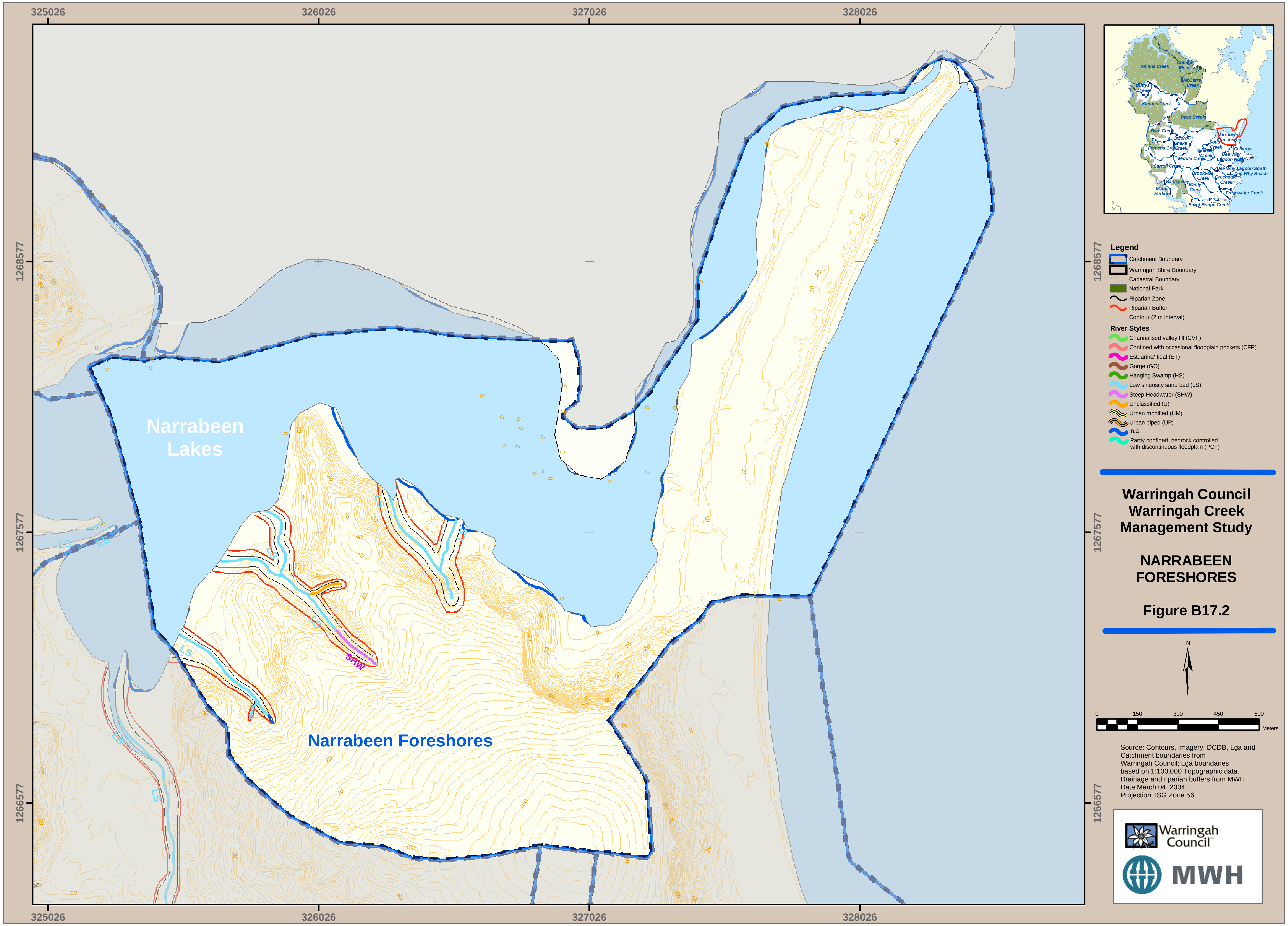


17. Collaroy Creeks

Three creek lines have been identified running from the Collaroy Plateau - two along either side of the Salvation Army Centre (running parallel to Alexander Street and running through the recreation reserve adjacent to Kent Street, respectively) and the other running from Edgecliffe Boulevard to The Avenue (Figures B18.1). These are confined systems with occasionally floodplain pockets, eventually discharge onto Collaroy beach to the north of Long Reef Golf Course (Figures B18.2). The entire Collaroy sub-catchment is over 40 % impervious with suburban development dominating the landscape.

17.1 Values

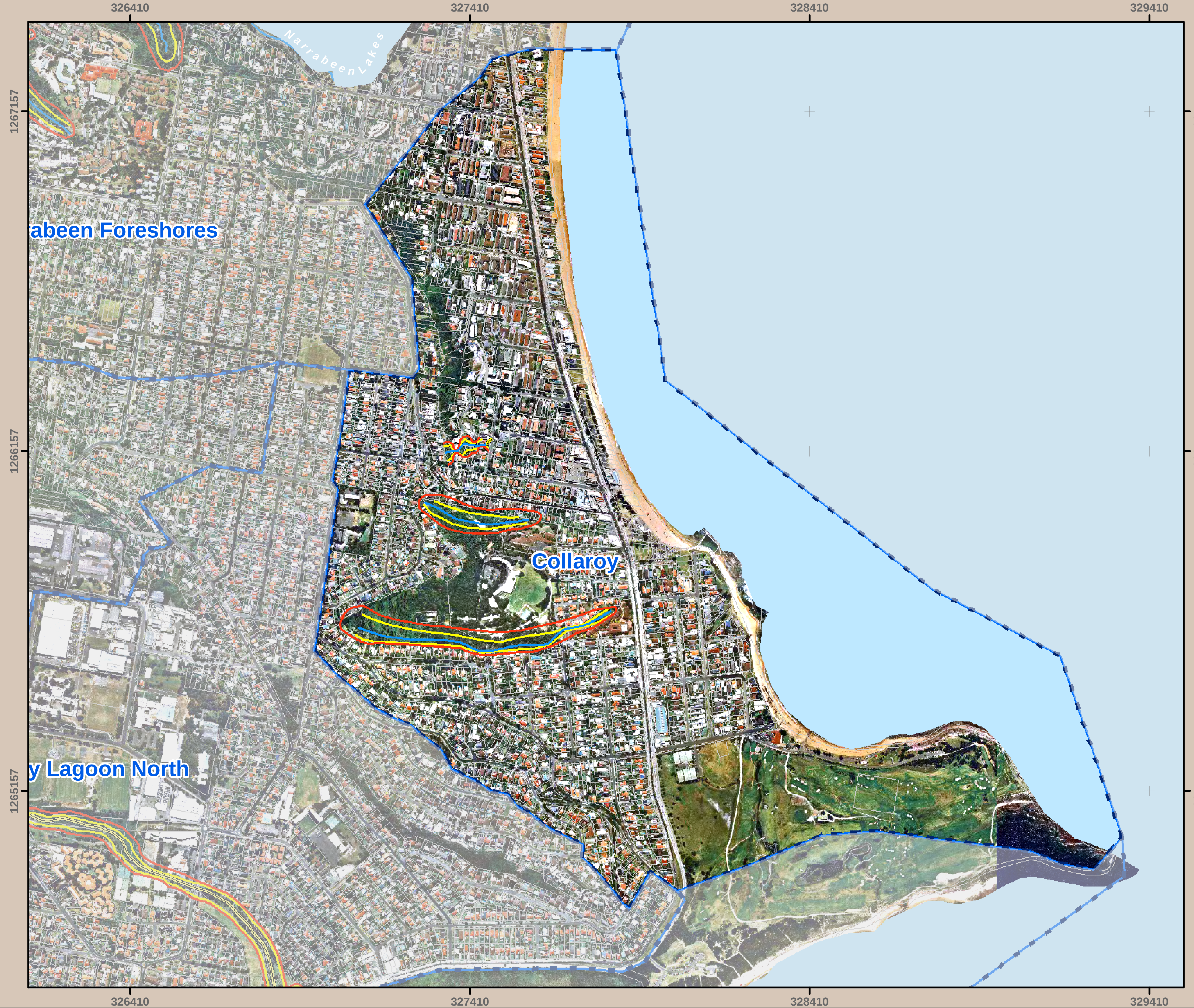
Recent observations suggest that some natural catchment land use has been retained along the creek lines and environmental values within the floodplain are in fairly good condition, despite the surrounding urbanisation. For example, the creek system running through the recreation reserve adjacent to Kent Street has retained moderate connectivity and native species richness in the floodplain and good quality habitat for dispersal and refuge of native fauna. Although the majority of the riparian zone is heavily weed infested, an unusual transitional community has been retained on the floodplain, containing rainforest, swamp forest and coastal dry sclerophyll elements. This includes Swamp Mahogany trees, which are a significant winter flowering species for native fauna, and coastal banksia trees, which are typical of coastal/sandy habitats. The creek systems also provide landscape and recreational value, in contrast to the predominantly urban landscape of the catchment.

17.2 Risks

Any remnant natural floodplain elements associated with the creeks within the Collaroy sub-catchment are threatened by the progressive invasion of weeds. In the long term, simplification of the representative, native vegetation (such as the moist forest transitional character of the Kent Street site) will lower species diversity and reduce the quality of habitat for native fauna.

17.3 Recommendations

The creek lines appear to be stable and may be able to cope with mass weed eradication. Community rehabilitation activities are already taking place in the upstream section of the reserve adjacent to Kent Street and weed infested areas could be included in the program.



Legend

- Adjacent Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Creek or open channel
- Engineered Channel

Warringah Council
Warringah Creek
Management Study

COLLAROY

Figure B18.1

N

0 120 240 360 480 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 Topographic data. Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council

MWH

MARCH 03, 2004
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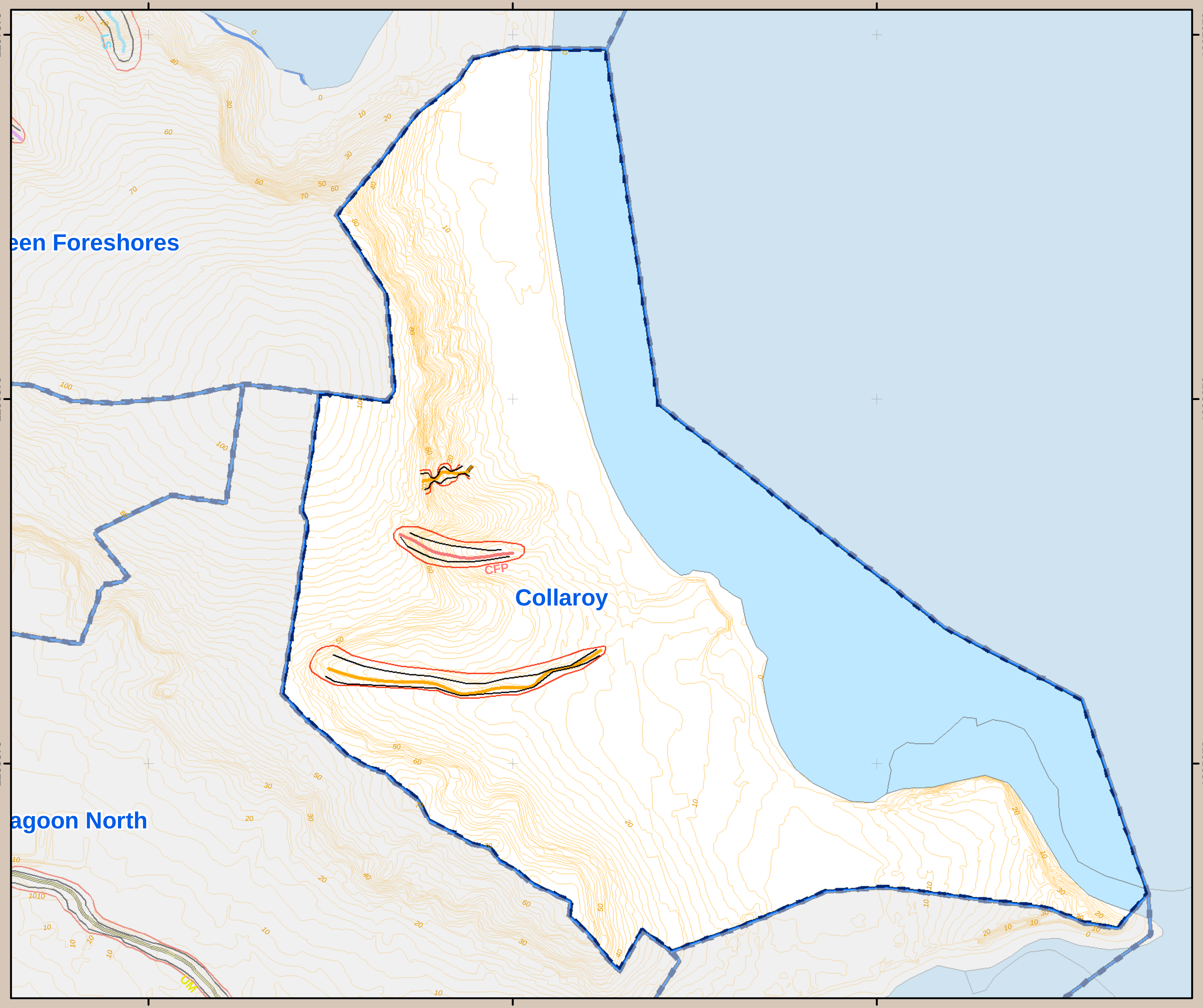
Produced in ArcMap 8 by MWH Environmental Division



Legend

- Catchment Boundary
- Warringah Shire Boundary
- Cadastral Boundary
- National Park
- Riparian Zone
- Riparian Buffer
- Contour (2 m interval)

River Styles

- Channalised valley fill (CVF)
- Confined with occasional floodplain pockets (CFP)
- Estuarine/ tidal (ET)
- Gorge (GO)
- Hanging Swamp (HS)
- Low sinuosity sand bed (LS)
- Steep Headwater (SHW)
- Unclassified (U)
- Urban modified (UM)
- Urban piped (UP)
- n.a
- Partly confined, bedrock controlled with discontinuous floodplain (PCF)

Warringah Council
Warringah Creek Management Study

COLLAROY

Figure B18.2

N

0 120 240 360 480 Meters

Source: Contours, Imagery, DCDB, Lga and Catchment boundaries from Warringah Council; Lga boundaries based on 1:100,000 topographic data. Drainage and riparian buffers from MWH
Date: March 03, 2004
Projection: ISG Zone 56

Warringah Council
MWH

MARCH 03, 2004

Produced in ArcMap 8 by MWH Environmental Division

Appendix B1

Reach Values Analyses

Kierans Creek – Cnr Aumuna Rd and Larool Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
1.1	• Site consists of two reaches. Upstream reach is a channelised valley fill, that drains into a steep headwater • Upstream reach is laterally stable channel, 1-5m wide, and < 1m deep, bedrock steps create a series of small cascades and plunge pools. Short pool-riffle (<5m) sequences occur between sets of bedrock steps. Reach is flanked by narrow modified floodplain. Valley slope is very shallow • As valley width constricts the channel moves into a steep headwater setting. The transition from channelised valley fill to steep headwater is market by a broad sandstone platform which falls away into waterfalls, cascades, plunge pools and pseudo pool-riffle sequences (15-20m).	• Upstream of falls riparian vegetation is mostly exotic and poorly connected on the floodplain (mown grass). • The land upstream of the bedrock platform has been landscaped for the nursing home. • A road crosses the stream that is fitted with a GPT. The GPT is very full and very dirty; sediment rich water is emptying into it. Although the GPT is collecting this sediment, the stream downstream of it is discoloured and has a foul odour. • Minor sedimentation occurring in channel due to runoff from roadwork's • GPT forms barrier to fish movement • Low Native Species Richness, minimal canopy cover, narrow riparian width, abundant weeds • Some remnant native species on upstream side of road. • Poor native fauna habitat (Pardalote, Raven, Kookaburra and Red-whiskered Bulbul) • Within the gorge setting there is good native vegetation diversity and connectivity.	• Run-off from urban development producing foam and depositing silt in the channel. • GPT is a threat to fish passage but of benefit in reducing silt and gross pollutants • Water Pollution/Weeds are a threat to remnant native species • Possible illegal water discharges to creek line; Tannins, Sewage, Detergents and Silt apparently present • Upstream of National Park (KCNP) • Poor habitat for dispersal of native species. • Mowing of the lawn too close to the riparian zone could also be a potential threat. • Water Pollution/Weeds are a threat to native species/habitats/communities in KCNP • Vegetation remaining in upper reach threatened by runoff, poor water quality and continuing substitution of native species by weeds.	Naturalness: 2 Representativeness: 2 Diversity: 2 Rarity: 1 Special Features: 1 **Overall Ecological Value: 1.6**	• GPT requires more frequent maintenance and cleaning. • Road works and building developments need to be fitted with adequate sediment traps. These need to be maintained.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Neverfail Gully – Kinma State School, Coolowie Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
1.1.4	• Steep headwater bedrock channel 4-5m wide, <1m deep. • Swamp (weed dominated) located upstream of road - • Channel characterised by series of broad bedrock steps scattered with accumulations of boulders (forming tunnels etc). Cascades, falls, plunge pools, chutes, short pool-riffle sequences (<10m) also characterise channel • Minor sediment accumulations present in pools or on the margins of riffles.	• Swamp located upstream of road -crossing is infested with exotic species • Bedrock channel is in good geomorphic condition with a diverse array of geomorphic units actively functioning. • Most sediment that is moved though the system is flushed out due to high flow velocities. • Natural vegetation retained on NW bank • Good connectivity of natural vegetation on adjacent valley slopes and within riparian zone on North West side of channel • Weeds are degrading good native species richness on southeast bank. • Moderately good habitat for fauna in floodplain zone on NW side • Site located upstream of Ku-ring-gai Chase National Park • Good potential for terrestrial species dispersal on NW side • Good refuge habitat on NW side for native species affected by landscape alteration	• Threatened by potential future clearing and/or development on western side of creek line, increased invasion of weeds and new farming activities in catchment • Remote runoff from rural land due to current farming in catchment may effect water quality • Potential threats to National Park due to runoff and decreasing water quality • Threat due to potential future fragmentation of corridor habitat	Naturalness: 3 Representativeness: 3 Diversity: 3 Rarity: 2 Special Features: 2 **Overall Ecological Value: 2.6**	• Weed infested swamp provides rich seed source that may be released in good condition reaches downstream in the national park. Staged weed eradication is necessary to reduce the likelihood of this occurring.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Duffys Creek – Booralie Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
1.2	• Transition from channelised valley fill to steep headwater type channel. Moderately steep channel 4-5 m wide with minor floodplain pockets transforms into a narrow very steep bedrock channel. • Broader upstream channel situated within horse paddock, modified and landscaped, two weirs hinder flow. Although channel has been altered is characterised by a series of shallow bedrock steps that form cascades and pools. • Steeper downstream reach characterised by steep valley walls and channel slope, boulders, bedrock steps forming cascades, falls, plunge pools, chutes, and short pool-riffle sequences (<10m). No floodplain apparent within this reach	• Upstream of road river character has been severely disturbed by landscaping. A pond and two concrete weirs have been formed across a first order stream. • Construction of weirs and dam prevent fish passage compromise natural habitat diversity • Natural catchment highly modified by clearing for rural residential development • Good vegetation connectivity in downstream reach, no connectivity upstream as vegetation has been modified to parkland. • Moderate species richness with moderate weed invasion Good fauna habitat on downstream side of road • Moderately high native species richness below road Upstream of KCNP conservation reserve. • Good potential for dispersal of terrestrial species downstream of road • Good local refuge on downstream side of road from altered landscapes on upstream side of road	• Possible illegal dam / weir. • Runoff from upstream semi-rural properties and import of weed propagules from gardens eg. Impatiens • Threats to water flow from dam Weed invasions, eutrophication and alteration of flow patterns. • Potential threats to national Park habitats due to runoff weed propagules and decreasing water quality and flow. • Remote runoff from human activities, intensified weed invasion, potential future fragmentation	Naturalness: 3 Representativeness: 3 Diversity: 3 Rarity: 2 Special Features: 2 **Overall Ecological Value: 2.6**	• Presence of dam and weirs may be illegal as constructed on a first order stream. Their presence changes flow patterns, water temperature and habitat diversity. Investigations need to be conducted to determine the effects of the structures and whether they can be allowed to remain. • Nuisance plants such as 'impatience' that have been deliberately planted near the creek need to be removed. • Bush regeneration to remove weed species from the steep headwater reach would be beneficial in reducing the likelihood of infestation within the national park. Access may be an issue as slopes are reasonably steep and rugged.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Dee Why Creek – Campbell Ave

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
3.1	• Channel is completely; Concrete canal • No geomorphic units apparent in channel • Floodplain altered into parkland, no remnant floodplain features present	• No natural catchment land-uses retained - highly urbanised and industrialised • No natural vegetation in floodplain - except for planted Casuarinas • No native species in riparian zone except for artificially planted locally native species. Occasional but sparse exotics • Low diversity of native species, all artificially cultivated Little habitat for dispersal of terrestrial native species, except for some artificial tree canopy cover • No permanent refuge for native species due to the openness of the under-storey. Only birds tolerant of open spaces present: White Ibis	• Threats are low because of the highly unnatural state of this site, but planted trees typical of the original natural flora (*Casuarina glauca*) could eventually die-back and be lost because of lack of regeneration opportunities due to mowing • Artificial native diversity is threatened either by regular under-story mowing and park manicuring, or if mowing ceases, then re-invasion of weeds in the absence of care • Loss of the canopy of artificially planted native species would have some impact on transitory use by native fauna species.	Naturalness: 1 Representativeness: 1 Diversity: 1 Rarity: 1 Special Features: 1 **Overall Ecological Value: 1**	• This is not a priority site management. • Natural regeneration could be encouraged within the riparian zone. Natural density and diversity needs to be given priority over aesthetics. • As channel has been so modified. Natural interactions between channel and floodplain may not be sufficient to sustain riparian zone vegetation. If regeneration was to occur it would require frequent maintenance

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Burnt Bridge Creek – Cnr Eileen St and Worrobil St

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
4.1	• Irregular shaped low sinuosity channel, width <7m and depth varies from <1 –2m. Partly confined channel, bedrock controlled with discontinuous floodplain. • Bed is comprised of sand, gravel and bedrock; banks are comprised of organic rich clayey sand. • Channel is characterised by pool-riffle sequences, bedrock steps forming shallow cascades, .and intermittent bedrock platforms • A continuous thin strip of floodplain flanks either side of the channel. This has been modified into parkland; as a result, there are no apparent geomorphic units apparent. • Revegetation and channel stabilisation works are active at this site • The removal of weeds at this site has released some sediment into the channel which has accumulated as bank attached bars	• No natural catchment land-uses remain. All suburban housing and mown, cultivated parkland • Variable connectivity of natural vegetation in both riparian zone and floodplain (from good to poor) depending on the stage of bush regeneration of each section of creek line. Likely to improve with time. • Generally good riparian and floodplain species richness (mostly planted local native species) but patchy structure and canopy cover, most exotics removed in the course of regeneration activities but low abundance remain. Some untreated lengths. • The creek line vegetation is a good example of successful restoration of a highly degraded creek line at various stages, from the earliest to advanced stages. It provides a model for restoration of similarly degraded creeks and a demonstration of the species diversity and community structure achievable given ongoing treatment over a period of time. • Good native species diversity and abundance as a result of the revegetation program. Many locally native species have been planted to supplement the few native species surviving on the • Marginal habitat only for dispersal of terrestrial native species and refuge for fauna species, this is likely to improve as regeneration matures	• As this is a similar case to many sites within the catchment, this can be used as an example of what can be done to such creek systems. • SEPP19 bushland on Manly side • The main potential threat is erosion of steeper banks due to removal of weedy vegetation before natives have re-established. This is currently being well managed by use of coconut-fibre matting and 'eco-logs'. • Other threats include nutrient-rich runoff from nearby houses, parkland and the bitumen bicycle path. Mowing of the parkland lawn • The threat of bank erosion and invading environmental weeds is being constantly monitored and addressed by the restoration program. • The good level of native species diversity achieved since restoration could potentially suffer reversal by inadequate monitoring and maintenance. • The acknowledged special status of part of the site on the Manly Council side as SEPP19 urban bushland would be under threat if uncontrolled processes allowed degradation of the vegetation to the extent that it no longer qualified as urban bushland. • Potential habitat for native terrestrial fauna.	Naturalness: 2 Representativeness: 3 Diversity: 3 Rarity: 3 Special Features: 2 **Overall Ecological Value: 2.6**	• Channel already being managed by Manly Council. Maintenance needs to be ensured

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Burnt Bridge Creek tributary – Birrima St

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
4.1.1	• Low velocity asymmetrical channel comprised of organic material and minor sand. Channel < 1m wide, <1m deep. Confined channel with occasional floodplain pockets. • Channel characterised by pool -riffle sequence. Pools are well defined while riffles are narrow vegetated depressions. Some sand and gravel accumulations present within pools. • Pockets of floodplain present, exotic vegetation is too thick to identify geomorphic units • The channel is narrow and shallow, banks are low grade and are held together by dense vegetation. • Vegetation masks the margins of the channel.	• Canopy species good, under story infested by weeds • Channel runs adjacent to back yards, many small footbridges have been constructed across channel • Very limited natural catchment land-use. Some natural bushland on N. side of creek line. • Riparian zone is mostly overrun by exotic weeds with discontinuous native species. Creek is partially channelised on S. side to protect property. • Limited native species richness in floodplain - mainly exotics • Native vegetation that is present at the site is representative of local moist gully flora (on N. side of creek at edge of floodplain. • Whip-birds heard at site • Good habitat for dispersal of native species on N. side of creek -relatively natural vegetation with dense under-story • Good refuge habitat - dense vegetation under-story for fauna on N. side of creek in contrast to the altered landscape of S. side (Birds: Spotted pardalote, Australian Raven, Kookaburra, Rainbow Lorikeet, Whip-bird)	• Needs to be a priority for rehabilitation as feeds into burnt bridge creek where there are major weed eradication programs in place. The weeds at this site if left untouched will continually reintroduce weeds to a rehab site. • Weed removal would destabilise the channel and initiate bank and bed erosion. Adjacent property may be put at risk. • Naturalness threatened by runoff from houses, closeness of houses to stream, continuing invasion of weeds, incursions and extension of gardens into floodplain and soil/ disturbance/digging. Loss of native trees due to dieback. Garden refuse-dumping. • Representative native flora on N. side threatened by future invasion of weeds and possible disturbances in this area. • Species richness on N. side threatened by progressive invasion of weeds and possible disturbances in this area. • Potential degradation of the vegetation on the N. side would reduce the number of less common or less robust native species utilising the site. • Refuge habitat on N. side of creek line is at risk of future degradation for the reasons discussed above.	Naturalness: 2 Representativeness: 2 Diversity: 2 Rarity: 2 Special Features: 2 **Overall Ecological Value: 2**	• Weed removal required at this site to prevent the reintroduction of weed species into rehabilitated reaches located in the trunk stream. • Weed eradication needs to be coupled with stringent bank stabilisation and replanting of endemic natives to prevent channel incision and damage to property through bank collapse.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Manly Creek (lower) – David Thomas Reserve, Solane Cr

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
4.2	• Moderately sinuous irregular channel 6-7 m wide, ~3m deep. Partly confined channel, bedrock controlled with discontinuous floodplain. • Bed comprised of bedrock, boulders, sand and gravels; Bank comprised of Boulders and sandy clay • Channel characterised by erosional bench on southern bank, pool-riffle sequences, cascades and bedrock platforms. Sandstone weir present. • Large floodplain pocket flanks southern side of reach, this has been modified with fill to construct a playing field. Floodplain geomorphic units have been buried. • Channel is deeply incised; flow will rarely reach bank full. Channel-floodplain interaction has been greatly reduced. • Banks are high, vertical and comprised of sandy clays, boulders and fill. Exotic vegetation is actively stabilising these banks. • The banks of the low flow channel are actively eroding forming a continuous erosional bench. • Intermittent reaches comprised of bedrock and boulders increase the energy of the channel. This contributes to bank erosion in non-bedrock reaches.	• Excess runoff rates within the catchment and removal of vegetation from adjacent floodplain and riparian surfaces have resulted in channel incision. Boulders have used to stabilise the low flow channel • Reach location directly downstream from Manly Reservoir, the water flowing into the creek is derived from low flow pipes at the base of Manly Reservoire • Sandstone weir in channel acting as barrier to fish migration • No natural land-uses retained • Little natural vegetation in floodplain – fill on southern side, mainly weeds on the north side • Riparian zone is highly discontinuous on southern side due to mowing, sparse natural vegetation on N. side. Low native species richness – exotics common • Swamp Mahoganies present on floodplain, (significant winter-flowering faunal food-source), • Water Skink and Bangalay also noted at site • Limited dispersal opportunities for terrestrial fauna • Limited refuge habitat for native species – some cover on N. side for fauna tolerant of modified vegetation. Birds present: Whip-bird, Rainbow Lorikeet, Red-whiskered Bulbul	• Threats to natural values of creek line include nutrient-rich runoff from oval on S. side, development on N. side, and cold water being released into channel from reservoir upstream. • Actively eroding channel will cause localised channel sedimentation and release sediment slugs downstream. • Predominantly exotic vegetation community source of propagules that may cause infestation downstream. • Relict natural features (mainly mature trees) threatened by dieback due to the impacts described above • Remnant and planted native trees threatened by dieback due to continuing degradation, mowing and competition with exotics. • Flagship species indicative of now-rare swamp forest community threatened by dieback as described above • The limited faunal habitat available is threatened by dieback of trees, or else excessively rapid removal of exotic weed cover without replacement by native cover.	Naturalness: 2 Representativeness: 1 Diversity: 1 Rarity: 2 Special Features: 2 **Overall Ecological Value: 1.6**	• Bank stabilisation works required at this site to prevent release of sediment into downstream reaches. As channel located adjacent to playing fields its banks are subject to frequent pedestrian traffic. May be dangerous if banks remain unstable. • Given size and condition of channel, bank stabilisation and rehabilitation works will be very expensive with little ecological returns. If there were no threat to public safety site would be a low priority for rehabilitation. • May be more cost effective to put in measures to prevent public access to channel.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Curl Curl Creek – Manly Warringah War Memorial Park, Wakehurst Parkway

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
4.2.2	• Irregular shaped Bedrock channel up to 3 m wide, <1m deep. Confined channel with occasional floodplain pockets. • Channel characterised by, pools, short riffles, cascades, overhanging rock shelves, chutes, glides and CWD, sand and gravel accumulations occur in pools • Where valley locally widens, floodplain pockets appear, some are dissected with chute channels. There are fresh deposits of sands and the surface of these small floodplain features indicating that channel-floodplain interaction is active. • Channel gradient is shallow and set within a moderately sloped valley setting. • River in very good condition, confined with occasional floodplain pockets. • Fire has passed through this area within the last 12 months, burning very hot. Many of the canopy natives survived the fire.	• Minor sediment is moving through the system, most likely due to removal of ground cover by the recent fire. • This site is an excellent candidate for rehabilitation. Upstream areas need to be kept weed free to protect natural diversity. • Geomorphic diversity at this site is excellent providing a wide range of habitats. • Totally natural catchment land-use retained – natural bushland in council reserve. • Excellent connectivity of natural vegetation in floodplain and riparian zone – few weeds but recovering from hot fire approx. 1 year ago. Some exotics present at low cover and abundance • Excellent native species richness (*Callicoma serratifolia present at site* • Good habitat for dispersal of terrestrial native fauna species and refuge habitat but value temporarily reduced by loss of cover due to the fire	• The major threat to naturalness is new invasions and continuing re-invasion and expansion of the exotic weed species present. Deteriorating water quality from urban development upstream at the head of the catchment is also a possible threat. • Rarity of this ecosystem could ultimately be under long-term threat of creeping urbanisation, such as possible development proposals not in the reserve but in bushland areas in the catchment • The site has potentially excellent habitat opportunities for native fauna, but until the full vegetative cover is re-established following the fire, this will be sub-optimal in the short term. In the long term, the habitat values are threatened by progressive degradation due to weed invasions.	Naturalness: 4 Representativeness: 3 Diversity: 4 Rarity: 4 Special Features: 3 **Overall Ecological Value: 3.6**	• As site has been recently burnt and cleared of weeds, it is perfect condition to be rehabilitated. Frequent monitoring is required so that weed can be removed before they establish. Endemic natives can be introduced so they colonise before weeds have a chance to take hold. • As site is easy to access (frequently used walking tracks) and management requirements are straightforward, it is a good site for community group to take responsibility for.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Brookvale Creek (lower) – Warringah Golf Course, Condamine St

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
4.3a	• Modified alluvial sand bed channel up to 4m wide and 1-2m deep. Banks are comprised of silty sand. • Channel has recently undergone rehabilitation works and is now characterised by mid channel bars, bank attached bars, pool-riffle sequences (engineered 20m) and artificial rock weirs. • Extensive floodplain flanks SW side of channel which ahs been altered by golf course. On extremity of golf couse there may be a minor flood channel. • Creek in state of repair following rehabilitation works. Weeds have been removed, bends have been put back in the channel, and banks have been stabilised using vegetation, boulders and geo textiles. • Rehab works have improved geomorphic and habitat diversity.	• No natural catchment land uses retained - golf course and suburban development • Poor maintenance has created areas of erosion that require attention. Bank materials are friable and prone to erosion, constant maintenance is required if this site is to stabilise. • Replanted natural vegetation in floodplain and in riparian zone - early stage of growth so low connectivity but likely to improve • Good native species richness (although artificially created) but needs time to develop community structure. Low exotics richness and abundance • The creek line vegetation is a good example of successful application of restoration techniques to a highly degraded creek line in its early stages. It provides a model for restoration of similarly degraded creeks. • Poor potential for dispersal of terrestrial species, but likely to improve in the short to mid-term as native vegetation cover develops. • Poor refuge for native fauna species due to the immaturity of the developing vegetation apart from small native birds. Refuge opportunities are likely to improve as cover develops, but local native fauna is likely to be impoverished and isolated from other nearby populations by development. Birds present: Scaly-breasted Lorikeets.	• Short-term threats include bank erosion (minor signs noted) until vegetation becomes well established. Re-invasion of weeds is a potential threat in the absence of adequate monitoring and follow-up of the restoration process after initial plantings. Nutrient-rich and/or pollutant-laden runoff from adjoining golf course, road, houses and from industrial activities further upstream could reduce water quality if not controlled and lead to renewed degradation in the long term. • The biggest threat to this site is lack of future monitoring and follow-up work to ensure continuing success of the restoration process into the future. • Threats to native species richness include lack of follow-up of the restoration process allowing environmental weeds to re-invade and inadequate control of runoff from within the immediate catchment • Few native faunal species would be present to utilise the available habitat because of clearing, isolation and habitat degradation over a number of years. Birds are the main faunal group likely to utilise the improved habitat, which would be under threat from potential future neglect as discussed above	Naturalness: 3 Representativeness: 4 Diversity: 3 Rarity: 3 Special Features: 2 **Overall Ecological Value: 3**	• This site is already being managed. Maintenance of site needs to be improved so that rehabilitation efforts are not degraded

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Brookvale Creek (upper) – Doulton Ave

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
4.3b	• Narrow bedrock channel <1m deep and <1m wide. Steep Headwater. • Channel gradient is very steep. Channel is set within very steep v shaped valley. • Channel characterised by bedrock steps, large boulders, plunge pools and small riffles (1-2m) • Channel currently in good condition with good geomorphic and habitat diversity.	• Weed invasion is very minor and confined to the channel zone. • Candidate for a community project; access is easy and only very minor weeding is needed. The local community needs to be educated about weed species and appropriate disposal methods for garden refuse. This is a good site and it needs to be kept this way. • Natural catchment land within steep valley slopes fully developed with suburban housing on top of slopes and ridge tops. • Good continuity of vegetation in riparian zone and immediate valley slopes with little disturbance and few weeds. Species richness, canopy cover and width are good with only moderate exotic diversity of low abundance (early stages of invasion). A few exotics are beginning to invade slopes adjacent to channel • Good example of natural moist creek line gully vegetation of the district with only minor to moderate degradation. • Good native species diversity, cover and abundance Coachwood (*Ceratopetalum apetalum*) present at site • Good habitat for dispersal and refuge of native species due to good cover and diversity of native species. Birds present: Kookaburra	• At top of slope adjacent to houses, weeds are establishing. In time, if not controlled, they will invade the channel and riparian zone. Major threat to site increasing invasion and abundances of environmental weeds and progression down stream. • Naturalness, representativeness and diversity are also threatened by nutrient-rich runoff from houses at top of gully and leakage from sewerline near creek. This will affect water quality. • Flagship taxa at risk of dieback from decreasing water quality and invasion of weeds in the long term • Habitat for native fauna at risk from loss of native species and reductions in native ground and canopy cover	Naturalness: 3 Representativeness: 3 Diversity:3 Rarity: 3 Special Features: 2 **Overall Ecological Value: 2.8**	• Excellent candidate for community project. Only minor weed infestation has occurred in the riparian zone and on adjacent slopes at this site, complete eradication will be relatively simple task of pulling weeds. • Adjacent property owners need to ensure exotic species do not escape their back yards. Community education is required to let people know the importance of maintaining the natural diversity of an ecosystem.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Brookvale Creek tributary – Owen Stanley Ave

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
4.3.1.1	• Bedrock channel up to 2m wide and <2m deep. Banks are comprised of sandy mottled clay. • Channel typical steep headwater channel characterised by bedrock steps, cascades, riffles, plunge pools, waterfalls, small accumulations of sand occur in inactive pool margins • Bank materials are sandy but are tied together well by dense root mats.	• Within the valley profile the weeds are confined to the riparian zone, over time this nutrient profile will move upslope. • Nutrient and weed source seems to be confined to a storm water outlet; this is an area that can be rehabilitated quite easily. • Accessibility is the major issue for this site as slopes are quite steep and vegetation is dense. • Good quality habitat, apart from some gross pollutants. • Immediate natural catchment largely intact - suburban development at head of creek and on ridge tops surrounding creek line • Good connectivity of natural vegetation in floodplain - minor invasion of weeds • Moderately good continuity of natural riparian zone, with moderate invasion of weeds near edge of bushland. Species richness is moderate but also high diversity and low abundance of weed species • Native vegetation in general represents the common elements of typical moist gully flora locally. • Good potential for dispersal of terrestrial native species in partially natural vegetation either side of creek • Good refuge for native species in vegetation with good cover that connects with the wider bushland area of the reserve	• Naturalness, representativeness and diversity is threatened by perturbations from houses upstream - runoff, mowing of firebreak, dumping of garden refuse and grass clippings and continuing invasions of exotic weeds. • Quality of habitat for fauna is threatened by further invasion by environmental weeds, and disturbances such as garden-refuse dumping.	Naturalness: 2 Representativeness: 3 Diversity:3 Rarity: 1 Special Features: 2 **Overall Ecological Value: 2.2**	• Weed eradication required at this site. • As weeds are confined to the riparian zone at the upstream end of the creek, it is a relatively small area that requires weed removal and maintenance. • As substrate is sandy, immediate bank stabilisation will be required. • As slopes are very steep and densely vegetated, access may be difficult.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Bantry Bay tributary – Forestville Park, Pildra Pl

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
5.1.1	• Irregular shaped channel with intermittent bedrock, 4-5m wide, 1-3m deep. Confined – Partly confined channel, bedrock controlled with discontinuous floodplain. • Channel characterised by pools-riffle sequences, cascades, plunge pools and some minor sand accumulations • River behaviour may have been significantly altered by construction of playing fields and park area on floodplain either side of the channel. • Channel is located within irregular valley setting. • Eastern bank is severely eroded in places • GPT present in channel, this is creating ponding problems which have reduced bank stability. • Downstream of GPT channel becomes severely choked by weeds.	• Western side of channel cleared for housing, parkland, Eastern side elevated and supports playing fields • Sparse natural vegetation in floodplain – disturbed and discontinuous. Low species richness and many exotics present • Riparian vegetation very weedy and discontinuous – highly disturbed and interrupted by clearing and mown grass. Riparian species richness is low with a high number of species and abundance of exotics. • Moderately poor representation of native creek line vegetation typical of the district • Poor opportunities for dispersal of terrestrial species but better quality habitat downstream of GPT. • Good refuge habitat for native fauna downstream of GPT (south side of Currie Rd), poor on upstream side, apart from tolerant species. White-faced Heron, introduced Spotted Turtle-dove and introduced Red-whiskered Bulbul.	• Species diversity threatened by runoff from surrounding land uses and decreasing water quality due to sewer line, further invasion and increasing abundance of weeds. • Small area of bush regeneration on northeast side could result in some improvement. • No rare or significant biotic features, but characteristic species threatened by processes discussed above. • Runoff and downstream transport of weed propagules could threaten the superior habitat for native species downstream of the GPT.	Naturalness: 2 Representativeness: 2 Diversity: 2 Rarity: 1 Special Features: 1 **Overall Ecological Value: 1.6**	• As creek flows into a national park, weed eradication combined with bank stabilisation should be a priority for this site. • Native species diversity and density can be improved in the riparian zone through weed removal and planting. Those who maintain park need to stop mowing to the edge of the riparian zone so that a buffer can be provided.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Carroll Creek – Merrilee Cr

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
5.2	• Irregular bedrock stream, width 2m, depth <1m. Steep headwater. • Channel characterised by stepped bedrock, between bedrock steps short pool-riffle sequences occur. Boulders accumulated on the bedrock steps creating cascades, falls and plunge pools. Some accumulations of sand create bars at the margins of pools • No floodplain present at this site • The reach has been modified for aesthetic purposes .The creek is heavily urbanised on each valley side • Creek has been made a feature in a park, it has a bridge and spot lights focused on waterfall and various plants.	• No natural catchment land uses retained – all suburban housing development • Site highly manicured – sparse natural vegetation remaining, mainly trees. Natural riparian zone largely replaced by planted vegetation. • Low native species richness good canopy cover, a few exotic weeds, most introduced species artificially planted and cultivated. • A poor example of stream and bank native vegetation, due to the extent of replacement by garden plants, although some representative native species remain. • Native species diversity highest in tree stratum. Some native ferns have survived • Cabbage Palm (Livistona australis) present at site • Upstream of Garigal National Park • Habitat unsuitable for dispersal of and refuge for native species due to extent of modification	• Proximity to urbanisation increases the likelihood of water quality problems and localised weed infestation and transport of weed propagules downstream. • Most environmental weeds have been removed, but in most cases replaced by cultivated exotic garden plants (not locally indigenous species) • Remaining native species under threat due to unsuitable habitat being present for natural regeneration and therefore the eventual replacement of native species by exotic or non-local species • The scant habitat available for native species (native canopy) is under threat from dieback.	Naturalness: 2 Representativeness: 2 Diversity: 2 Rarity: 2 Special Features: 2 **Overall Ecological Value: 2**	• Exotic species that have been planted at this site need to be replaces with natives to reduce the risk of spreading propagules. • As creek drains into Garigal National Park, weeds need to be controlled at this site. As site is already maintained by the local community, it may be a good site for community management.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Carroll Creek tributary– Prahran Ave

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
5.2.1	• Irregular bedrock stream, width up to 6m, depth v. shallow except for in established pools. Steep headwater. • Channel characterised by stepped bedrock, boulders cascades, falls and plunge pools. Some accumulations of sand create bars at the margins of pools • No floodplain present at this site • Large GPT present on lower gradient upstream reach. This short reach acts as an urban drain and su ffers from weed infestation. • Waterfall marks transition between good condition and poor condition.	• Little natural catchment land uses retained - all occupied by suburban development • Channel upstream of waterfall is highly modified by GPT and sediment pond and is infested by weed species • GPT Potential fish barrier • Limited natural vegetation in riparian zone and on adjacent slopes – connectivity improves downstream of waterfall. • Good species richness on adjoining valley slopes, particularly below waterfall. • Some good habitat for native fauna below waterfall. • The site is typical of a creek degraded by urban development upstream, but relatively natural away from urban influences. • Good native species richness below waterfall • Upstream of Garigal National Park • Good habitat for dispersal of and refuge for native species downstream of waterfall.	• Threats include nutrient-rich runoff from suburban development in upstream reach and progressive invasion of environmental weeds downstream into more natural areas. • The downstream half of the site (below the waterfall) is in danger of becoming as degraded as the upstream part. • Native species diversity threatened by downstream spread of weeds and declining water quality. • Potential negative impacts on the biodiversity of Garigal National Park due to entry of polluted runoff and due to import of weed propagules • Habitat for native fauna threatened by declining water quality, invasion of weeds downstream, loss of native flora species and eventual dieback of trees.	Naturalness: 3 Representativeness: 3 Diversity: 3 Rarity: 2 Special Features: 2 **Overall Ecological Value: 2.6**	• As the main concentration of weeds occurs in an accessible area upstream of the waterfall, weeds can be removed and the site maintained relatively easily.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

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Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
5.3	• Poorly defined well vegetated channel ranging from<1m to 10m wide, <1mdeep. Channel bed is a highly organic clayey sand. Channelised valley fill/altered hanging swamp. • Possible that site is an altered hanging swamp. • Channel is shallow and swampy; no geomorphic units are visible. • There is no real floodplain; the swamp dominates the entire width of the valley floor except for a boggy park located at the upstream extremity of the reach with a narrow heavily vegetated channel running through it. • Phragmites dominant vegetation • Capacity for adjustment at this site is high given the friable substrate.	• Natural catchment landuse retained on SE side, urban housing on opposite side Most of floodplain modified by mowing and parkland • Continuity of riparian zone reasonable/good but degraded by weeds • Species richness moderate but naturally low. Site invaded by some exotics. Native species diversity is good. • Some habitat for fauna in riparian strip e.g. Bandicoots • Good representation of native creek line vegetation of the district and typical local species assemblages • Eucalyptus leumanniana listed as ROTAP 2Rca on edge of floodplain on NE side. • Bandicoot diggings – not currently listed as threatened but becoming scarce in urban areas of Sydney • Flows into Garigal National Park • Good potential for dispersal of fauna such as the bandicoots – locally threatened in urban areas • Good refuge habitat from altered urban landscape, for terrestrial ground-dwelling fauna such as bandicoots	• If vegetation is altered or removed friable sandy clay substrate will rapidly erode. • Naturalness, representativeness and diversity of site threatened by urban runoff from upslope houses and road, invasion by weeds and excessive reserve maintenance such as mowing. • Habitat for Eucalyptus leuhmanniana under long-term threat from upslope invasion by weeds. • Habitat for sensitive native fauna under threat from possible extension of mown area into currently semi-natural vegetation • If not managed weed propagules may flow into Garigal National Park • Given the good accessibility to the site and its potential for rehabilitation, this site is s good candidate for community management.	Naturalness: 3 Representativeness: 3 Diversity: 3 Rarity: 4 Special Features: 3 **Overall Ecological Value: 3.2**	• As accessibility is good and weed invasion is minor, this site is an excellent candidate for community management. • Weed removal must occur simultaneously with bank and bed stabilisation, as substrate is easily erodable.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Bare Creek tributary – Narabang Way

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
5.5.2	• Narrow channel <1m wide and <1m deep, substrate is sandy clay and some small gravels. Steep headwater. • Channel set within moderately steep v shaped valley that is well vegetated and in good condition • Channel characterised by boulders, pools, cascades and vegetation lined runs • Reach is located immediately downstream of a detention basin for a construction site. Outlet from basin appears to be reasonable clean. • Retention basin is holding a large volume of water. This is effecting the volume of flow reaching the channel • Abundant gross pollutants present at site. • Unprotected tributary entering from the north is carrying gravels, rubble and suspended material into channel	• Natural catchment land uses only to the east and west of the site. Industrial Park to the north • Good natural vegetation and high species richness on adjacent slopes increasing in quality. • Good continuity of riparian zone particularly downstream of detention basin • The site is typical of upper catchment streamside communities of the district and still in relatively good condition. • Very high richness and abundance of native species • Excellent habitat for dispersal of terrestrial species since good natural cover is present. • Excellent habitat for refuge of native fauna from altered landscape of business park. Good cover and habitat diversity.	• Reduced flow in channel from collection of water in the detention basin is reducing the channels ability to transport sediment. This combined with the introduction of sediments and gravels from the northern tributary are is responsible for increased sedimentation rates in the channel. The detention basin is playing a vital role at this time so can not be removed. • Tributary to the north needs to be fitted with a sediment trap • The main threat to naturalness, representativeness and diversity is nutrient-rich runoff from the Business Park north of the site, establishment of new species of environmental weeds and spread of weed species downstream into currently good quality vegetation towards Garigal National Park. • Fauna habitat threatened by possible reductions in native flora species cover.	Naturalness: 3 Representativeness: 3 Diversity: 4 Rarity: 3 Special Features: 2 **Overall Ecological Value: 3**	• Site needs to be monitored for weed invasion. As site has been disturbed weeds will colonise quickly and will infest area if left unmanaged. • Tributaries need to be fitted with sediment traps. The effectiveness of these and the detention basin need to be monitored and maintained.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Snake Creek – Cnr Morgan Rd and Hilversum Cr

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.1.3.3	• Irregular shaped, sand dominated channel 2-5min width, 1-2m in depth. Transition from Steep headwater to Partly confined, bedrock controlled reach with discontinuous floodplain. • Channel characterised by pool-riffle sequences (5m), cascades, high waterfalls, plunge pools, sand and gravel bars (~1-2m length), erosional benches. • Pockets of floodplain show scour features indicating channel floodplain connectivity is functional. Accumulations of sediment form pseudo levee • Channel at this site goes through transition from steep headwater to partly confined with alternating floodplain pockets. The transition point between these river styles is a large waterfall. • Downstream of the waterfall the valley opens up and becomes moderately sinuous. The creek meanders within this broad valley floor (>100m). • The channel within this reach is narrow and shallow, and is kept stable by the infestation of weeds. • The reach upstream of the waterfall has a bad odour	• Input of large amounts of sand and gravel from upstream construction and land clearing are depositing sediment bars in channel. • Upstream of the waterfall channel suffers bank erosion and bed aggradation. • Water quality is poor, resulting in the dieback of angophoras and the proliferation of weeds. • GPT and small retention basin .prevent fish passage • Some areas of natural catchment land-use, small farms also making up large part of catchment. • Good connectivity, species richness and composition of natural vegetation on floodplain and in riparian zone upstream of waterfall • Good representation of native vegetation of local creeks upstream of waterfall, but showing signs of degradation. • Good native species richness and abundance upstream of waterfall • Crayfish in creek (upstream of road) Good connectivity of vegetation for dispersal of terrestrial species especially upstream of road (limited corridor on downstream side) • Good refuge for native fauna on upstream side, limited refuge downstream of road due to exposure to road and adjoining farm	• Naturalness, representativeness and diversity threatened by deteriorating water quality due to runoff from farms, import of weed propagules and consequent intensification of weed invasion. Dieback of some trees further downstream. Mown lawn of adjacent house is fairly close to stream. Fill for road on north-east side • Native stream fauna such as crayfish strongly affected by water quality, particularly downstream. • Habitat for native fauna threatened particularly downstream of road, due to its narrow width, high edge to area ratio and consequently high vulnerability to weed	Naturalness: 2 Representativeness: 2 Diversity: 3 Rarity: 2 Special Features: 2 **Overall Ecological Value: 2.2**	• Source of effluent entering the channel needs to be discovered and controlled. • Sediment runoff from construction and agriculture upstream needs to be controlled • Weed removal and bank stabilisation is required both at this site and upstream

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Oxford Creek – Cnr Oxford Falls Rd and Morgan Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.1.3b	• Irregular shaped sand-dominated channel, 4-5m wide and 2-4m deep. Partly confined, bedrock controlled with discontinuous floodplain • Channel characterised by pool-riffle sequences (spacing approximately 25m in length); length of riffles increases as you move downstream. There are some bedrock outcrops within the channel that create a cascade. Erosional benches (~50-80 cm wide) occur intermittently along the study reach. • Adjacent floodplain on eastern side is covered by a road and may extend into rubbish tip. Therefore floodplain geomorphic features highly altered. • Riparian vegetation is in moderately good condition on the western margin, and has been dramatically altered to the east. • The study reach lies adjacent to a rubbish tip that is still in operation. • The western valley margin that abuts the channel is relatively undisturbed and in good condition • Bank erosion is evident on the eastern side of the channel and in some areas on the western side. Runoff from the road and minimal vegetation has increased runoff into the channel.	• A road comprised have crushed roof tiles runs along the eastern margin of the study reach, the tiles use to surface this road are stored on the roadside. A large amount of debris from the roadside has entered the channel as well as some larger debris from the rubbish tip. • Total Retention of natural catchment land-use on western side, almost total loss on eastern side (cleared for agriculture) • Vegetation composition, diversity and abundance good on western side, poor on eastern side • Riparian and Floodplain species excellent on western side, poor on eastern side with abundant exotics • Excellent natural habitat for native fauna on western side, poor/limited on eastern side • Western side is an excellent example of native streamside vegetation of the area but not the eastern side. • High species richness and abundance on western side low on eastern side. • Ferns listed as protected but not threatened. Some species present that are easily affected by disturbance and degradation e.g. ferns such as Sticherus flabellatus. • Excellent potential for dispersal of terrestrial native species and refuge habitat for native species along western bank, poor potential on eastern bank	• The input of road material into the channel has increased the bmax of the bed-load. As this is a sand dominated system, and stream-powers are relatively low, this coarser load will only be reworked by the channel during higher flows • Naturalness, representativeness and diversity of vegetation on western side of creek will be eventually threatened by invasion of weeds from eastern side and possible progressive deterioration of water quality due to runoff from farmland on eastern side. The few natural elements remaining on the eastern side will be gradually threatened by intensifying weed invasion and reduction in water quality leading to possible die-back of tree stratum • Non-robust, sensitive native species at risk from invasion of weeds from eastern side and from deterioration of water quality • Habitat features for native fauna on western side at risk from degradation eventually extending from the eastern side to western side. Some habitat features in trees compromised by tree trimming for power line maintenance.	Naturalness: 2 Representativeness: 3 Diversity: 3 Rarity: 2 Special Features: 2 **Overall Ecological Value: 2.2**	• Site requires weed eradication and bank stabilisation. As condition of slope on western side of channel is good, it need to be protected from weed infestation. • Crushed tiled that are being used to pave road adjacent to site need to be removed as they are entering a channel that does not naturally transport sediment of that size. If this is stopped, bed aggradation will be reduced.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Oxford Creek – @ falls

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.1.3a	• Bedrock channel 3-4m wide and <1m deep. Gorge. • Channel characterised by a rock platform at the top of the reach that drains into a large falls. Downstream of this bedrock steps, cascades, long deep pools and short riffles occur. There is some sand accumulations in pools that will emerge as bars during low flow. • Falls flow into U shaped gorge with very steep valley walls and no floodplain. • Due to the rugged nature of the geomorphology at this site, it has suffered very little human disturbance	• Land use adjacent to site mainly picnic area and semi-rural farms, good quality bushland occurs downstream of falls. • Good canopy connectivity of natural vegetation on slopes adjacent to channel - mostly intact. Under-story interrupted by dense invasion of Watsonia. Species richness and community structure is good. • The site is only partially representative of similar native creek line communities in the district, due to local disturbances such as clearing and weed invasion. Good representative elements of natural vegetation remain. • The diversity of native species is moderately good, mainly in the tree and shrub layers • Grey Gums (*Eucalyptus punctata*): listed SEPP44 Koala habitat tree present at site. • Coachwood (*Ceratopetalum apetalum*) present at site. • Moderately good habitat for dispersal of terrestrial fauna species, mainly for arboreal species through canopy. • Moderately good refuge for native fauna from altered landscapes in uncleared areas of vegetation away from the picnic area, and further downstream from the waterfall.	• Threats to naturalness, representativeness and species diversity include continuing invasions of environmental weeds, nutrient rich runoff from surrounding farms and impacts due to the site's recreational use as a picnic and barbecue area • Significant trees at risk of loss in the long term from intensified weed invasion and reductions in water quality due to runoff • Habitat for native fauna under moderate threat in the long term from dieback of trees due to declining stream water quality and continuing invasion of environmental weeds.	Naturalness: 3 Representativeness: 3 Diversity: 2 Rarity: 2 Special Features: 2 **Overall Ecological Value: 2.4**	• Weed control will be beneficial to this site and reaches downstream.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Middle Creek tributary – Oxford Falls Grammar School, Dreadnought Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.1.7	• Irregular channel approx. 7m wide. Channel is oversized for its position within the catchment. Low sinuosity fine grained. • Channel cross-sectional area has been increased to the extent that it is unlikely that flow could move over-bank, thus channel-floodplain interaction has been greatly reduced. • Adjacent floodplain has been completely altered to accommodate playing fields • High banks comprised of loosely packed fill (large boulders and foreign debris with sandy silt matrix) • Sand slug emergent from culvert • Bank attached sand bars present within low flow channel • Sand dominated reach • Upstream of road crossing channel has been aesthetically modified. Native revegetation has taken place and geomorphic units such as pool-riffle sequences, in-channel benches and cascades have been reintroduced.	• Area is dominated by environmental weed species. Right bank is suffering from severe infestation. • No apparent riparian zone • Sand accumulation and in-channel weed infestation by weeds are creating barriers to fish migration • Low species richness and canopy cover • NO native species apparent on floodplain • Boulders derived from collapsing fill banks acting to block flow within channel • NO habitat available for most native fauna species • Bank stability is very poor on left bank	• Bank erosion resulting from turbulent flow created by sand accumulations may impact on the stability of culverts. • Channel is very unstable and infested by weeds: If weeds are removed already unstable banks will completely collapse, If weeds are not removed then they provide a continual seed source that will hinder rehabilitation works downstream. • Left bank is very unstable: loosely compacted fill is actively collapsing creating voids. As this creek is adjacent to a school and playing fields it may be a danger to children and infrastructure • Active channel erosion at this site is creating a sediment source for aggradation downstream • Sediment within channel is creating ponding effect upstream. This may effect pseudo rehabilitation/beautification works taking place upstream.	Naturalness: 1 Representativeness: 1 Diversity: 1 Rarity: 1 Special Features: 1 **Overall Ecological Value: 1**	• Banks stabilisation strategies are required to mitigate risk and reduce sediment supply to channel • There are no cost effective ecological benefits to be gained from attempting rehabilitation at this site. •

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Middle Creek (upper) – Carnarvon Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.1e	• Asymmetrical, moderately sinuous sand dominated channel 2-5 wide and <1-2m deep. Partly confined, bedrock controlled with discontinuous floodplain. • Channel characterised by short pool riffle sequences, bedrock steps forming small cascades and plunge pools. Sand accumulation has formed bars. • Large foreign bodies apparent in channel and buried within floodplain (bikes, car doors etc). It is likely that these objects are responsible for the atypical flow patterns observed in the channel. • Despite sinuosity no point bars apparent. Thalweg has been directed by debris onto the inside bend, this has created an acute hairpin bend and sedimentation on the outside bend. • Scour channels are present on the floodplain which are active during high flow events. • Some sediment deposition on the floodplain, coating dense vegetation litter. • Although not observed there is a hanging swamp present at this site. • Veg rehab occurring at this site. Some bank erosion is occurring where weeds have been removed and natives have not yet established.	• Limited natural catchment landuse elements – mainly surrounded by urban development with remnant vegetation • Large items of rubbish within channel are changing flow patterns within the channel. • Some remnant native species on floodplain and in riparian zone – connectivity is being enhanced by replanting and bush regeneration project • exotics progressively being removed by bush regeneration project • Limited habitat for native fauna, but likely to increase after bush regeneration. • Representative of remnant, robust native species – likely to be enhanced by bush regeneration plantings eg. Acacia spp. • Low native species richness but being enhanced by plantings of extra native species. • Limited potential for dispersal of terrestrial species but likely to improve as a result of bush regeneration program. • Some refuge for native species and likely to improve following temporary disruption by early stages of bush regeneration.	• Further clearing and/or degradation of remnant vegetation patches. • Changed flow patterns within the channel are modifying geomorphic units and diverting flow towards banks. This is creating bank erosion. • Erosion due to weed removal and potential future re-invasion of weeds if bush regeneration not followed up and monitored over time. • Short term threat of disruption to habitat for dispersal due to bush regeneration, but should improve in the longer term. • Temporary removal of refuge for some species but long-term improvement if bush regeneration is successful.	Naturalness: 2 Representativeness: 2 Diversity: 2 Rarity: 1 Special Features: 1 **Overall Ecological Value: 1.6**	• Bush regeneration already occurring at this site. Further weed removal and maintenance is required. • While Large items of rubbish within channel are altering flow patterns and causing subsequent erosion, their removal is likely to destabilise the system. Further investigation is required.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Middle Creek (mid-upper) – Dreadnought Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.1d	• Irregular shaped channel 4-5m wide and 2-3m deep. Channel substrate sand with intermittent bedrock. Low sinuosity fine grained. • Channel characterised by Pool-riffle sequences (45m long), lateral sandbars, erosional bench apparent along low flow channel margin (<1m wide, 1-2 meters in length). Recent sand deposits visible in channel which laminate pre-existing bars and benches. • Floodplain characterised by high and low level pseudo levee's, terracing occurs on eastern side of channel • Sand slugs present • Site heavily colonised by exotic species that are acting to stabilise channel. • The channel has a diverse range of geomorphic units providing good instream habitats	• Market gardens located upstream of study reach. • Presence of low level road-crossing causes ponding and localised bank erosion, while road running parallel to channel imposes on floodplain geomorphic features. • Floodplain geomorphology (terracing and levees) rare as most floodplain surfaces in the catchment have been altered. • No natural catchment landuses remaining. • Partly natural tree stratum on floodplain remains continuous while the continuity of the riparian zone is highly interrupted by weeds • Poor native species richness – abundant exotics • Limited habitat for native fauna. Grey Gums potentially used by range of threatened fauna species. • Grey Gum (Eucalyptus punctata) present –Koala feed tree species and species is potentially used by other threatened fauna species. • More or less intact tree stratum potentially provides for dispersal of local native arboreal fauna species • Limited potential refuge for some bird species in Lantana and for arboreal mammals in native trees.	• Market garden likely providing rich source of nutrients and exotic weed propogules. • If weeds were removed from this site, subsequent erosion may degrade relict floodplain features and destabilise system. • Dieback of trees and loss of native species is a potential threat to the area as a result of runoff and weed invasion. This may also compromise habitat in the area. • The overzealous removal of Lantana and other cover provided by weeds will destabilise the system causing localised bank erosion and release sediment into the system. • Abundance of weeds will provide source of weed propagules to less effected downstream reaches	Naturalness: 2 Representativeness: 2 Diversity: 3 Rarity: 3 Special Features: 2 **Overall Ecological Value: 2.4**	• Weed removal native regeneration is required at this site. • As substrate is sand any weed removal that takes place needs to occur simultaneously with bank and bed stabilisation.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Middle Creek (mid) – Oxford Falls, Oxford Falls Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.1c	• Large waterfall flowing into irregular channel (6-8m wide) set within a U shaped gorge. Waterfall drains large rock platform > 40m in width. Gorge. • Channel downstream of falls predominantly bedrock, characterised by falls, cascades, pools (25m), riffles (10m) bedrock steps, some submerged accumulations of sand in pools that will emerge as bars during low flow • Waterfall marks transition from alluvial to confined valley setting. • There is little human disturbance to river character at this site due to the rugged and inaccessible nature of the terrain.	• Within gorge, catchment landuse has been largely unaltered, apart from walking access tracks and fire trails • There is good connectivity and high species richness of natural vegetation in gorge, with only minor weed invasion at top of falls • Excellent example in parts of native riparian and floodplain vegetation – particularly flora species influenced by waterfall spray. • No threatened flora species but continuing presence of less robust native species that would be eliminated in more degraded sites • Hanging Swamp habitat on western side is special • Waterfall spray habitat unusual • Good habitat for dispersal of terrestrial species and refuge for native species in natural habitat on either side of gorge and below ford – compromised by heavy weed invasion on western side.	• Main threat to values at site is progressive weed invasion down the gorge from N to S.	Naturalness: 3 Representativeness: 4 Diversity: 4 Rarity: 3 Special Features: 3 **Overall Ecological Value: 3.4**	• Weed removal required at top of slope.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Middle Creek (lower) – Wakehurst Parkway (side road)

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.1b	• Asymmetrical sand dominated channel 1-2m wide, <1m deep with some bedrock outcropping apparent. • The channel itself is characterised by pool-riffle sequences approximately 40 m in length, large sand deposits and a narrow (<50cm) erosional ledge apparent along the length of the channel. • There is a large bridge crossing the channel, beneath the bridge there is a large sand bar laminated with gravel, and dissected by a minor low flow channel. There is a large sand and coarse gravel deposit on the southern bank that is now covered with wandering dew. • Minor pockets of floodplain have been stripped to produce steps. Most of the study reach however is confined	• The stone supports of the bridge trap sediment and reduce flow velocity resulting in sediment deposition underneath and adjacent to the bridge. • The access track to the creek acts as a tributary to the creek, introducing fine material into the system, it is also used as a dumping ground for rubbish and garden refuse. • Natural catchment essentially intact surrounding site – generally natural bushland • Floodplain and riparian vegetation invaded by weeds but canopy largely intact • Significantly reduced species richness due to weed invasion. • Not representative of similar natural creeks in district because of level of exotics in vegetation – only elements of natural flora represented. • No protected communities but a good example of moist gully forest which is scarce in the area • Some reasonable habitat for dispersal of terrestrial species but highly modified. • Poor refuge for native species except for those tolerant of modified vegetation.	• Natural values threatened by continuing invasion, spread and increasing abundance of environmental weeds progressively displacing native species. • Further loss and degradation of habitat due to displacement of native flora species by continuing weed invasion	Naturalness: 2 Representativeness: 2 Diversity: 2 Rarity: 3 Special Features: 2 **Overall Ecological Value: 2.2**	• Weed control and bank and bed stabilisation required at this site. • Garden refuse and large items of rubbish need to be removed from access track. • Silt traps need to be placed areas draining access track to stop input of sediment into the creek

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Middle Creek (lower) – Wakehurst Parkway Bridge

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.1a	• Very degraded alluvial channel >10m wide, ~3m deep. • NO in channel geomorphic units apparent, may be submerged. • Channel and floodplain are choked with weeds that are actively accumulating sediment • Extensive floodplain present on either side of the channel (>100m), has been drastically altered. Floodplain composition is sandy, and regularly used as a borrow site. • River is in very poor condition, channel has been over-widened and infested with weeds that are choking the channel and catching sediment. • Water has a bad odor and is visibly of very poor quality. • The site is also used to dump rubbish both in the channel and on the floodplain. • Flow is moving at low velocity through reach (slowed by weeds), this will inevitable result in ponding upstream of the site, and flow deprivation downstream. • The accumulation of sediment in some sections of the reach is almost completely blocking flow and causing the channel to widen as it seeks a more efficient path. • Capacity for channel • adjustment is very high.	• Natural catchment largely intact surrounding site – mostly natural bushland with some disturbances. • Very little natural vegetation on floodplain or in riparian zone - highly invaded by weeds • No continuity of natural vegetation in riparian zone due to density of weeds • Floodplain flora highly unnatural and invaded by weeds. Some floodplain species (Eucalyptus piperita) remaining but showing severe dieback. • Good cover for dispersal of terrestrial species tolerant of exotic vegetation • Dense exotic vegetation would provide refuge only for limited species of native fauna tolerant of exotic vegetation	• Values already very low but further threatened by ultimate replacement of the remaining native flora by weeds. • Regeneration potential of creek line vegetation severely hampered by density of exotic vegetation • Few remaining native species threatened by continuing degradation resulting mainly in dieback of Peppermint trees • Over zealous or indiscriminant removal of exotic weeds without progressive replacement with indigenous species would destroy habitat for some native fauna species and lead to a risk of soil instability and erosion. It would also release large amounts of sediment into a channel that is already sediment choked.	Naturalness: 1 Representativeness: 1 Diversity: 1 Rarity: 1 Special Features: 1 **Overall Ecological Value: 1**	• There are no cost effective management strategies that could be employed at this site to improve condition.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Wheeler Creek (upper) – Maybrook Ave

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.2.2b	• Irregular shaped bedrock channel, 2-5m width, <1m deep. Confined channel with occasional floodplain pockets. • Channel characterised by bedrock steps, cascades, plunge pools, sets of shallow cascades separated by pools ~ 25m long and cascade complex up to 50m in length. Minor sand accumulations are present at this site in the pools and on top of sandstone steps. • Storm water pipe enters channel on northern side. Upstream of this site water quality is good and the are no accumulations of fine sediments. Downstream of the pipe the water becomes milky and small silt deposits are apparent. •	• Natural catchment use retained on southern side, altered on northern side by urban development (retirement village - SEPP 5 complex • Excellent natural vegetation continuity on flood plain and in riparian zone - almost nil weeds • Pristine vegetation especially on the southern side with high native species richness, canopy cover etc. Exotics absent except for a few minor herbaceous weeds • Excellent species richness and community composition. Only one serious environmental weed on northern side: minor Whisky Grass presence. • A good example of a creek with high Dry Sclerophyll and riparian native species diversity. Only compromised by development on northern side. • Leucopogon amplexicaulis: ex ROTAP present at site but uncommon regionally • Excellent potential for dispersal of native terrestrial species on southern side, much more limited on northern side. Excellent refuge for native species in dense native vegetation on southern side, from more altered landscape on northern side.	• High level of naturalness, representativeness and diversity at site under threat from recent clearing on northern side of creek and development of retirement village, housing etc. Severe threat from runoff and ingress of weed propagules from gardens and activities in catchment. • Significant and uncommon species vulnerable to future invasion by weeds. • High quality habitat particularly on the southern side, would eventually be threatened by increasing degradation on northern side of creek line.	Naturalness: 4 Representativeness: 4 Diversity: 4 Rarity: 3 Special Features: 4 **Overall Ecological Value: 3.8**	• Creek in very good condition. Management strategies need to be put into place that ensure creek remains in its current condition. This may include extending the buffer zone around site. • Storm water pipe that is emptying into channel should have a filtering mechanism fitted.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Wheeler Creek (lower) – Little Wilandra Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.2.2a	• Degraded channel up to 8m in width and 3m in depth. Partly confined, bedrock controlled with discontinuous floodplain. • Channel up stream of road crossing highly degraded by construction site: channel over widened, banks are nude and protective structures are failing (ie: rock wall and geotextiles), large slugs of sediment are apparent in the channel and are blocking culvert beneath road. • Construction occurs right up to the top of the banks, no buffer strip has been left for the channel. There are no bank support structures to compensate this activity • Channel downstream of road crossing is completely choked by environmental weeds, this, combined with increased sediment influx from the construction site is ponding flow and diverting towards the banks. Banks are actively eroding and encroaching on infrastructure. Ponding will increase the likelihood of flooding during future storm events.	• No natural catchment land-use retained • Poor connectivity - limited to scattered, remnant native trees. • All vegetation removed in upstream half and only continuous weeds in downstream half with remnant natives only. • Poor native species richness - high abundance and diversity of exotics • No habitat for native fauna except adaptable native birds • Very poor native species richness - • Swamp Mahogany (Eucalyptus robusta) are a significant winter-flowering tree being food source for range of fauna including potentially threatened fauna species e.g. Koala, Regent Honeyeater etc present at site • May have once been a marginal example of Sydney Coastal Estuary Swamp Forest (Endangered Ecological Community under the TSC Act) • No real opportunities for dispersal of terrestrial species - insufficient habitat and houses too close to creek line. • No refuge values for any native species except those most tolerant of urban environments	• Potential for remnant native trees to die as a result of runoff and degradation - few opportunities for regeneration of remnant native trees due to mown and weedy undergrowth • Natural bank of creek destroyed by channelisation and stabilisation with sandstone blocks (upstream areas) • The degree of disturbance and continuing degradation will ensure that the handful of natural features (ie native species) remaining are likely to soon disappear. • Native shrub and groundcover species are in imminent danger of disappearing due to weed invasion. Tree layer species may be under long-term threat from lack of regeneration opportunities and poor creek water quality due to sewer line and runoff • Significant species such as Swamp Mahogany may be under long-term threat as discussed above • Little habitat for fauna remains to be destroyed except for the Swamp Mahogany trees, Black She-oaks and possible weedy habitat that could impact some native species if removed too rapidly • Significant risk of further bank erosion, flooding and loss of infrastructure due to ponding and deflection of flow towards banks.	Naturalness: 1 Representativeness: 1 Diversity: 1 Rarity: 2 Special Features: 1 **Overall Ecological Value: 1.2**	• Ludwigia infestation needs to be managed as it is spreading downstream. • Banks need to be stabilised to mitigate property damage through bank collapse. • Sediment needs to be controlled within the channel as it is blocking culverts that may result in flooding.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

South Creek (mid) – Lillihina Ave

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.2c	• Steep boulder and bedrock channel, ~2m wide, <1m deep. Steep Headwater. • Channel characterised by pool-riffle sequences, boulders and bedrock steps cre ating cascades, falls and plunge pools. Some accumulations of sand create bars at the margins of pools • The downstream end of the reach is piped beneath small park and houses. The drain exiting the stream is not efficient at transporting flow; excess flow is spreading out across the parkland. •	• Canopy natives in good condition, understory is suppressed by casuarina needles • Creek heavily urbanised on each valley side, this increases the likelihood of water quality problems and infestation be weeds • Good continuity of natural vegetation in riparian zone and on adjacent valley slopes floodplain – well connected • Moderately good species richness, but some minor exotics • A good example of a moist forest (Coachwood Rainforest) remnant. • Coachwood (Ceratopetalum apetalum) present at site • Good canopy cover for dispersal of arboreal mammals. • Good refuge for native fauna species such as birds: Whip Bird and Grey Butcherbird	• Threats include nutrient rich runoff from surrounding suburban development and suppression of native species regeneration by an increasingly thick canopy of Sweet Pittosporum. • Flagship rainforest taxa e.g. Coachwood under long-term threat from suppression of natural regeneration by Sweet Pittosporum and possibly by poor quality runoff. • Reduction in species diversity (as a result of failure to naturally regenerate and eventual dieback) could lead to simplification of habitat and lower faunal species diversity	Naturalness: 3 Representativeness: 3 Diversity: 3 Rarity: 3 Special Features: 3 **Overall Ecological Value: 3**	• This site will benefit from minor weed removal and monitoring for weed encroachment. This could easily be carried out by a community group. • Thinning of the canopy may be necessary so that light can penetrate through to the un derstory and give natives the chance to regenerate. • The removal of the build up of pittosporum needles would also be beneficial to regeneration.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

South Creek (upper) – Willandra Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.2e	• Low sloped irregular shaped bedrock channel, 3m wide, <1-2m deep. Transition from Partly confined, bedrock controlled with occasional floodplain pockets to Steep headwater. • Channel is characterised by Pool-riffle sequences, Boulders and bedrock steps creating cascades and plunge pools. Accumulations of sand create bars at the margins of riffles and in pools • Upstream of road crossing a thin discontinuous strip of floodplain flanks eastern side of channel; no geomorphic features present as modified to parkland. Channel slope and valley slope are low angle. • Where vegetation has been removed sandy banks are eroding releasing sediment into channel. Pools are accumulating large quantities of sand. • Garden refuse has been packed against banks as a stabilisation technique. • Study reach is in close proximity to housing; effluent has been released into channel causing odor and suds. • Downstream of road crossing the valley constricts, valley slope and channel slope become steeper as the channel moves into a gorge setting and the floodplain disappears. • The geomorphic units within this reach are the same as above the road, but more exaggerated. Flow velocities are also higher due to increased slope.	• Partial retention of natural catchment land uses (on valley slopes downstream of road-crossing) - remainder suburban housing • Some remnant native vegetation but mostly planted species and manicured areas. There is a higher concentration of native canopy species downstream of road crossing. There are high levels of exotic species. • Riparian zone discontinuous - interrupted by mowing and manicuring - few native species • Represents a creek that has experienced a long history of disturbance and degradation • Grey Gums (Eucalyptus punctata) on eastern side of Willandra Rd. This species of significance to fauna potentially including threatened fauna e.g. Koala. • Low potential for dispersal of native terrestrial fauna due to altered nature of vegetation • Little refuge for native fauna because the vegetation is itself highly altered and discontinuous. Rainbow Lorikeets, Whip Birds present.	• Natural values of site threatened by continuing replacement of native species by exotic garden plants, manicuring and mowing, nutrient rich runoff and continuing invasion by exotic environmental weeds. Houses are very close to creek edge on northern side. • Substrate of reach upstream of road crossing is a friable clayey sand; continued adhoc removal of vegetation will enhance bank erosion and release sediment into the system. • Significant tree species under long-term threat from dieback and lack of natural regeneration opportunities • The few natural biotic features remaining are at risk of long-term loss due to the threatening processes discussed above. • Concentrating of weed species providing seed source that can be transported to downstream reaches.	Naturalness: 2 Representativeness: 2 Diversity: 2 Rarity: 2 Special Features: 1 **Overall Ecological Value: 1.8**	• Source of effluent being released into channel needs to be found and managed. • This site would benefit from weed removal, bank stabilisation and denser planting of endemic natives in the riparian zone. Upstream reach is located in a park that appears to be maintained locally, this site could be good candidate for community management. • As houses back onto creek, community education would be beneficial.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

South Creek (mid) – Willandra Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.2d	• Very incised channel 2-4m wide, 4-5m deep. Partly confined, bedrock controlled with discontinuous floodplain. • Channel characterised by steep vertical banks. The bed of the channel has a stepped morphology created by bedrock and consolidated sediments. There is an erosional bench present at intervals along the low flow channel margin and large sediment slugs present in the channel. • Pockets of floodplain are present but modified by urbanisation.	• Banks of channel are vertical and actively eroding, no apparent stabilisation strategies are in place. • GPT presents barrier to fish passage. • No natural catchment land uses retained – surrounded by suburban housing. • No natural vegetation on floodplain (floodplain except for Swamp Mahogany) – wide bands of mown Kikuyu. On either side of creek line • Swamp Mahoganies (significant winter flowering species for fauna) • Very poor remnant of Sydney Coastal Estuary Swamp Forest Complex (TSC Act) • Poor habitat for dispersal of native terrestrial species • Little refuge for native fauna except for those tolerant of highly disturbed habitats. Nectivorous fauna could utilise Swamp Mahoganies for feeding and roosting. Birds present: Whip Birds, Rainbow Lorikeets	• If banks are left destabilised further channel widening will occur releasing sediment downstream and may encroach on infrastructure. • Natural values of site under long-term threat from lack of regeneration opportunities due to regular mowing and continuing weed invasion. Also threatened by runoff and garden refuse dumping. • The remaining native species that are indicative of the significance of the site's vegetation as a relict of a listed endangered ecological community are at risk of loss in the long term. • The limited habitat for native fauna could be threatened by ultimate loss of Swamp Mahoganies, or by excessively rapid removal of weeds without replacement with native cover.	Naturalness: 1 Representativeness: 1 Diversity: 2 Rarity: 2 Special Features: 1 **Overall Ecological Value: 1.4**	• Banks stabilisation is required at this site to prevent bank collapse and sedimentation of channel.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

South Creek (mid-lower) – Carcoola Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.2b	• Asymmetrical shaped channel, 5-15m wide, 3-5m deep. Partly confined, bedrock controlled with discontinuous floodplain. • Channel characterised by broad overwidened channel, large sediment slugs (sand) and erosional bench. Most geomorphic features are submerged. • Large pockets of floodplain apparent, dissected by minor flood channel . • Channel is actively eroding and weed species have densely colonised within the channel downstream of the road -crossing.	• Box culverts beneath road are b eing blocked by sediment, channel upstream of culverts is experiencing severe erosion from ponding and eddying caused by blocked flow. • Dense weed species have colonised in the channel downstream of road-crossing, any water that passes through culverts is p onding behind vegetation and destabilising banks. The channel banks regain stability downstream. • This reach upstream of the road has been recently cleared of weeds, lack of maintenance and stabilisation has created enhanced erosion and weed infestation at the site. • No natural catchment landuses retained – suburban housing • No natural vegetation or connectivity in floodplain – open mown parkland. • Riparian zone consisting of almost continuous weeds with occasional remnant native species e.g. Swamp Mahogany • Very poor remnant of Sydney Coastal Estuary Swamp Forest complex (TSC Act • Minimal habitat available for dispersal of native terrestrial communities – discontinuous canopy only Refuge habitat for robust native fauna tolerant of degraded or open habitats.	• Weeds are actively compromising flow in channel and are providing a rich seed source to reaches downstream. • Sedimentation and bank erosion are severely compromising the stability of the site. This needs to be addressed immediately before effects are move upstream and downstream • Remaining native species including Swamp Mahogany) threatened by total displacement by weeds and dieback in the longer-term. • Garden refuse dumping and mowing of grass too close to creek bank are also threats. • The low native species diversity is at risk of further reduction due to displacement and competition by invading environmental weeds • The minimal habitat available for native fauna is threatened by continuing degradation in the long-term, due to runoff, weed invasion, gar den refuse dumping and grass mowing	Naturalness: 1 Representativeness: 1 Diversity: 1 Rarity: 2 Special Features: 1 **Overall Ecological Value: 1.2**	• Banks stabilisation is required at this site to prevent bank collapse and further sedimentation of channel. • Weeds that are choking channel need to be removed so that natural flow velocities can return. • Sediment needs to be removed from culverts to prevent ponding and altered flow patterns.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

South Creek (lower) – Kirkstone Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.2a	• Asymmetrical moderately sinuous Alluvial channel, 6m wide, 1-2m deep. • Alluvial channel characterised by erosional benches, most instream geomorphic units are submerged. Tributary entering trunk stream is stepped with a sandy clay substrate. Active erosion occurring as evidenced by freshly exposed plant roots • Narrow strip of floodplain on the eastern margin of the channel, extensive floodplain to the west. Although floodplain on either side of the channel is altered (park and golf course), indentations may be meander cutoffs and flood channels. Swamp mahogany on floodplain indicates frequent inundation • Banks are currently stabilised by dense exotic vegetation. If this vegetation was to be removed it would result in bank instability and channel widening. • Submerged accumulations of sand observed within the channel	• No natural catchment landuses retained – suburban housing and golf course. • Only trees retained on floodplain – all under-story replaced by mown lawn. • Riparian zone consisting of continuous exotic species. • Very low species richness. High numbers and density of exotics • Native trees in floodplain represent a remnant of significant Swamp Mahogany Swamp Forest. • Remnant of Sydney Coastal Estuary Swamp Forest complex (TSC Act) but poor quality • Limited opportunities for dispersal of terrestrial native species except in canopies of remnant trees. • Very marginal refuge for native fauna in dense weed vegetation except for those tolerant of weedy or open habitats. Wood Ducks, Noisy Miners, introduced Spotted Turtle-doves present.	• Removal of weeds would drastically destabilise this system, releasing large amounts of sediment downstream. • Remaining native vegetation communities under threat from urban runoff and encroaching exotics. May cause dieback	Naturalness: 2 Representativeness: 2 Diversity: 1 Rarity: 2 Special Features: 1 **Overall Ecological Value: 1.6**	• Weed removal and subsequent bank stabilisation would be beneficial to this site but not cost effective given ecological returns.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Deep Creek (upper) – Madang Rd

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.3.3 and 6.3.3.1	• Irregular shaped bedrock channel 1-5m width, <1m deep. Steep headwater. • Channel characterised by pools, riffles, bedrock shelves, bedrock overhangs, bedrock steps, cascades, plunge pools. • There are some gravel accumulations within pools, these are natural for the position in the catchment • No floodplain present at this site. • River in excellent condition, vegetation in excellent condition. Thick native vegetation hold together the shallow banks comprised of a mottled clay and organic material. • Water quality is very good with water in deep, active plunge pools clear to the base. • River runs along access road to national park..	• Site warrants immediate conservation as it is currently in a pristine state. • Total retention of natural catchment land uses - extensive natural bushland surrounding • Excellent connectivity of vegetation and native species richness in riparian zone and on adjacent valley slopes • Excellent native species richness and community structure - exotic species practically absent (very occasional Whisky Grass) • The plant community is highly representative of a natural riparian community in dry sclerophyll forest in the local district, with very minor disturbance or modification and practically no exotic weeds present. • Excellent native species richness, cover and abundance • Grey Gums (*Eucalyptus punctata*): listed SEPP44 Koala habitat tree • Suitable Red-crowned Toadlet (TSC Act) habitat in areas of Coral Fern (*Gleichenia* sp.) along creek line • Excellent habitat for dispersal of terrestrial native species in high quality, well structured and diverse vegetation • Excellent refuge habitat for native fauna, but owing to the naturalness of the surrounding extensive bushland area, this habitat is not critical as a refuge from altered landscapes. High bird diversity: Whip-bird, Wattle Bird, Yellow-faced Honeyeater, Spinebill, Spotted Pardalote.	• Vehicles and pedestrians entering site need to check for weed seeds and propagules before entering site to maintain condition. • The value of this site are subject to a remote threat of subtle impacts from the upper catchment, minor impacts from recreational users of the bushland (e.g. horses, trail bikes), and fire trail maintenance. • The very high level of natural species diversity could be at minor long-term threat of progressive downstream weed invasions from upstream disturbed areas. • Values of rarity such as potential Koala habitat trees could be at a small and remote risk in the long term from declining water quality and displacement of characteristic flora species due to eventual invasion of weeds • Faunal habitat values are not under high or immediate risk, but in the long term could suffer from gradual degradation such as weed invasion moving progressively downstream from the upper catchment	Naturalness: 4 Representativeness: 4 Diversity: 4 Rarity: 4 Special Features: 4 **Overall Ecological Value: 4**	• Creek in very good condition. Management strategies need to be put into place that ensure creek remains in its current condition. This may include extending the buffer zone around site or extending the national park to contain the whole Deep Creek catchment. • As adjacent road is frequently used for recreation signs need to be erected asking those who use the area to be sure that don't bring in weed propogules etc.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Narrabeen Lagoon tributary – James Wheeler Pl

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
6.4	• Very narrow, shallow Alluvial channel. Is more a depression in the ground than a channel. Substrate is sandy clay. Although no real geomorphic units, behaves as pool -riffle system. • Flows through flat, low sloped valley bottom. Floodplain flanks either side of channel. • Site is stable and colonised by lush exotic vegetation. • Channel lies in close proximity to houses	• Natural catchment land use retained to NE of site - expanse of natural bushland • Mostly dense, weedy vegetation in floodplain • Riparian zone wide, mostly weeds except for some native trees • Swamp Mahoganies (significant winter flowering species for fauna), Bangalays, Cabbage Palms present at site • Very degraded relict of Sydney Coastal Estuary Swamp Forest Complex (TSC Act) • Some potential for dispersal of terrestrial native species particularly on the NE side of the creek bordered by natural bushland. • Poor refuge for native fauna species in the creek line area itself except for those tolerant of degraded environments. Birds present: Noisy Miners, Rainbow Lorikeets.	• Threats to remaining natural values include runoff from suburban housing on SW side, garden refuse-dumping, ultimate complete replacement of native species by weeds and possible future clearing of bushland for SEPP5 development on NE side of creek. Dieback of native trees. • Remaining native species diversity is threatened by continuing invasions of weeds and lack of regeneration opportunities due to density of weed cover • Rarity is at threat by long-term loss of species indicative of the threatened swamp-forest community. • The main threat to fauna habitat would be newly-imposed disturbance or progressive degradation of habitat in natural bushland adjoining the site on the NE side	Naturalness: 1 Representativeness: 2 Diversity: 2 Rarity: 3 Special Features: 1 **Overall Ecological Value: 1.8**	• Weeds needs to be managed in this area to prevent them encroaching on adjacent slope in good condition. • Vegetation cover needs to be maintained so that nick points do not develop.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Collaroy Beach tributary – Cnr Hendy Ave and Kent St

Reach Number	Current Condition and Processes	Environmental Values (generally ecological)	Environmental Issues or Risks	Value Indicator	Environmental Management Strategy
7.2	• Asymmetrical channel~2m wide, 1-2m deep, Swamp present at site~50m wide, >5m deep. Confined with occasional floodplain pockets • Channel structure is mottled clay banks, bedload is organic matter and muds. Sand apparent in channel has been derived from eroded fill around storm water pipe. • Channel and swamp characterised by minor bars consisting of silts and muds in small channel (30cm wide, 80 cm long) that exits the swamp, large sand bar apparent at the outlet of the storm-water pipe. Inset bench apparent along the margins of the swamp. Dense weed cover inhibits a clear view to confirm this. • minor strip of floodplain present exhibiting no geomorphic features, due to infestation of weeds. • Upstream of the active swamp, weeds are being cleared. Anecdotal evidence suggests that this upstream area was similar to the downstream swampy area, removal of weeds has dried up the swamp and it now acts as a narrow floodplain and channel complex within a narrow valley setting.	• Natural catchment land-use has been retained for some distance north of the site, otherwise surrounded by suburban development • Some elements of natural vegetation in floodplain, connectivity moderately good and native species richness moderately good. • Riparian zone mainly consisting of environmental weeds • Highly modified, example of creek line rainforest/coastal dry sclerophyll forest transition • Moderately good native species richness, many of a moist gully/rainforest character • Swamp Mahoganies significant winter-flowering species for fauna. Cabbage Palms typify moist gully habitats, Coastal Banksias typify coastal/sandy habitats • An unusual transitional community containing rainforest, swamp forest and coastal dry sclerophyll elements. None listed as threatened except Swamp Forest elements. • Good habitat for dispersal of terrestrial species on northern side of creek - good cover • Good refuge for native fauna on northern side - good cover and diversity of native species in all strata	• Natural elements of floodplain vegetation on northern side of creek could be threatened by progressive invasion of weeds and dieback of Swamp Mahoganies in the long-term. • Whole site burnt in 1993, but occasional fire likely to be natural/beneficial to this community. • The representative moist forest transitional character of the vegetation is threatened by simplification through loss of species • Species diversity threatened by simplification due to increases of environmental weeds including Sweet pittosporum • Quality of habitat for native fauna is threatened by the degrading processes as detailed above	Naturalness: 2 Representativeness: 2 Diversity: 3 Rarity: 2 Special Features: 2 **Overall Ecological Value: 2.2**	• Site is very weed infested but stable. As substrate is moderately cohesive the site may be able to cope with mass weed eradication. Fire may be an option for weed removal. • Rehabilitation is taking place upstream, coordinated by a community group. The weed infested site may be able to be included into rehabilitation strategy.

Ecological Value Indicator:
4=Very High; 3=High; 2=Moderate; 1=Low

Appendix B2

Reach Risks Analyses

REACH NUMBER: 1.1

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Discharge of effluent through accidental or deliberate release	3	4	**12**
	Changes in water quality from future urban development areas	3	4	**12**
2 Riparian and Aquatic Areas - Biodiversity	Loss of native flora by suppression by weeds and poor water quality	3	4	**12**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 1.1.4

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Changes in water quality from future urban development areas	3	3	**9**
2 Riparian and Aquatic Areas - Biodiversity	Loss of native flora by suppression by weeds or poor water quality	3	4	**12**
4 Riparian Areas - Weed Encroachment	Continued loss of understorey and canopy leading to loss of endemic plant species diversity	4	3	**12**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 1.2

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1. Water Quality	Discharge of effluent through accidental or deliberate release	3	4	**12**
2 Riparian and Aquatic Areas - Biodiversity	Loss of native flora through suppression by weeds or poor water quality	4	4	**16**
6 In-stream Fauna Health	Reduction in habitat diversity and loss of fish passage through channel modification	4	4	**16**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 3.1

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
3 Adjacent Natural Areas - Biodiversity	Lack of continuous riparian corridor to support fauna movement	2	5	**10**
	Loss of waterway corridors linking bushland areas	2	5	**10**
6. In-stream Fauna Health	Reduction in habitat diversity due urban modification	3	5	**15**

Consequence: *1 (Insignificant) to 5 (Catastrophic)*
Likelihood: *1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 4.1

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
7 Sedimentation - Channel	Sediment overload in a number of areas	3	4	**12**
8 Erosion - Banks	Lack of bank stability following weed removal or revegetation (short term)	4	4	**16**
	Instability in flood events because of shallow rooted riparian weeds	4	4	**16**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 4.1.1

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	4	4	**16**
4 Riparian Areas - Weed Encroachment	Continued loss of understorey and canopy leading to loss of endemic plant species diversity	4	4	**16**
	Creating source area for weed propagules that may infest downstream reaches	5	5	**25**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 4.2

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	3	4	**12**
7 Sedimentation - Channel	Sediment overload in a number of areas	3	5	**15**
8 Erosion - Banks	Downstream sedimentation and loss of aquatic habitat	4	4	**16**
12 Safety	Dangers due to people visiting sites with steep and/or eroded banks	4	3	**12**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 4.2.2

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Discharge of effluent through accidental or deliberate release	4	3	**12**
	Changes in water quality from future urban development areas	5	3	**15**
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	5	4	**20**
4 Riparian Areas - Weed Encroachment	Continued loss of understorey and canopy leading to loss of endemic plant species diversity	5	4	**20**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 4.3a

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Reintroduction of weeds into rehabilitated area through poor maintenance	4	4	**16**
8 Erosion - Banks	Downstream sedimentation and loss of aquatic habitat	4	3	**12**
	Lack of bank stability following weed removal or revegetation (short term)	4	4	**16**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 4.3.1.1

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	5	4	**20**
4 Riparian Areas - Weed Encroachment	Continued loss of understorey and canopy leading to loss of endemic plant species diversity	4	4	**16**
10 Solid Wastes and Leachates	Dumping of garden and solid waste	4	5	**20**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 4.3b

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	5	4	**20**
	Encroachment of weeds from adjacent landuse	5	5	**25**
10 Solid Wastes and Leachates	Dumping of garden and solid waste	5	5	**25**

Consequence: *1 (Insignificant) to 5 (Catastrophic)*
Likelihood: *1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 5.1.1

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	3	3	**9**
4 Riparian Areas - Weed Encroachment	Suppression of "natural" plant regeneration	3	4	**12**

Consequence: *1 (Insignificant) to 5 (Catastrophic)*
Likelihood: *1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 5.2

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Discharge of effluent through accidental or deliberate release	3	4	**12**
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native plants by landscape modification	3	5	**15**
	Loss of waterway corridors linking bushland areas	4	4	**16**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 5.2.1

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Discharge of effluent / nutrients through accidental or deliberate release	3	4	**12**
2 Riparian and Aquatic Areas - Biodiversity	Invasion of weeds from adjacent landuse	4	4	**16**
10 Solid Wastes and Leachates	Dumping of garden and solid waste	4	4	**16**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 5.3

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1. Water Quality	Loss of native species through poor water quality ie: dieback	4	4	**16**
2 Riparian and Aquatic Areas - Biodiversity	Invasion of weeds from adjacent landuse	4	4	**16**
8 Erosion - Banks	Lack of bank stability following weed removal or revegetation (short term)	4	4	**20**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 5.5.2

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Changes in water quality from future urban development areas	4	4	**16**
2 Riparian and Aquatic Areas - Biodiversity	Invasion of weeds from adjacent landuse	5	3	**15**
6 In-stream Fauna Health	Reduction in habitat diversity due to sedimentation	5	3	**15**
	Reduction in habitat due to altered flow regimes	4	4	**16**
7 Sedimentation - Channel	Influx of sediment from adjacent landuse	4	5	**20**

Consequence: *1 (Insignificant) to 5 (Catastrophic)*
Likelihood: *1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.1.3.3

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1. Water Quality	Discharge of effluent through accidental or deliberate release	4	5	**20**
	Changes in water quality from future urban development areas	4	5	**20**
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	3	5	**15**
8 Erosion - Banks	Downstream sedimentation and loss of aquatic habitat	4	5	**20**
	Incision of channels leading to geomorphological and ecological impacts	4	4	**16**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.1.3b

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Particulate and nutrient pollution from bank/channel erosion	4	4	**16**
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	4	4	**16**
	Loss of native fauna habitat by weeds and sediment	4	4	**16**
3 Adjacent Natural Areas - Biodiversity	Encroachment of weeds from riparian areas	5	4	**20**
	Reduction in habitat diversity due to sedimentation	4	4	**16**
8 Erosion - Banks	Incision of channels leading to geomorphological and ecological impacts	4	4	**16**

Consequence: *1 (Insignificant) to 5 (Catastrophic)*
Likelihood: *1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.1.3a

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Invasion of weeds from adjacent landuse	3	4	**16**
	Suppression of native flora by weeds	3	4	**16**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.1.7

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
7 Sedimentation - Channel	Ongoing aggradation and blocking of culverts causing flooding	4	4	**16**
	Sediment overload in a number of areas	3	5	**15**
12 Safety	Dangers due to people visiting sites with steep and/or eroded banks	5	5	**25**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.1e

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
4 Riparian Areas - Weed Encroachment	Continued loss of understorey and canopy leading to loss of endemic plant species diversity	4	4	**16**
7 Sedimentation - Channel	Sediment overload in a number of areas	4	4	**16**
8 Erosion - Banks	Incision of channels leading to geomorphological and ecological impacts	4	5	**20**
	Large articles of rubbish altering natural flow pattern	4	5	**20**
	Lack of bank stability following weed removal or revegetation (short term)	4	4	**16**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.1d

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
4 Riparian Areas - Weed Encroachment	Continued loss of understorey and canopy leading to loss of endemic plant species diversity	3	4	**12**
8 Erosion - Banks	Downstream sedimentation and loss of aquatic habitat	4	4	**16**
	Incision of channels leading to geomorphological and ecological impacts	5	4	**20**
	Lack of bank stability following weed removal or revegetation (short term)	5	4	**20**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.1c

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	5	3	**15**
4 Riparian Areas - Weed Encroachment	Loss of understorey and canopy endemic plant species diversity	5	3	**15**
	Suppression of "natural" plant regeneration	5	3	**15**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.1a

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
4 Riparian Areas - Weed Encroachment	Continued loss of understorey and canopy leading to loss of endemic plant species diversity	3	4	**12**
7 Sedimentation - Channel	Sediment overload in a number of areas	3	5	**15**
10 Solid Wastes and Leachates	Dumping of garden and solid waste	4	5	**20**

Consequence: *1 (Insignificant) to 5 (Catastrophic)*
Likelihood: *1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.1b

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
8 Erosion - Banks	Downstream sedimentation and loss of aquatic habitat	4	5	**20**

Consequence: *1 (Insignificant) to 5 (Catastrophic)*
Likelihood: *1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.2.2b

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Changes in water quality from future urban development areas	5	5	**25**
3. Adjacent Natural Areas - Biodiversity	Encroachment of weeds from riparian areas	5	5	**25**
4 Riparian Areas - Weed Encroachment	Encroachment of weeds to main channel from adjacent landuse	5	5	**25**
6. In-stream Fauna Health	Toxic effects of pollutants (see also 1.1	5	5	**25**

Consequence: *1 (Insignificant) to 5 (Catastrophic)*
Likelihood: *1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.2.2a

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
6. In-stream Fauna Health	Choking of in-stream habitats by weeds	4	5	**20**
7 Sedimentation - Channel	Ongoing aggradation and blocking of culverts causing flooding	4	4	**16**
8 Erosion - Banks	Downstream sedimentation and loss of aquatic habitat	4	5	**20**
	Erosion adjacent to urban areas - potential economic loss	4	5	**20**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.2c

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Discharge of effluent through accidental or deliberate release	3	4	**12**
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora regeneration by canopy shading	3	4	**12**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.2e

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	4	4	**16**
6. In-stream Fauna Health	Water quality changes associated with nutrient runoff from adjacent landuse	3	4	**12**
8 Erosion - Banks	Lack of bank stability following weed removal or revegetation (short term)	4	4	**16**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.2d

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	3	4	**12**
4 Riparian Areas - Weed Encroachment	Continued loss of understorey and canopy leading to loss of endemic plant species diversity	3	4	**12**
7 Sedimentation - Channel	Ongoing aggradation and blocking of culverts causing flooding	4	4	**16**
8 Erosion - Banks	Downstream sedimentation and loss of aquatic habitat	4	4	**16**
	Mass failures in steep bank	4	4	**16**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.2b

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	3	4	**12**
6 In-stream Fauna Health	Choking of in-stream habitat by weeds	4	4	**16**
7 Sedimentation - Channel	Ongoing aggradation and blocking of culverts causing flooding	4	5	**20**
8 Erosion - Banks	Downstream sedimentation and loss of aquatic habitat	4	5	**20**
	Lack of bank stability following weed removal or revegetation (short term)	4	5	**20**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.2a

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	3	4	**12**
4 Riparian Areas - Weed Encroachment	Continued loss of understorey and canopy leading to loss of endemic plant species diversity	3	4	**12**
7 Sedimentation - Channel	Encroachment of weeds into depositional areas	3	4	**12**
8. Erosion - Banks	Lack of bank stability following weed removal or revegetation (short term)	4	3	**12**

***Consequence**: 1 (Insignificant) to 5 (Catastrophic)*
***Likelihood**: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBERS: 6.3.3 AND 6.3.3.1

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1 Water Quality	Changes in water quality from future urban development areas	5	3	**15**
2 Riparian and Aquatic Areas - Biodiversity	Invasion of weeds	5	3	**15**
3 Adjacent Natural Areas - Biodiversity	Encroachment of weeds from riparian areas	5	3	**15**
6 In-stream Fauna Health	Reduction in habitat quality through weed and sediment introduction	5	3	**15**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 6.4

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1. Water Quality	Changes in water quality from future urban development areas	3	4	**12**
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	3	4	**12**
3 Adjacent Natural Areas - Biodiversity	Encroachment of weeds from riparian areas	4	4	**16**

Consequence: *1 (Insignificant) to 5 (Catastrophic)*
Likelihood: *1 (Rare) to 5 (Almost certain/currently occurring)*

REACH NUMBER: 7.2

RISK CATEGORY	ENVIRONMENTAL RISK	ISSUE PRIORITY		
		Consequence	Likelihood	Priority
1. Water Quality	Particulate and nutrient pollution from bank/channel erosion	3	4	**12**
2 Riparian and Aquatic Areas - Biodiversity	Suppression of native flora by weeds	3	4	**12**
3 Adjacent Natural Areas - Biodiversity	Encroachment of weeds from riparian areas	4	4	**16**
6 In-stream Fauna Health	Choking of in-stream habitat by weeds	4	4	**16**

Consequence*: 1 (Insignificant) to 5 (Catastrophic)*
Likelihood*: 1 (Rare) to 5 (Almost certain/currently occurring)*

Appendix C

Preliminary Heritage Advice

Contents

List of Figures

1. Introduction

This preliminary heritage advice was commissioned by Montgomery Watson Harza to examine the Indigenous heritage potential of lands included in the Warringah Council Creek Management Study (**Figure 1**). Strictly a preliminary assessment, this study is designed to identify broad Indigenous heritage issues which may require addressing in more detail in the future. The report was prepared by archaeological research consultant Adam Ford of DIG International Pty Ltd.

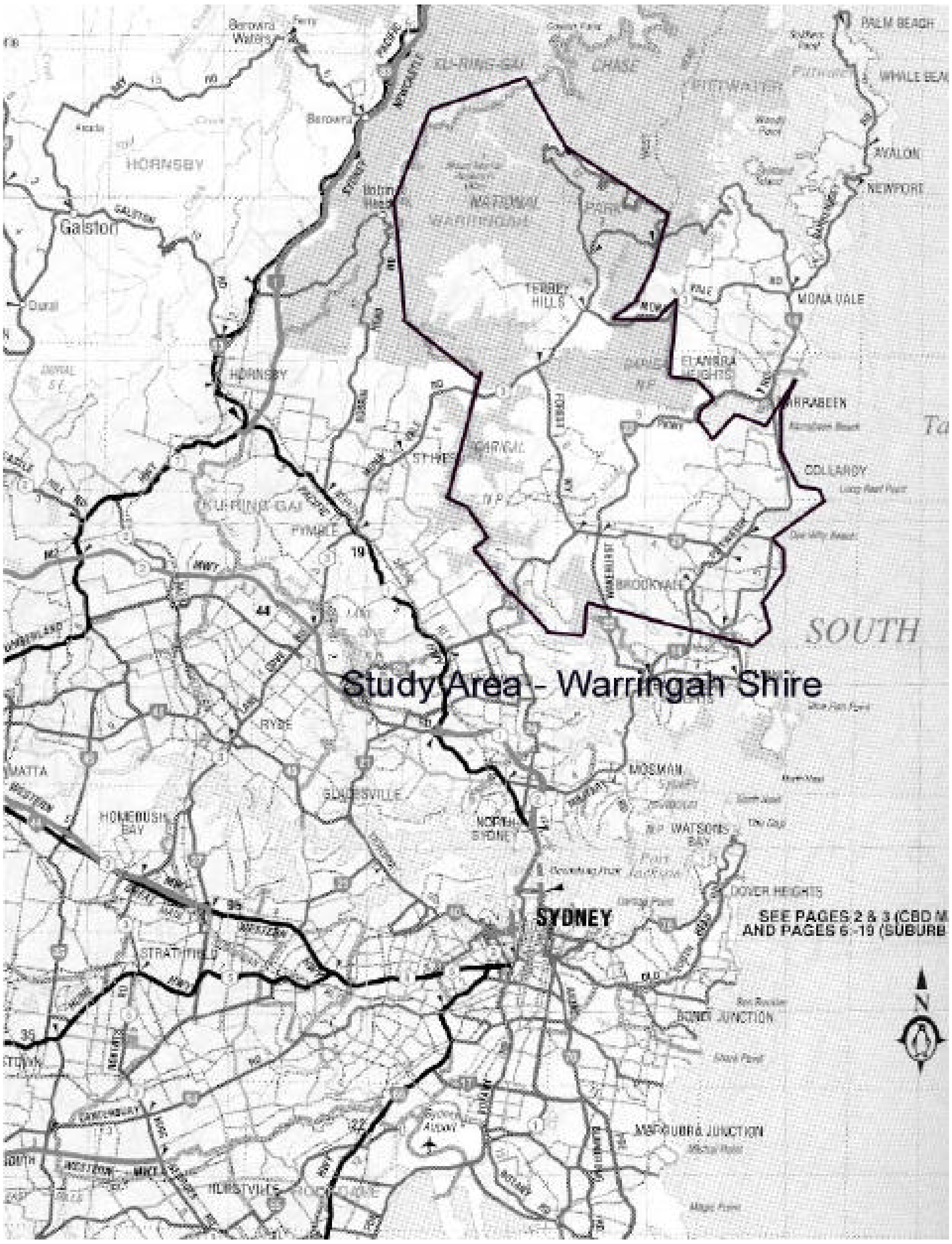

Figure 1: Location of Study area

1.1 Methodology

A desktop study was the most appropriate method for the level of heritage advice required at this stage.
A desk-based assessment determines, as far as is reasonably possible from existing records, the nature of the archaeological resource within the specified area. It was undertaken using appropriate methods and practices, which satisfy the stated aims of the project, and which comply with the code of conduct and guidelines of the NSW, NPWS Aboriginal Cultural Heritage Guidelines and Standards (1996) and NSW Heritage Office as described in the NSW Heritage Manual (1996).
The desk based study included a search of the National Parks and Wildlife Service (NPWS) Aboriginal Sites Register and review of the following planning instruments and studies applied to the Warringah area:

- National Parks Association 2001, Biodiversity Survey of Wheeler Creek Valley, from the *Wandering Wildlife Website*.
- Willing and Partners 1999, Middle Harbour Catchment Stormwater Management Plan. For the Stormwater Trust.
- Warringah Council 2000, Allenby Park, Allambie Heights, Plan of Management.
- Nelson Consulting 1998, Manly Warringah War Memorial Park, Plan of Management. With Warringah Council and DLWC.
- Warringah Council 2000, Red Hill and Golden Grove Parks, Plan of Management.
- Warringah Council 2000, Jamieson Park Narrabeen, Plan of Management.
- Warringah Shire Council 1990, Middle Creek Restoration Project, Environmental Impact Statement.
- LandArc Pty Ltd 2001, JJ Melbourne Hills Memorial Reserve and Adjoining Community Land, Terry Hills, Draft Plan of Management. For Warringah Council.
- Clouston 1996, Dee Why Valley and South Creek Open Space Corridor, Geographic Plan of Management. For Warringah Council.
- Warringah Council 2001, Warringah's Environmental Strategy (Draft).
- PPK 2000, Warringah Non Urban land Study. For Warringah Council.
- Warringah Council 2000, Interim Warringah Design Guidelines. For Warringah Local Environmental Plan 2000.
- Warringah Council 2000, Warringah Local Environmental Plan 2000.

1.2 Study Area

The study area comprises all sections of creeks within the Warringah Council area (approximately 153 km^2) and outside National Parks and nature reserves.

1.3 Study Limitations

This document provides preliminary advice only, it is not a detailed consideration of all aspects of potential heritage issues within the study area and is not a substitute for detailed archaeological assessment. It is designed to flag issues which require further, detailed assessment, if appropriate and identify stakeholders (specifically the Local Aboriginal Land Council).

The study did not include a field component and did not involve consultation with the Local Aboriginal Land Council.

Where relevant, the need for further studies has been identified in the management section.

2. Historical background

The greater Sydney region has been inhabited for at least 20,000 years. The Warringah Local Government Area is known to have significant Aboriginal heritage values with over 470 Aboriginal sites recorded in Warringah (PPK 2000). At the time of European settlement (invasion) of the Sydney region in 1788 the Warringah area was home to the Guringai people who were a language group of the Garigal clan. Ethnographic evidence from early white settlers suggest that large Aboriginal communities of extended families exploited marine, terrestrial and riparian environments with a hunter gatherer style existence.

Land grants were provided in the early 1800s but settlement of the area by Europeans was slow until transport links were provided to the area in the 1850s. Even then the difficult terrain and relatively remote location meant that economic and population growth was slow through out the 19th century.

Since the construction of the Spit and Roseville bridges in the first half of the 20th century the Warringah area has transformed from a semi rural region with sparse 'weekender' homes to a prime residential area of Sydney with an estimated population (1996 census) of over 130,000 people.

2.1 Land Tenure

Warringah LGA covers 153 km² of which over 40% or 62 km² is remnant bushland in reserve. 51 km² is National Park (Garigal and Ku-Ring-Gai Chase) and 11 km² is Council managed bushland. The Metropolitan Local Aboriginal Land Council (MLALC) owns the largest amount of land in the Warringah area with much of its land supporting natural bushland (Warringah Council 2001).

3. Deskbased Study Results

3.1 NPWS Sites Register (Minark)

A 20 km by 15 km area including the whole of the Warringah Council area was searched in the NPWS Aboriginal Sites (Minark) Register. However information on site types and site locations for large areas such as LGAs is restricted and cannot be accessed without licence and is generally only given to councils on condition that it is not relayed to the public.

3.2 Known Archaeological Resource

Aside from the NPWS Sites register the other documents reviewed identified a rich and varied Aboriginal archaeological resource within the Warringah Council area. PPK in their Non Urban Land Study commented that over 460 archaeological sites were recorded within the government area up to 1997, a figure which is likely to have increased in the last 4 years. Exact locations are not given for the reasons described above. The known archaeological resource includes rock engravings, middens, open camp sites, isolated finds, burial sites, water holes /wells, shelter deposits, shelter art sites, shelter middens, axe grinding grooves, quarries, stone arrangements and caves. The majority of sites recorded are rock engravings. This is a biased result caused by two major surveys conducted in the last century which specifically looked for art sites and the result is not representative of the potential archaeological resource.

4. Predictive Model

In order to begin to design a management strategy it is firstly necessary to develop a predictive model for site location. The first objective of any archaeological investigation must be to observe and record sufficiently the archaeological record that is present to be able to propose that it is representative of the record as a whole. The objective must be to detect material evidence, to consider the extent to which artefactual material may be present and the degree to which it is visible or might be discovered.

4.1 Predictive Model for Site Location (general)

It is necessary to make a number of assumptions based in part on observations made on archaeological sites throughout NSW and part based on common sense.

Locations that are the richest in resources are more likely to have been visited by people than those locations with fewer resources.

Sites that do occur in areas of few resources are usually on communication or access routes between areas which are resource rich.

Frequency of visits and use of particular locations is determined by the “accessibility” or freedom from environmental constraints in those locations.

Surviving material evidence represents a fraction of past Aboriginal activities, as many activities did not leave material evidence and much of the material culture was organic and therefore does not survive.

The identification of archaeological sites is dependant on factors, which present bias in the instance of location and site type. These factors could be cultivation and season, soil type and erosion, which affect the ‘detectability’ of sites during filed survey. Burials are usually undetectable and as a consequence are relatively rare in the archaeological record. Stone artefact scatters may go unnoticed if the vegetation is dense or flood has covered the historic ground level with sediment.

4.2 Model for the Study Area

With these assumptions in mind, together with the characteristics of the landform and location of the study area the following is predicted for the study area:

It is anticipated that open camp sites (stone artefact scatters) of pre and post European settlement date exist in the region, particularly in proximity to reliable water supplies. Therefore there is a potential for campsites throughout the study area and in particular near to creek lines and water bodies such as Narrabeen Lakes and Dee Why Lagoon.

There is some potential for scarred trees to exist within the study area however most mature trees have been cleared in areas outside of the National Parks.

There is a high likelihood of sites associated with the sandstone country of the study area. These sites include art sites such as rock engravings and rock paintings, and shelter sites such as caves and rock overhangs.

Middens are likely, particularly near to marine and estuarine environments, and are often associated with shelter sites and open camp sites.
Quarries are likely to occur where suitable tool material such as mudstone, chert and silcrete outcrop.
Grinding grooves are likely where sandstone and water are found together and are often within or next to creek lines.
Accidental findings of Aboriginal burials during activities such as sand mining, has resulted in predictive conclusions that burials most often occur in sand or soft soil deposits. However there is no reliable way to find out whether burials remain or not, without disturbing them further.
Isolated finds such as single stone artefacts are likely to occur on all landscape units throughout the study area.
Culturally significant sites such as spiritual sites occur throughout the Australian landscape and are often undetectable to the uninitiated and, unless Aboriginal people deem it appropriate, remain private.

5. Management Strategies

Considering the well documented evidence of Aboriginal activity in the area, particularly the amount of previous findings of cultural material in the region (as described above), the potential for significant archaeological deposits to occur within the study area (as described in the predictive model) is high. The following management strategies are appropriate for general management of the archaeological resource and follow strategies already developed by Warringah Council:

- A more extensive and systematic archaeological survey of the shire is recommended to map known sites and identify areas of archaeological potential in order to facilitate site by site management policies, particularly in relation to creek management;
- Employ and enforce objectives SE13 and SE14 of the Warringah's Environmental Strategy (Draft) (see **Appendix A**) which sets out aims to achieve 'zero loss' of Aboriginal sites through communication with the Metropolitan LALC (through the Aboriginal Land Working Group, amongst other avenues) and the integration of archaeological sites management in the planning instruments such as the LEP;
- In the meantime, Aboriginal Heritage Assessments should be carried out prior to any development which may impact:
  - on natural bush land, land previously undisturbed or subject to little disturbance;
  - land containing sandstone outcrops, rock shelters, old growth trees, sand bodies and land adjacent to creeks, rivers, lakes and swamps; and
  - land adjacent to known archaeological sites or areas of importance to Aboriginal people such as story places, missions and relocation reservations.

- All Aboriginal sites are protected under the National Parks and Wildlife Act 1974, regardless of their inclusion in the Aboriginal Sites Register and it is an offence to damage or destroy them without prior permission of the Director-General of the NPWS; and
- In determining development applications under the *Environmental Planning and Assessment Act 1979*, local councils must include matters relating to Aboriginal Heritage in the decision making process. As part of this process, the NPWS may be asked for advice on whether an area proposed for development should be subject to Aboriginal heritage assessment.

5.1 Non Indigenous Heritage

Items or relics of non indigenous origin over 50 years of age are protected under the *NSW Heritage Act 1977*. An assessment is required to establish items or relics are significant before they can be altered or destroyed. The established process of assessment is described in the NSW Heritage Manual 1996 and the Heritage Manual update document "*Assessing Heritage Significance*" 2001.

References

Clouston 1996, Dee Why Valley and South Creek Open Space Corridor, Geographic Plan of Management. For Warringah Council.

LandArc Pty Ltd 2001, JJ Melbourne Hills Memorial Reserve and Adjoining Community Land, Terry Hills, Draft Plan of Management. For Warringah Council.

National Parks Association 2001, Biodiversity Survey of Wheeler Creek Valley, from the *Wandering Wildlife Website*.

Nelson Consulting 1998, Manly Warringah War Memorial Park, Plan of Management. With Warringah Council and DLWC.

PPK 2000, Warringah Non Urban land Study. For Warringah Council.

Warringah Shire Council 1990, Middle Creek Restoration Project, Environmental Impact Statement.

Warringah Council 2000, Allenby Park, Allambie Heights, Plan of Management.

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Warringah Council 2000, Warringah Local Environmental Plan 2000.

Warringah Council 2001, Warringah's Environmental Strategy (Draft).

Willing and Partners 1999, Middle Harbour Catchment Stormwater management Plan. For the Stormwater Trust.

Appendix D

Estimating the Extent of Riparian Zones and Buffers: A Discussion Paper

Warringah Council
Creek Management Study - Appendix D

Contents

List of Tables

1. Introduction

This paper presents an initial discussion of riparian zone management principles and provides conceptual guidelines for estimating the extent of riparian buffers. This is the first stage in attempting to identify riparian management boundaries in Warringah, with particular emphasis on:

- discussing the functional significance of the 'riparian zone' and 'riparian buffers'; and
- recommending 'width designation tools' for the identification of riparian management boundaries, with respect to management objectives.

Riparian management has been the subject of several recent projects sponsored by the former Land and Water Resources Research and Development Corporation (LWRRDC now LWA) and other research groups such as the CRC for Catchment Hydrology, and the Centre for Catchment and In-stream Research. One implication of this research is that the riparian zone represents the complex interplay of structural (e.g. vegetation, channel form, floodplain) and functional (e.g. erosion, deposition, energy transfer, streamflow, habitat interactions, ecological connectivity, nutrient cycling) elements that defy simple definitions. NSW does not have a clear legal framework in relation to riparian protection and management. Throughout Australia, riparian management is currently treated as a sub-component of land and water management and their relative legislative frameworks (Maher et al, 2000).

This discussion paper aims to provide Council with a defensible basis for the definition of riparian zones. Zone delineation needs to have scientific credibility because it will potentially limit future development as well as influencing other aspects of creek management.

2. Functional Significance of the Riparian Zone

Traditional definitions of 'riparian' are structural in context, and refer primarily to land, vegetation or habitat occurring on, or adjacent to, the banks of a river or other water bodies. However, it is now acknowledged that in order to adequately define riparian land, its functional significance should also be taken into account. For example, in the recent *Interim State Water Management Outcomes Plan* released by the DLWC (2001), it was suggested that '*riparian land may be defined as that part of the landscape, which exerts a direct influence on stream channels or lake margins, and on the water and ecosystems contained within them*'. In terms of the 'Riparian Zone', the functional definition provided in the LWRRDC's Riparian Lands Management Newsletter (LWRRDC, 1998) may be the most appropriate for the present study. This definition includes *'any land which adjoins, directly influences, or is influenced by a body of water'* (LWRRDC, 1998).

Recent approaches to stream management have emphasised the importance of protecting/improving the most important aspects (values) of any particular stream environment, including those associated with the riparian zone (eg. Rutherfurd et al, 1999). In the context of its functional definition, riparian land is known to influence certain features of water bodies, including:

- channel and floodplain morphology and bank stability;
- the land/water interface (the ecotone);
- physical/chemical properties of the water;
- water quality;
- the aquatic ecosystem;
- ecological connectivity;
- conservation, wildlife, recreational and aesthetic values; and
- broader catchment health – facilitating the provision of ecosystem services.

The management of watercourses will therefore rely significantly on the effective management of the riparian zone. This is particularly important for streams in developed areas where alterations to natural conditions, such as higher overland flows (land clearing, grazing, urban infrastructure), higher nutrient and sediment loads (agriculture, urban wastewater) and habitat reduction (clearing of native vegetation), need to be offset. For example, riparian vegetation:

- decreases overland flow velocities, thereby enhancing bank and channel stability and reducing risk to human safety;
- improves water quality via the trapping of soil and nutrients;
- supports food-chain processes that trap and breakdown nutrients and toxic substances; and
- maintains ecological diversity via the provision of aquatic and semi-aquatic habitats.

Other benefits associated with the riparian zone, such as providing important habitat for terrestrial species, providing flood protection to nearby properties and increasing adjacent real estate value, should also be considered.

Unfortunately, the highly productive nature of riparian land makes it a prime target for intensive cropping, intensive grazing and intensive irrigation. In addition, the scenic values associated with waterways make adjacent land a prime target for development. Certain trade offs will exist, depending on the relative importance of development and waterway improvement to the community.

In a natural catchment, the water table adjacent to drainage lines is located at a relatively shallow depth. Riparian vegetation becomes established as a result of the available moisture. Natural riparian vegetation is also tolerant of nutrient-rich soils, up to a degree.

In a disturbed catchment, once the nutrient levels in the water of the creek and creekbank soils become too elevated, the natural vegetation seems to be out-competed by weeds. Consequently, protection from clearing or erosion is insufficient to protect the integrity of the riparian vegetation.

The following section outlines a recommended approach to determining riparian management boundaries.

3. Determining Riparian Boundaries

The use of nominated riparian buffer distances is common in planning and development regulation (e.g. a 40m protection zone applies in the Rivers and Foreshores Improvement Act 1948). However, the basis for the distances are not always apparent and may have a number of shortcomings, including:

- compromises which reflect social and political realities;
- adherence to a single width, regardless of biophysical context;
- use of arbitrary distances which may bear little relationships to a functional riparian zone; and
- a wide range of distances used in plans and policies (e.g. HNCMT (1999) reported a range from 5m to 400m in a selection of Australian planning documents).

The use of such approaches does not offer a great deal of confidence that the correct buffer distance will be chosen to sustain riparian function. In particular, the adoption of buffer zones 30m or less may be justifiable on geomorphic terms for smaller streams, but it is difficult to believe that this distance would be sufficient to sustain other considerations in all circumstances – such as stream water quality and the integrity of riparian vegetation.

In this paper, we attempt to compromise between the complexities of riparian interactions and the need for clear definitions for planning and management purposes. We recognise that the literature search is not exhaustive (for example, one recent bibliography on one aspect of riparian zone function contained 715 references (Correll, 2000) and we are also aware that many aspects of riparian function are poorly understood. For instance, nitrogen removal in riparian zones is well accepted, but the mechanisms for the transformations are still speculative (Correll, 1997).

4. Riparian Zones and Buffers

Our approach has the following assumptions:

- the riparian *zone* is a definable biophysical unit;
- a riparian *buffer* is a practical/functional construct, which may be influenced by the width of the riparian zone, but can include considerations of social equity, cost, practicality etc;
- the riparian zone width can vary between streams and along streams; and
- geomorphological protection generally defines a minimum riparian zone (see Rutherfurd et al, 1999).

A buffer in theory should extend beyond the riparian zone itself as a means of physical protection from weeds, water quality and the like. However, when other factors prevail, buffer width designation can actually be smaller than the riparian zone (see section 6).

5. Riparian Zone Delineation

Our suggested approach to defining the riparian zone was to use both structural (channel geomorphology, vegetation type) and functional (geomorphological, hydrological and water quality processes) relationships. On this basis, different reaches will generally have different riparian zone widths and the best depiction of the zone is a continuously mapped line. The approach adopted the *largest* of a range of estimates at reach scale, based on using one or more of the methods in Table 1.

The riparian zone is taken to start at the edge of the low flow channel (i.e. the edge of the water in average dry weather flow. For ephemeral streams without a defined channel, the start of the riparian zone is the creek centre line). This side steps the issue that in many of Warringah's creeks, the top of bank is difficult to define and therefore may lead to inaccuracies.

Table 1: Alternative methods for riparian zone estimation

Basis for width	***Method***	***Comments***
Channel depth and erosion rate	5m minimum, plus depth factor, plus establishment allowance[1]	The method is a means of determining widths for revegetation. For stable channels, riparian width may be underestimated (minimum 5m). *Very useful for modified creeks.*
Flora	Extent of riparian vegetation species or associations	Transitional or ecotonal vegetation tends to blur the boundaries. Clearing or weed growth can invalidate the estimate by masking potential riparian areas. *Most useful for natural systems, but reliant on detailed species mapping. Some weed species can also be good indicators of zone, due to their response to moisture and nutrients.*
Flood levels	The zone of influence of relatively frequent flood events (e.g. ARI 1 year flood zone)	Choice of recurrence interval is subjective; inundation zone tends to increase rapidly from headwaters to lowlands. Otherwise, the method is reasonably precise and simple - if flood studies are available[2]. Wong et al (2000) suggested that 1.5 year ARI represents a re-set mechanism for stream communities. 1.5 year ARI may be a reasonable benchmark for riparian zones, although more research is needed to determine whether it is equally valid for pristine or fully developed streams. For small creeks, the entire floodplain may be narrow and smaller floods may not exceed channel capacity. Riparian vegetation may extend well above flood levels due to deep roots of some trees.
Water quality	The minimum distance through which the effects of surface water runoff are likely to be attenuated. The distance is primarily a function of soils, rainfall intensity, groundcover densities, slope and type of pollution.	This recognises that the riparian zone protects waterways from the direct influence of overland flow and the associated dissolved and particulate matter. The corollary is that the riparian zone itself influences water quality, ecology and local geomorphology (e.g. by supplying organic matter to the stream). *Table 2 provides some rules of thumb.*
Channel form	The shape of the channel can be used to infer a riparian zone for rock platforms (edge of platform) and for steep-sided gorges (edge of gorge at base).	The majority of channels in the LGA do not fall into these categories and channel form is difficult to use as a surrogate for riparian zones.

Notes:

1. Abernethy and Rutherfurd (1999); establishment is erosion rate (m/yr) multiplied by time for natural riparian forest to mature and stabilise banks (yr).
2. Flood studies in Warringah are limited to the coastal lowlands – so this factor is of little current use.

Table 2: Minimum distances to attenuate impacts of overland flow[A]

Slope	**Groundcover density**		
	Low	*Medium*	*High*
Steep	50m	40m[B]	30m
Moderate	35m	30m	20m
Gentle	20m[C]	15m[C]	10m[C]

Notes:

A. There is no definitive scientific study of water quality processes in the riparian zone in Australia, and the figures are a rough estimate, based on a various publications. The figures do not allow for rainfall intensity and soil type variation across the LGA.

B. A number of US brochures suggest a range of 38-46m for nutrient removal in forests with medium density groundcover on moderate slopes (e.g. Connecticut River Joint Commission, 1998)

C. Based on a study by McKergow et al (1999) and allowing for lower rainfall intensities and overland flow velocities; LWA (2000) recommend a minimum of 20m as being suitable for most situations, but needing to be wider where pollutant loads and slopes are greater.

We acknowledge that there could be other considerations, such as groundwater hydrology and carbon transport, but these are more complex to measure and we are not aware of definitive studies. Determining values associated with fauna movement are also complex, although such considerations may be useful, especially if a creek's value could increase through the provision of a basic corridor linkage (i.e. ecological connectivity).

The implication of this approach is that the riparian zone may include existing developed areas – such as sporting fields, ovals, fences and even small buildings. In effect, these are part of the functional riparian zone, even though they are unnatural. From a land use management perspective, we suggest that the designation should not affect existing use rights, but that community education and landholder co-operation could be used by Council to actively support and encourage better management (such as joint rehabilitation projects and control of polluted runoff). Development control implications are set out in section 7.

6. Riparian Buffer Widths

The term *'riparian buffers'* is used in this report as a land area which is *additional to* the riparian zone (we note this distinction because the term *'riparian buffer zone'* (RBZ) is popularly used to mean the vegetated area necessary to protect the creek; however, particularly where creeks are close to natural condition, an additional buffer is needed to protect the riparian zone itself).

Given that the riparian zone protects the creek from water quality and hydrological impacts, it follows that the primary purpose of the buffer is to protect the integrity of the riparian zone. The combined width of the buffer and the riparian zone then constitute a key protective mechanism for the ecological values of the creek corridor system.

Drawing from the analysis in Table 1, the buffer is primarily designed to:

- Prevent water from affecting riparian vegetation (e.g. additional moisture, local erosion, nutrients, toxicants);
- Prevent weeds from invading the riparian zone; and
- Protect fauna from external threats (such as domestic animals).

Where weeds have already invaded, the value of a buffer is challengeable, but the wider the maintenance area the better. Our field observations suggest that the dominant form of weed invasion is downstream transport of weed propagules from disturbed catchments, rather than lateral movement. However, in built up areas, there is certainly evidence of local invasion and transport by birds and winds can also be a factor for widespread transport from weed areas. Even in undisturbed areas, there is some evidence of weed growth at track edges that may be a propagule source for downstream riparian areas.

In pristine areas, weed protection and fauna movement/habitat require very large buffers – possibly of the order of 100-300m (e.g. Catterall, 1990; Recher *et al*. 1995; Donatiu, 1999). Again, where there is a risk of upstream invasion by weeds, the value of buffers could be challenged, but in undeveloped catchments, it is likely that weed and animal protection is the critical determinant of minimum width. For the purposes of protection against weeds and animals, buffer widths may also extend beyond catchment boundaries, particularly where boundaries are defined by low gradients (eg. flat ridge tops/plateaus).

We suggest the following method to designate buffer widths:

- *Cleared or degraded open space:* ***5m wider*** than the riparian zone (an arbitrary figure to allow access for future rehabilitation and maintenance etc.);
- *Weed infested riparian zones in bushland:* ***20m wider*** than the riparian zone (recognises that weed management will initially be through control, rather than prevention; the 20m allows for access as well as providing some buffering for water quality and visual amenity; e.g. if a future walking trail is constructed at the edge of the riparian zone);
- *Relatively undisturbed riparian zones:* ***100m wider*** than the riparian zone (a minimum width for buffering the riparian zone from weed invasion. There may be a case for different width depending on soil types and slopes; 100m is the buffer required by DUAP for the Georges River REP and is the recommended figure for ecosystem protection in the Wollondilly catchment - cited in HNCMT 1999);
- *Gorges:* ***50m from edge*** of gorge for flat slopes and ***100m from edge*** for steep slopes above the gorge (gorges may have little or no width to the riparian zone, so that the main issues are water pollution from developments abutting the gorge as well as weed invasion); and
- *Where existing structures occur within a buffer determined using one of the above methods*: amend the buffer to follow the ***edge*** of the structure (this simply recognises that buffer is already compromised at that point). The implications are that in such circumstances, buffer widths can actually be narrower than the riparian zone (i.e. where the structure occurs within the riparian zone).

The most contentious of these will be the third and fourth, which represent a major departure from past practices. However, as noted in the next section, our recommendation is that the buffer can be legitimately challenged and does not represent an absolute restriction on development.

In commentary on an earlier draft of this document, DLWC suggested that the setting of buffer widths should also take into account future management intent for riparian zones. For example, the recommended buffer width of 20m for a weed infested riparian zone would desirably be wider if there is a long-term intention to rehabilitate the riparian zone to a more natural condition.

7. Development Control

Both the riparian zone and the riparian buffer should be designated on the LEP as clearly marked lines for every watercourse within the Study boundary.

At the end of Section 5, we note that the *riparian zone* designation need not be used to affect existing use rights in developed areas. However, proposed development - including re-development, subdivision, building construction, public works (except essential infrastructure), land clearing and drainage - could be ***prohibited in the riparian zone***. This would effectively conserve natural areas, as well as retain degraded areas for future rehabilitation. DLWC has suggested that the latter could include progressive ‘buy backs’ of development that intrudes into the zone using an environmental levy or similar funding.

In relation to the *riparian buffer*, we suggest that it could be used as a process trigger, rather than a prescriptive requirement. For example, any development proposed within the riparian buffer (but obviously not within the riparian zone) would need to demonstrate that neither the creek nor the riparian zone would be adversely affected. This would require an environmental assessment or compliance with performance objectives aimed at protecting the creek from adverse impacts.

We believe that this is procedurally fair because the designation of the riparian buffer is somewhat arbitrary and different developments will have different levels of sustainability. Proponents would be invited to undertake appropriate study of the local hydrology, geomorphology, ecology and water quality as a basis for demonstrating that their particular development is compatible with the creek corridor protection.

The designation of riparian buffers as a defined line, rather than a generic description is valuable, because it puts the onus on developers to show why the line should be moved. Brisbane City Council uses a regulation line approach to waterways and Council officers are very much on the front foot in any negotiation to relax controls. From a conservation (and sustainability viewpoint) this approach is likely to lead to better outcomes.

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Appendix E

Sustainable Waterway Management and the Warringah LEP: A Discussion Paper

Note: The recommendations presented in this document were made part way through the Creek Management Study. Subsequent to submission of the Study, the recommendations will be rigorously reviewed as part of the LEP review process.

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1. Introduction

The Warringah Creek Management Study will deliver a number of products, including suggested revisions to the Warringah LEP 2000 and Design Guidelines. The aim is to assist proponents and Council officers to determine levels of development that are compatible with sustaining waterways.

The outputs from the study can assist Council in both statutory planning and other Council functions (such as creek rehabilitation, stormwater management and open space planning). Council intends to develop a Warringah Creeks' policy which will influence these 'operational' activities. Figure 1 shows various study outputs and the planning and other functions that they can support. Some of the proposed guidelines support only statutory planning, some support other Council functions the remainder target both.

This discussion paper focuses on the ability of the existing statutory planning system to effectively address issues raised in the study. The content covers each of the boxes on the left hand side of Figure 1, namely:

- LEP principles;
- LEP maps;
- Development control for riparian zones and buffers;
- Locality Statements; and
- Design guidelines.

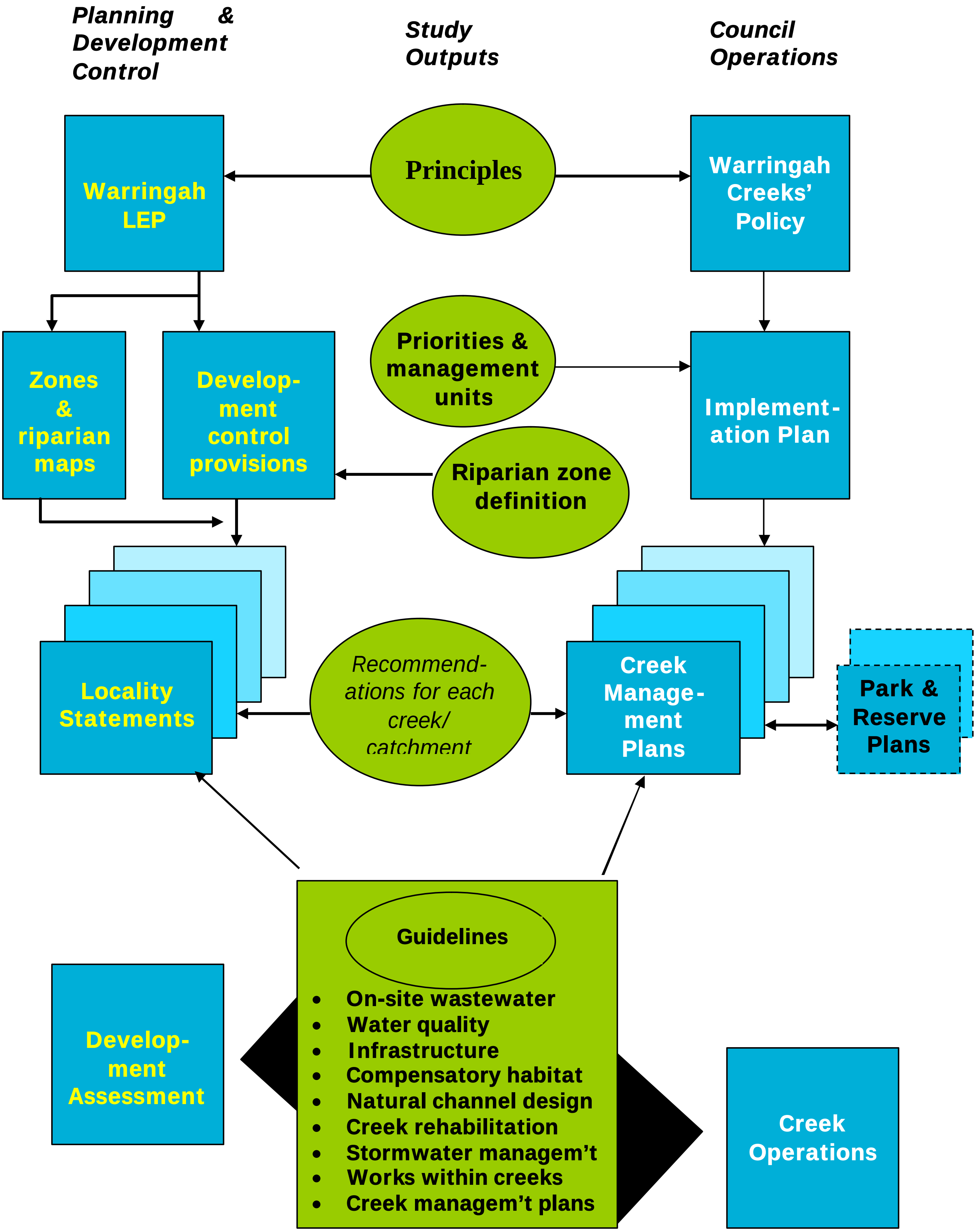


Figure 1: Relationship between study outputs, planning and operations

2. Existing Planning Mechanisms

The main components of the planning system that influence waterway management are:

- Warringah Local Environmental Plan 2000:
  – General Principles of Development Control;
  – Schedules;
  – Locality Statements; and
- Warringah Design Guidelines:
  – General Principles of Development Control.

The LEP and the Design Guidelines apply to the entire LGA, although two Schedules are area specific. All Locality Statements are area specific and are grouped by catchment. However, locality boundaries often include more than one sub-catchment. For example, Oxford Falls Valley is entirely within the Narrabeen Lagoon catchment, but includes parts of the Middle Creek sub-catchment and the Wheeler/South Creek sub-catchments.

Specific provisions are summarised in Table 1.

Table 1: Summary of existing LEP 2000 planning provisions relevant to creek values

General Principles of Development Control	Warringah LEP 2000	Interim Warringah Design Guidelines
Cl 42 – Construction Sites	• construction sites must be managed to ensure water-borne pollutants are minimised.	• minimise site disturbance • prevent unnecessary damage to the landscape • locate drainage in close proximity to the built area • implement and maintain during construction methods to control stormwater and erosion • implement rehabilitation techniques to the restore site.
Cl 45 – Hazardous Uses	• development must not pose a significant risk to the biophysical environment.	• avoid posing a significant risk to people, property or the environment • conduct a preliminary hazard analysis
Cl 47 – Flood Affected Land	• development is not to reduce flood storage area or impact upon the existing flood regime.	• plans accompanying development proposals should show the 1% annual exceedence probability level.
Cl 52 – Development near parks, bushland reserves and other public open spaces	• complement the landscape character and public use and enjoyment of the public land	• maximise public access • provide an outlook and visual transition • provide bushfire buffers • protect and preserve bushland
Cl 54 – Provision and location of Utility Services	• habitable buildings connected to a sewerage system if density 1 dwelling per 1,050m^2 or	• Provide services in an underground trench • Dispose of on-site effluent within

	greater. On-site disposal of effluent considered where sewerage systems operate without causing unreasonable adverse effects.	boundaries and consider environmental health impacts

Cl 56 – Retaining Unique Environmental Features on Sites	• development to be designed to incorporate or be sympathetic to environmental features such as remnant bushland and watercourses.	• site building where minimum disturbance results • utilise construction methods that limit impact • implement soil and water management plan • avoid introduction of foreign soils • select plant species similar to the site adjoining • select plant species that existing fauna habitats depend upon
Cl 57 – Development on sloping land	• minimise height and bulk of development	• reduce cut and fill • minimise building footprint
Cl 58 – Protection of Existing Flora	• development to be sited and designed to minimise the impact on remnant indigenous flora and ground cover.	• locate buildings to minimise disturbance of vegetation and landforms
Cl 60 – Watercourses and Aquatic Habitat	• development to be sited and designed to maintain and enhance natural watercourses and aquatic habitat.	Siting and design of development should not: • result in piping or artificial channeling of natural watercourse • alter or inhibit natural flow path of watercourses • be located within close proximity of the riparian zone Methods to maintain and enhance watercourses and aquatic habitats: • protect habitats, ecosystems, vegetation and bank stability from erosion • restore riparian zones • provide a riparian buffer zone • treat stormwater before it enters the watercourse • avoid excessive use of fertilisers and pesticides • retain native vegetation on site.
Cl 63 – Landscaped Open Space	• landscaped open space to facilitate water management including on-site detention and stormwater infiltration	• retain existing vegetation • integrate landscaping with existing environmental features
Cl 68 – Conservation of Energy and Water	• landscape design to assist in conservation of energy and water.	• rainwater tanks encouraged, to recycle roof water as irrigation to landscaped areas.
Cl 75 – Design of carparking areas	• carparking is to provide on-site detention of stormwater.	• minimise driveway areas to reduce runoff
Cl 76 – Management of Stormwater	• stormwater runoff to have minimal impact on any receiving stormwater infrastructure, lake, watercourse, waterway. • stormwater runoff to be controlled using on-site	• provide on-site stormwater detention • construct perimeter/diversion banks • provide stormwater pollution treatment measures • divert flows around construction site

	stormwater detention in accordance with the Council's *On-site Stormwater Detention Technical Specification*	• integrate with site landscaping • retain existing trees • minimise impervious areas • direct runoff to landscaped areas and openspace • integrate open spaces with site drainage for large sites • collect roof runoff in rainwater tanks
Cl 77 - Landfill	• landfill for development is to have no adverse impact on the visual and natural environment or adjoining and surrounding properties	• use uncontaminated fill • control bulk, scale and location, • ensure stability • protect drainage lines, waterways and landforms • integrate with surrounding landscape
Cl 78 – Erosion and Sedimentation	• development is to be sited and designed so as to minimise the potential for soil erosion. • soil erosion and sedimentation to be controlled at source. • a soil and water management plan is required where some degree of sedimentation and soil erosion is likely to occur, prepared in accordance with the Council's *Specification for Erosion and Sediment Control* and *Design and Specification Manuals for Engineering Works.*	• limit number of access points to the site • stagger site works • install sediment traps, basins, filter fences etc • store building materials within sediment fence • stockpile and protect top soil for reuse • limit area and duration of disturbance • install and connect guttering to stormwater system immediately • revegetate or stabilise site upon completion and prior to removing sediment controls • intercept/divert clean water away from disturbed areas.

Schedule	**Warringah LEP 2000**
S3 – Conditions of complying development certificates	• where soil and water management plan not prepared, run-off and erosion controls must be provided. • Removal or disturbance of vegetation and topsoil confined to within 3m of the approved building area.
S5 – State Policies (also S6 – Preservation of Bushland)	• State policy to preserve and protect bushland within urban areas, to protect existing landforms such as natural drainage lines and watercourses.
S7 – Matters for consideration in a subdivision of land	• lot boundaries should relate to natural land features such as creeks. • subdivision of flood-prone land should be avoided. • design and construction is to be in accordance with the Council's *Specification for Engineering Works* and *On-site Stormwater Detention Policy and Technical Specification*.
S12 – Requirements for complying development	• collect stormwater and dispose to an approved drainage system • total impervious area less than 35% of the total site area or total impervious area of any proposed addition less than 50m^2.
S15 – Statement of environmental effects	• analysis of the development including description of likely impact on the environment and full description of measures proposed to mitigate any adverse effects on the environment. • include the likelihood of water pollution arising from the development, and the effect of the development on soil erosion and the silting up of rivers or lakes.

3. Planning Issues Arising from the Creek Study

Warringah's creeks can be divided into three groups:

- ***Group A***: Pristine or near pristine (high value) (e.g. Deep creek);
- ***Group B***: Modified, but most of catchment is protected (e.g. creeks draining to National Parks); and
- ***Group C***: Developed catchments and (usually) modified channels (e.g. coastal creeks, South Creek).

The focus of the first two groups should be protection (particularly through statutory planning). The last group represents substantially modified systems that are usually in developed catchments. Although of low ecological value, they are generally of high recreational value. These should be protected from further degradation, but the main management tool is likely to be repair (stormwater quality management, revegetation, bank stabilisation, weed removal etc).

More specific recommendations relevant to statutory planning are summarised below.

3.1 Riparian Zones

- Creek protection should consider both the waterway itself and the adjacent riparian zone (see Appendix D '*Estimating the Extent of Riparian Zones and Buffers'*). Therefore any protective buffer must be sufficiently wide to protect both. Protection should:
  - exclude development from riparian zones; and
  - restrict development in riparian buffer zones.
- Riparian zones and buffers vary in width depending on a number of factors. They should be delineated on maps to accompany the LEP, rather than be based on a nominated distance.

3.2 Catchment Land Use

- Catchment land use is a major (if not ***the*** major) factor governing condition of most creeks. Creek management must include consideration of catchment land use and in-stream activities (such as riparian clearing, placement of structures, dredging).
- Creeks flowing into National Parks from urban areas can potentially impact on the values of the parks. It is important to regulate land uses in those catchments.
- Conventional subdivision and drainage design in relatively undeveloped catchments will lead to substantial losses of creek values.
- The keys to maintaining creeks with high ecological values through catchment controls are to:
  - Limit impervious areas to less than 10-15% of the catchment; and
  - Minimise direct connectivity between creeks and drainage system.
- Some areas – particularly those draining to National Parks – could be considered for retrofitting drainage systems (including houses) to reduce peak flows and pollutant

loads. This will mostly occur through Council operations, but any new development could also be captured through the LEP.

- Compensatory habitat may be possible in some instances where the net impacts are sustainable.

3.3 Operational Controls

- Some activities are having significant impacts and are inherently difficult for Council to ensure satisfactory management once development approval is granted. Examples include:
  - Filling;
  - On site wastewater treatment and disposal;
  - Agriculture; and
  - Landscape supplies.
- Waterway management plans will need to be prepared for many creeks. They will have limited effectiveness unless given statutory effect through the LEP.

3.4 Construction

- All development has short term consequences during construction and it is essential to provide a series of redundant safeguards for development near any creek or in the catchments of Group A and B catchments. For example, a combination of source controls, interception devices and rehabilitation of any offsite impacts.

4. Principles

The remainder of this paper describes *recommended* approaches for Warringah. As such, they are put forward to stimulate discussion, rather than as prescriptions. ***The full implications of the recommendations will need careful consideration by Council prior to adoption.***

The following goal and principles are adapted from the *'Australian Guidelines for River Protection'* which are about to be published by Land and Water Australia. Principles for social and cultural heritage values have also been added.

The goal of creek planning and management in Warringah is to:

Protect creek values and maintain healthy ecosystems.

This can be achieved by the following principles:

For all creeks:
- *Support the health of target species/communities;*
- *Protect rare or threatened species and natural features;*
- *Prevent serious loss of natural diversity;*
- *Minimise damage to public and private property through creek processes;*
- *Maintain and enhance creek landscapes;*
- *Create opportunities for public access and recreation in waterway corridors;*
- *Ensure that people are safe in and around waterways; and*
- *Preserve cultural heritage values.*

Additional protection for creeks of high ecological value:
- *Preserve all natural components that contribute to ecological value – particularly streamflow, water quality and flora/fauna.*

Stream health (the first principle) is dependent mainly on streamflow, habitat and water quality. The selection of target species/communities is a matter for Council to consider when more ecological survey information is available. The targets should be chosen on the basis of local or regional significance.

The last principle only applies to a small number of creeks in near pristine condition. If adopted, it would result in severe constraints on further catchment development. Although the principle emphasises ecology, other values such as landscape would also be protected.

These principles form the basis of the recommended revisions to the LEP in sections 5 to 10.

5. Development Intensity

Creek catchments have been classified into three ***preliminary*** groups, based on the ecological values and the extent of catchment imperviousness, as a sustainable development limit:

- **Group A**: maintain at less than 10% connected impervious area (Wheeler, Deep, Curl Curl);
- **Group B**: maintain at less than 15% connected impervious area, with all future developments incorporating WSUD (Snake/Oxford, Duffys, Kierans, Bare); and
- **Group C**: no additional catchment constraints, but require development controls to prevent further deterioration (Bantry Bay, Carroll, Frenchs, Middle, South, Manly, Dee Why, Greendale, Brookvale, Burnt Bridge).

The majority of creeks are in Group C, and these are beyond protection through strict catchment density controls. Group C creeks will be protected by a combination of riparian zone and buffer zone development controls (see Section 6), plus comprehensive land management. Groups A and B will also require these as additional controls.

The minimum target for all creeks is no further deterioration in stream health. In many cases, there will also be enhancement programs, so that health and values will increase (particularly for Group C creeks, most of which are close to residential and recreational areas).

The creek categorisations should be adopted within the LEP in order to control catchment development below the identified thresholds of imperviousness.

6. Evaluation of Development Proposals

The principles set out in section 4 are broad and there is a need to provide more detail to assist proponents and Council officers. Appendix E1 suggests 'performance criteria' and 'acceptable solutions (design guideline)' for each principle, and these have been included in a new scheduled 18 and a new design guideline respectively.

We propose that development should *not be permitted within Riparian Zones*, but *may be permitted within Riparian Buffers* if the developer can demonstrate that the development will not adversely affect the Riparian Zone and/or the waterway.

Certain development applications would be required to demonstrate how their solutions meet the performance criteria. The target applications would be developments which:

- require an environmental impact assessment (such as a Statement of Environmental Effects under the LEP or an Environmental Impact Statement under the

Environmental Planning and Assessment Act 1979) and which may impact on creek values; and/or

- are proposed within a Riparian Buffer.

We propose a 'Waterway Impact Study' should be carried out in these circumstances. Depending on the nature of the development, the CIS could either be a stand alone study or as an integral part of the environmental assessment for the development. The content of the waterway impact study could be set out in a new schedule to the LEP and would be required to demonstrate consistency with the relevant principles and performance criteria from Schedule 18.

7. Land Ownership

In mapping the riparian zone, existing uses and creek condition have been taken into account, so this is unlikely to constrain most forms of development. Notable exceptions are currently undeveloped areas such as the Wheeler Creek and Deep Creek catchments.

The zone is usually below the 100 year ARI flood level, in which case many developments are excluded anyway. However, some developments are compatible with flooding, but not with riparian values – such as car parks and sealed sportsfields. Again, this should have only limited impact in existing urban areas, where riparian zones tend to be narrower.

If Council accepts the need to exclude development within the riparian zone, the development rights most affected will be properties in undeveloped catchments and non-urban areas. Where land identified as Riparian Zone is privately owned, Council will need to take into consideration the extent to which the riparian zone would limit development potential of the site, if at all. Where development potential is affected, Council may need to determine whether favourable consideration be given to any development on the remainder of the site, or in extreme circumstances, whether to purchase the site, or a portion of the site, to ensure the creeks protection.

An added consideration for Council would be the desirability of acquiring developed land within riparian zones for rehabilitation. The types of sites will be identified in the Study report, but will be limited to those of strategic value (e.g. to address a major erosion issue or to revegetate part of a wildlife corridor).

8. Warringah LEP – Recommended Modifications

8.1 Zones and Riparian Maps

The LEP map should be modified to show the revised creek centrelines, riparian zones, riparian buffers and Groups A, B and C creek catchments.

The LEP should be revised to include wetland buffers and mapping that are currently recorded in Warringah's Geographic Information System. This will complement the creek mapping – for the purposes of the proposed Schedule 18 (Waterway Impact Study). It will also provide for subsequent incorporation of the model DCP for wetlands (Sydney Coastal Councils Group and Protecting Wetlands Steering Committee, 2001).

8.2 Development Control Provisions

8.2.1 General amendments

Amend the LEP to:

- Maintain creek channels as close as possible to their natural state, by preventing further channelisation, piping, filling or other physical modifications;
- exclude development from the riparian zone, except for permissable developments as set out in Clause 60;
- require any development proposals within a riparian buffer to undertake a waterway impact study and demonstrate compliance with the principles set out in Schedule 18; and
- align catchment boundaries with Localities and adopt catchment imperviousness limits in Group A and B catchments *[Note: this amendment is a significant undertaking and will require revision of both planning and development assessment processes. The package of amendments should be considered as a longer term aim].*

8.2.2 Amend Clause 42 – Construction sites

Add a new dot point in the general principle:

- Construction sites are to be managed to ensure that riparian zones and buffers are not cleared or damaged during construction.

Add:

- Further, that the following standard conditions are to be adopted by the Local Approvals Service Unit:
  - Riparian zones and buffers adjacent to the area to be cleared are to be fenced prior to clearing and construction
  - Fencing is to be maintained for the duration of construction;
  - Vegetation within riparian zones and buffers that is at risk of accidental damage is to be suitably protected for the duration of construction

8.2.3 Amend Clause 52 – Development near parks, bushland reserves and other public open spaces

Add:

- Maintain and enhance creek landscapes;
- Temporarily detain runoff to prevent erosion;
- Stormwater pollutant loads to bushland or groundwater should not increase as a result of development;

- On site sewage treatment and disposal must not result in increased pollutant loads to surface or groundwaters; and
- Maintain natural surface and sub-surface hydrology.

8.2.4 Amend Clause 54 – Provision and Location of Utility Services

Add:
The type, scale and location of on-site effluent management systems must be sufficient to prevent short or long term increases in off-site surface waters, groundwaters and soils.

8.2.5 Amend Clause 56 – Retaining unique environmental features on sites

Add:
The riparian zone and riparian buffer of creeks classified as Group A are to be protected such that rare natural structures and functions (e.g. flora, fauna, waterfalls, hydrology) are preserved.

8.2.6 Amend Clause 57 – Development on sloping land

Add:
- Filling on land within a Category A or B catchments is not to result in changes to vegetation, hydrology or water quality of any creek, including the riparian zone.

8.2.7 Amend Clause 60 – Watercourses and Aquatic Habitat

Add:
- Watercourse protection and management will be guided by the principles and performance criteria set out in Schedule 18*;*
- ‘Riparian Areas’ to title of clause; and
- For the purposes of reading this Clause, ***riparian zone*** and ***riparian buffer*** mean the areas marked “riparian zone” and “riparian buffer” on the map.

In particular:

Permissable developments and in-stream structures within Riparian Zones
- The table identifies developments which are permissable with consent in the riparian zone of creeks, *provided that*:
  - no reasonable alternative location is available; and
  - a waterway impact study (Schedule 17) demonstrates that the proposed development meets the principles set out in Appendix E1:

Creek Group	Permissable development in Riparian Zone
A	public footbridge, unsealed pedestrian trail
B	public footbridge, vehicular bridge and associated roadway, pedestrian walkway or recreational trail, off-stream stormwater management device
C	footbridge, vehicular crossing and associated roadway, pedestrian walkway or recreational trail, in-stream or off-stream stormwater

	management device.

- Permissable developments will require an approved environmental management plan (Schedule 17) for construction and operational phases. The plan will contain a monitoring program of sufficient comprehensiveness and covering a sufficient time period to establish that the construction and operation have no adverse impacts.
- In the event that monitoring reveals adverse impacts, rectification will be required in accordance with the approved environmental management plan.

On-site wastewater
On-site wastewater management is not to result in short or long term adverse changes in water quality, stream ecology, soil structure or riparian vegetation. On site wastewater treatment or effluent disposal areas will not be permitted within riparian buffers.

Water Quality
Stormwater and wastewater discharges into creeks or into drainage systems flowing to creeks must not exceed the water quality objectives for each of the creek categories (A, B and C) set out in the Water Quality Objectives Guideline.

8.2.8 Amend Clause 75 – Design of carparking areas

After 'Provide on-site detention of stormwater' add:
- and for car parks with 10 spaces or more, provision for capture of sediments and hydrocarbons (e.g. vegetated buffer strips, sand/gravel filters, vegetated swales, gross pollutant and/or hydrocarbon trap).

8.2.9 Amend Clause 76 – Management of stormwater

Add:
- No increase in stormwater pollution loads will be permitted for all developments in Group A or B catchments and for developments in excess of 0.5ha impervious area in Group C catchments.
- Stormwater collection systems are to incorporate on-site detention and collection (such as in rainwater tanks). Subject to soil and groundwater conditions, on site infiltration and irrigation of stormwater is to be maximised.

8.2.10 Amend Clause 77 – Landfill

Add:
- Filling is not to occur within a riparian buffer; and
- Filling on land within a Category A or B catchment is not to result in changes to vegetation, hydrology or water quality of any creek, including the riparian zone.

8.2.11 Amend Schedule 7 – Matters for consideration in a subdivision of land

Environmentally sensitive/constrained land
Insert at end of (2):
- Subdivision layout should encourage occupiers to monitor and manage the riparian zone (e.g. provision of public access, esplanade roads between allotments and waterway corridors);
- Lot boundaries should relate, where possible, to natural features such as creek terraces, riparian zones and escarpments;
- Riparian lands should be managed as conservation areas, whether under private, community title or public ownership; and
- Vegetation clearing within the riparian buffer of category A and B catchments is to be minimal and is to be justified in a Waterway Impact Study (Schedule 17) and addressing the principles for creek protection in Schedule 18.

Drainage
Add:
- Subdivision stormwater management should follow the principles and practices of Water Sensitive Urban Design (WSUD);
- *Remove 'drained by pipeline to a Council-approved drainage system' and insert*: drained by pipeline, vegetated swale or infiltration system to Council approved discharge to groundwater, soil or surface water (including non-permanent waterways); and
- *Remove 'drain directly to a Council-approved drainage system and not via' and insert:* not drain.

Add:
- Provided there is no extended ponding or waterlogging, infiltration of water should be maximised, with formalised drainage available only for conveying higher flows (above 3 mth *ARI).*

Add:
On-site wastewater
- On site wastewater management must be sustainable in the long term and allotment characteristics (such as size, proximity to watercourses, slope, soil permeability and depth) must achieve the performance requirements set out in the On-Site Wastewater Guideline.

Add:

Water Sensitive Urban Design
- Subdivisions should conform to the principles of water sensitive urban design in order to reduce peak stormwater flows, pollutant loads and water use. Performance requirements are set out in the WSUD guideline.

8.2.12 Amend Schedule 12 – Requirements for complying development

A. Housing and ancillary structures: Water and soil management

- *Remove: dispose of it to an approved drainage system and insert:*

retain as much as practicable within the site, with the excess discharged to Council approved groundwater, soil or surface water (including non-permanent waterways).

B. Swimming pools

Add:

Water pollution

- Water containing detectable chlorine, salt or other chemicals at concentrations exceeding local receiving water levels is not to be disposed of to a stormwater drain or watercourse.

Add:

On-site wastewater

- On site wastewater management must be sustainable in the long term and treatment systems and effluent management must achieve the performance requirements set out in the *On-Site Wastewater Guideline.*

8.2.13 Amend Schedule 15 – Statement of Environmental Effects

Add under 'Note' after (b):

- The impacts of the development on creek values (see Schedule 17).

8.2.14 Add new Schedule 17 – Waterway Impact Study

- The minimum contents of a Waterway Impact Study are:
  - (a) a detailed description of the development, including:
    - the nature and extent of proposed construction activities (including mitigation measures) – such as cut and fill, clearing;
    - the nature and extent of proposed operational activities (including mitigation measures) – such as agriculture, materials storage, on-site wastewater disposal; and
    - the location of proposed construction and operational activities relative to the riparian buffer, riparian zone and creek centreline.
  - (b) a detailed description of both on-site and off-site waterways, wetlands, groundwaters, riparian zones and riparian buffers areas which may be directly or indirectly affected by the development (with particular reference to Schedule 18), including, but not limited to:
    - biophysical characteristics;
    - connectivity with waterway corridors, bushland and open space;
    - streamflow characteristics, including flooding;
    - water quality;
    - channel form, erosion rate and bank stability;
    - ecological values;

- recreational values;
- landscape values;
- cultural heritage values; and
- other applicable values (e.g. economic).

(c) a description of the likely impacts of the development on the elements identified in (b).

(d) an assessment of the degree to which the development achieves the performance criteria set out in Schedule 18 and is in accord with Total Catchment Management Principles and Sydney Harbour Catchment Blueprints.

(e) a tabular summary of (d), set out in the same order as Schedule 18.

[Note: 'waterway' includes creeks and other waterbodies, such as wetlands and lagoons].

8.2.15 Add new Schedule 18 – Guiding Principle for Environmentally Sensitive Catchments and Waterways

- Schedule to include:

a) A map of catchment and locality boundaries *(Note: Figure 3.1 of Warringah Creeks Study Report shows catchments, but not locality boundaries)*

b) A table classifying localities into Groups A, B and C is set out below *(Note: Figure 8.1 of Warringah Creeks Study Report shows creek and creek catchments by grouping).*

Warringah Locality Areas, Catchment Groupings and Creeks

Locality	Catchment Groups	Portion of locality (%)	Catchments
A2	B	85	Kierans, Duffys
	Other	15	Other
A3	A	16	Deep
	B	38	Kierans
	Other	46	Other
A4	B	100	Kierans
A6	A	55	Deep
	B	45	Kierans, Duffys
A7	B	100	Bare, Kierans
B1	B	9	Oxford/Snake
	C	81	South, Middle
B2	A	25	Wheeler, Deep
	B	24	Oxford/Snake
	C	51	South, Middle
B3	B	3	Oxford/Snake
	C	97	Middle
B7	A	3	Wheeler
	C	97	Greendale, South, Narrabeen foreshores
B8	A	4	Wheeler
	C	96	South, Middle

Locality	Catchment Groups	Portion of locality (%)	Catchments
B9	A	91	Deep
	B	7	Kierans
	Other	2	Other
B10	A	1	Deep
	C	99	Middle, South, Narrabeen Foreshores
B11	B	87	Oxford/Snake
	C	13	Frenchs
B12	B	100	Oxford/Snake
C1	C	94	Carroll, Bantry Bay, Middle, Frenchs
	Other	6	Other
C4	B	23	Bare
	C	68	Carroll, Bantry Bay, Frenchs
	Other	9	Other
C7	B	100	Bare
C8	B	77	Oxford/Snake, Bare
	C	23	Frenchs
C9	B	100	Kierans, Bare
C10	B	100	Kierans, Bare
G3	C	100	Burnt Bridge, Bantry Bay, Manly, Brookvale
G4	C	100	Brookvale, South, Manly, Middle
G11	C	100	Brookvale Manly

c) The long term planning objectives for environmentally sensitive catchments are:

- **Group A**: maintain at less than 10% connected impervious area (Wheeler, Deep, Curl Curl); and
- **Group B**: maintain at less than 15% connected impervious area, with all future developments incorporating WSUD (Snake/Oxford, Duffys, Kierans, Bare).

These objectives will be considered when considering development applications in these catchments.

d) Principles and performance criteria are listed in the tables below. **Design Guidelines for development near creeks, riparian zones and buffers** provide acceptable solutions for each of the principles and performance criteria (see Appendix F of Warringah Creeks Study)

The goal of creek planning and management in Warringah is to ***Protect creek values and maintain healthy ecosystems.***

Principle 1: *Support the health of target species/communities* *(e.g. migration routes, habitat, streamflow, water quality)*
Performance criteria
Maintain natural habitats
Provide fauna movement routes
Prevent unnatural erosion or sediment deposition
Maintain acceptable water quality

Maintain connectivity between creeks and floodplains

Principle 2: ***Protect rare or threatened species and natural features***
Performance criteria
Prevent the loss of any rare or threatened natural features
Maintain existing protected creek areas
Maintain the total area of creeks designated as high value
Protect downstream protected areas, such as National Parks

Principle 3: ***Prevent serious loss of natural diversity***
Performance criteria
Avoid introducing plants or animals which may displace natural species
No increase in nutrient loads to riparian soils and creeks
Avoid displacing species by habitat changes
Protect natural areas from contamination

Principle 4: ***Maintain and enhance creek landscapes***
Performance criteria
Avoid development which is visible from riparian areas in Group A catchments
Avoid development which obscures views of natural valleys in Group A or B catchments

Principle 5: ***Minimise damage to public and private property through creek processes***
Performance criteria
Avoid increases in peak channel flows and sediment exports for events smaller than 2 year ARI.
Avoid local erosion at stormwater outlets
Avoid export of weeds from private properties into creeks

Principle 6: ***Create opportunities for public access and recreation in waterway corridors***
Performance criteria
Provide public access along creek corridors

Principle 7: ***Ensure that people are safe in and around waterways***
Performance criteria
Channel banks are not oversteepened
Channel banks are stable

Principle 8: ***Preserve cultural heritage values***
Performance criteria

Avoid the loss of indigenous cultural heritage values
Avoid the loss of non-indigenous cultural heritage values

Principle 9 (only for Group A and B creeks): ***Preserve all natural components that contribute to ecological value – particularly streamflow, water quality and flora/fauna.***
Performance criteria
Streamflow and water quality are natural
Aquatic and riparian vegetation are undisturbed and unmodified
Aquatic and riparian fauna habitat and movement corridors are retained

8.3 Locality Statements

Currently the LEP does not recognise sub-catchment boundaries as a planning entity. This presents a challenge because individual sub-catchments may have entirely different values and threats associated with them. The planning responses in many cases are more appropriate at sub-catchment rather than locality scale.

8.3.1 Add to Desired Future Character:

- Creek centrelines, catchment boundaries, riparian zones and riparian buffers are shown on the map. Creeks within the locality are grouped as follows:

    - Group A *[names of any group A creeks];*
    - Group B *[names of any group B creeks]*; and
    - Group C *[names of any group C creeks]*.

[Note: we suggest that the generic provisions in the LEP coupled with the specific recommendations for each Group will generally suffice. In a few cases, it may be necessary to make specific recommendations for individual catchments within a locality].

9. State Planning Legislation

9.1 SEPP 5 – Housing for Older People or People with a Disability

State Environmental Planning Policy No 5 (SEPP5) has been implemented under the Warringah Local Environmental Plan, Schedule 5 - State Policies.

This Policy enables the State Government to override Local Government legislation with regards to the allocation of land under SEPP 5 – Housing for Older People or People with a Disability.

Section 4(2) states that this Policy does not apply to:

> *(a)* land described in Schedule 1 (Environmentally sensitive land).

Schedule 1 Environmentally sensitive land refers to:

> Land identified in another environmental planning instrument by any of the following descriptions or by like descriptions or by descriptions that incorporate any of the following words or expressions:
>
> - conservation;
> - critical habitat;
> - environment protection;
> - water catchment; and
> - natural wetland.

It is recommended that an application for exemption from SEPP5 be made for land identified on the Warringah Local Environmental Plan on the basis of it being 'environmentally sensitive land':

- all land within riparian zones of any creeks;
- all land within riparian buffers of Group A and Group B creeks; and
- all land within the catchment of Group A creeks.

9.2 Warringah Section 94 Development Contributions Plan 2001

Under Section 94 of the *Environmental Planning and Assessment (EP&A) Act 1979*, Council may levy contributions towards, or recoup the capital cost of providing or extending facilities, infrastructure and services necessary to meet the increased demand created by new development in its area.

Section 94 Development Contributions Plan is the mechanism by which the entitlements are implemented and accounted for by Council. The Plan is implemented through the development process by attaching conditions to any development consents that result in an increased demand for the facilities and services identified in the Plan.

The Plan applies to all land within the Warringah local government area, as specified in the following table:

	Warringah Wide Plans	**WLEP 2000 Localities**
E1	Open Space Linkages and Cycleways	All Localities which permit housing
E2	Children's Services	All Localities which permit housing
E3	Library Services	All Localities which permit housing
E4	Sport Field and Open Space Embellishment	All Localities which permit housing
E5	Community Centres	All Localities which permit housing
	Planning Areas	
E6	Open Space Medium Density Areas	All Medium density areas except Dee Why
E7	Open Space – Dee Why Town Centre and surrounds	Localities E2, E4 to E20
E8	Roads and Traffic Management Plan	Medium Density Areas as specified
E9	Perentie & Dawes Road Area	Localities B11 and B12
	Special Purpose Plans	
E10	Car Parking – Dee Why Town Centre	Localities E4 to E12 and E17
E11	Car Parking for Brookvale	Locality F1
E12	Administration and Planning Studies	All Localities which permit housing

It is recommended that Council investigate the use of Section 94 Development Contributions to support waterway management. For future up-zoning or re-zoning of land, consideration should be given to protection of creeks through Section 94 funds.

10. Planning Guidelines

The following guidelines should be referred to for any proposed development or activity carried out within the Riparian Zone or Buffer:

10.1 LEP 2000 Design Guidelines

Design guidelines will be *amended* as required to assist with the changes recommended to the general principles and schedules (section 8). The following *additional* Guidelines are proposed:

- on-site wastewater management;
- water quality objectives (including EPA classification);
- natural channel design (reference to external sources);
- compensatory habitat; and
- development near creeks, riparian zones and buffers.

Water Sensitive Urban Design principles are referred to in the proposed amendments to Schedule 7. Council intends to conduct a separate project to develop a guideline for WSUD.

10.2 Operational Guidelines

Operations and developments not subject to LEP 2000 for which guidelines are recommended are *[note that some are common to the LEP 2000]:*

- water quality objectives (including EPA classification);
- natural channel design (reference to external sources);
- creek rehabilitation (reference to external sources);
- compensatory habitat;
- Waterway Impact Study (reference to similar documentation required under LEP 2000, but with focus on public works);
- stormwater quality interception devices (reference to external guidelines);
- works within creeks and riparian zones; and
- waterway management plans – content

Water Sensitive Urban Design principles are also applicable to non-statutory activities – notably road design. As noted above, Council intends to conduct a separate project to develop a guideline for WSUD and the scope should include public works and retrofit of established urban areas.

References

1. Warringah Local Environmental Plan 2000, gazetted 5 December 2000.

2. Interim Warringah Design Guidelines, Warringah Council, December 2000.

3. Montgomery Watson Harza (2001).Estimating the Extent of Riparian Zones and Buffers, a discussion paper. Internal report to Warringah Council.

4. Lloyd, S.D., Wong, T.H.F. and Porter, B (not dated): Implementing an Ecological Sustainable Stormwater Drainage System in a Residential Development. Unpublished report.

5. Hornsby Council (1998): Sustainable Water Development Control Plan and Sustainable Water Best Practices.

6. Brisbane City Council (2000): Brisbane City Plan 2000 – Volume 1, Chapter 5: Codes and Related Provisions.

7. Sydney Coastal Councils Group and Protecting Wetlands Steering Committee (2001): Model DCP: Protecting Sydney's Wetlands. Sydney Coastal Councils. Dee Why, Sydney.

Definitions

Activity – an undertaking by or on behalf of a public authority that does not require development consent under Part 4 of the *EP&A Act*. Defined in Section 110 of the *EP&A Act* and includes the erection of buildings, the carrying out of works, the use of land or of a building or work and the subdivision of land.

ARI – 'Average Recurrence Interval' (standard measure of rainfall intensity).

Catchment – the area within which rainfall contributes runoff to a particular point on a waterway.

Connectivity – the interconnection of functionally related ecological elements of a landscape so that species can move among them.

Creek - any watercourse, whether ephemeral, intermittent or perennial, whether on its natural course or altered by human interference, whether channeled or not. It also includes any drainage lines able to be identified by a linear vegetation assemblage reflective of regularly moist soil conditions or by a weed plume consistent with regularly moist soil conditions.

Waterway Impact Study – prepared for any development or activity occurring within a Riparian Zone or Buffer. May be stand alone or part of an Environmental Impact Statement, Statement of Environmental Effects or Review of Environmental Factors.

Development Consent – consent required for any development not listed in Schedules 1 or 2 of the *Warringah Local Environmental Plan 2000*. The consenting authority for the purpose of these guidelines is Warringah Council.

Diversity – variety of life forms (biodiversity), natural physical features (geodiversity), water quality or hydrological regimes.

Ecological Value – the natural significance of ecosystem structures and functions, expressed in terms of their quality, rarity and diversity. Significance can arise from individual biological, physical or chemical features or a combination of features.

Function (natural) – the biological, chemical and physical processes that take place within an ecosystem (e.g. carbon cycling, erosion, nutrient assimilation).

Floodplain – land that is adjacent to waterways (and includes the riparian zone) and is subject to flooding (typically at recurrence intervals of up to 100 years).

Group A catchments - Wheeler, Deep, Curl Curl creek catchments.

Group B catchments - Snake/Oxford, Kierans, Duffys, Bare creek catchments.

Group C catchments - all other catchments, including Bantry Bay, Carroll, Frenchs, Middle, South, Manly, Dee Why, Greendale, Brookvale, Burnt Bridge.

Habitat – the biophysical media (such as sand and water) able to be occupied by organisms.

Health (of creeks) – the ability of a creek to maintain natural structures and functions over time, and the degree of similarity to unimpacted creeks of the same type (naturalness).

Hydrology – patterns of stream flow.

Imperviousness – the measure of a substance's inability to allow fluids to pass through.

LEP – Local Environmental Plan.

LGA – Local Government Area.

Protected Areas – areas designated as conservational or park reserve or National Park under state or local government administration.

Riparian Zone – any land which adjoins, directly influences, or is influenced by a body of water. The width of the zone varies according to extent of riparian vegetation, flood levels, water quality, and channel form.

Riparian Buffer – an area of land which is additional to the riparian zone, necessary to protect the values and health of the riparian zone.

Structure (natural) – the site-specific biophysical characteristics of a creek system (e.g. channel form, species composition, soil, hydrology); synonymous with 'features' or 'patterns'.

Water Sensitive Urban Design (WSUD) – a form of urban development which aims to enhance waterways and conserve water (e.g. by reducing peak flows and pollutants using rainwater tanks, infiltration areas, grass drainage systems, artificial wetlands).

Appendix E1: Principles, Performance Criteria and Design Guideline for Acceptable Solutions

The tables that follow identify performance criteria for incorporation in the LEP. A range of acceptable solutions is included to guide proponents and decision making.

Principle: ***Support the health of target species/communities*** *(e.g. migration routes, habitat, streamflow, water quality)*	
Performance criteria	**Acceptable solutions (Design Guideline)**
Maintain natural habitats	- No disturbance of riparian vegetation OR - Compensatory habitat provided for any disturbance
Provide fauna movement routes	- No disconnection of riparian zone AND - No barriers to fish movement OR - Install fishways on any temporary or permanent barriers
Prevent unnatural erosion or sediment deposition	- No increase in peak flows AND - No increase in total sediment loads
Maintain acceptable water quality	- Council approved sediment and erosion control plan AND - Discharge concentrations less than water quality objectives
Maintain connectivity between creeks and floodplains	- No construction of barriers between creeks and floodplains

Principle: ***Protect rare or threatened species and natural features***	
Performance criteria	**Acceptable solutions (Design Guideline)**
Prevent the loss of any rare or threatened natural features	- No loss of any species, community or habitat listed under relevant conservation legislation - No loss of natural features identified in the LEP as rare or threatened
Maintain existing protected creek areas	- No development within the riparian buffer of creeks within protected areas
Maintain the total area of creeks designated as high value	- Maintain the integrity of all areas with high ecological value
Protect downstream protected areas, such as National Parks	- No more than 10% site imperviousness for site development in Group B catchments

Principle: ***Prevent serious loss of natural diversity***	
Performance criteria	**Acceptable solutions (Design Guideline)**
Avoid introducing plants or animals which may displace natural species	- Construction activities must not introduce new weeds species or allow weeds to spread AND - New housing subdivisions adjacent to riparian buffers must have an approved management plan for domestic animals
No increase in nutrient loads to riparian soils and creeks	- Use of wetlands, vegetated strips, swale drainage etc. designed to capture net increase in nutrient loads following development AND - Use of best practices in subdivision, building and stormwater design

Avoid displacing species by habitat changes	- No development within the riparian buffer OR - Provision of compensatory habitat
Protect natural areas from contamination	- No activities within the riparian buffer zone which may contaminate soils or vegetation
	- No storage of chemicals, fuels or oils within riparian buffers OR - Adequate bunding of stored materials

Principle: ***Maintain and enhance creek landscapes***	
Performance criteria	**Acceptable solutions (Design Guideline)**
Avoid development which is visible from riparian areas in Group A catchments	- Maintain a 10m width of screening vegetation between the development and riparian zones AND - Design the scale, setbacks and colour to minimise visual impact
Avoid development which obscures views of natural valleys in Group A or B catchments	- Design the scale and location of structures so that important views are not obscured (e.g. from roads, walking trails, lookouts, adjacent housing, commercial and public areas)

Principle: ***Minimise damage to public and private property through creek processes***	
Performance criteria	**Acceptable solutions (Design Guideline)**
Avoid increases in peak channel flows and sediment exports for events smaller than 2 year ARI.	- On-site detention or infiltration (e.g. through rainwater tanks, subsurface storage, swale drains, infiltration basins) AND - On-site sediment capture (e.g. through gross pollutant traps, wetlands, vegetated buffer strips)
Avoid local erosion at stormwater outlets	- Energy dissipation at stormwater outlets entering creeks AND - Infiltration and on site detention with minimal use of pipes or lined drains AND - Stabilisation of actively eroding banks using Natural Channel Design principles
Avoid export of weeds from private properties into creeks	- Householder education to control and dispose of invasive weeds on private property

Principle: ***Create opportunities for public access and recreation in waterway corridors***	
Performance criteria	**Acceptable solutions (Design Guideline)**
Provide public access along creek corridors	Set back developments to allow public access within riparian buffers

Note: private land within riparian areas may need to be acquired by Council where public access is desirable. Mechanisms for acquisition may be by purchase, exchange or donation. Council may also be able to negotiate easements or access agreements where acquisition is not possible.

Principle: ***Ensure that people are safe in and around waterways***	
Performance criteria	**Acceptable solutions (Design Guideline)**
Channel banks are not oversteepened	- Maximum 1:4 slopes
Channel banks are stable	- Revegetate with a combination of groundcover and deeper rooting species

	- Reinforce toes of bank and other areas prone to erosion or slippage, preferably using natural materials

Principle: ***Preserve cultural heritage values***	
Performance criteria	**Acceptable solutions (Design Guideline)**
Avoid the loss of indigenous cultural heritage values	- No development within an a distance acceptable to the Director General NPWS from listed sites AND - Undertake cultural heritage survey where there is a likelihood of finding artefacts - on natural bush land, land previously undisturbed or subject to little disturbance; land containing sandstone outcrops, rock shelters, old growth trees, sand bodies and land adjacent to creeks, rivers, lakes and swamps; land adjacent to known archaeological sites or areas of importance to Aboriginal people such as story places, missions and relocation reservations AND - Approval for a cultural heritage management plan from Director General NPWS, following consultation with the Metropolitan LALC.
Avoid the loss of non-indigenous cultural heritage values	- No development within 50m – or a distance acceptable to Council and NSW Heritage Office - from listed sites AND - Approval by Council and the NSW Heritage Office for any activity which may adversely affect a site or object of significance

Principle (only for Group A and B creeks): ***Preserve all natural components that contribute to ecological value – particularly streamflow, water quality and flora/fauna.***	
Performance criteria	**Acceptable solutions (Design Guideline)**
Streamflow and water quality are natural	- No artificial barriers to capture water - No removal of water for consumptive use (except riparian use rights) - Site imperviousness is less than 10% AND - Site design adheres to WSUD principles AND - On-site uses do not involve specific risks to water quality (e.g. chemicals, organic materials, exposed soil, effluent generation)
Aquatic and riparian vegetation are undisturbed and unmodified	- All development is outside riparian zone and riparian buffer zone
Aquatic and riparian fauna habitat and movement corridors are retained	- No disturbance to stream bed or banks

Appendix F

Planning, Design and Operational Guidelines

Warringah Council
Creek Management Study - Appendix F

Contents

1. ON SITE WASTEWATER DESIGN GUIDELINE

1.1 INTRODUCTION

The General Principle aims to protect waterway values, public health and groundwater quality from the impacts of on-site wastewater effluents.

GENERAL PRINCIPLE
• On site wastewater disposal must be sustainable in the long term and is not to result in adverse changes to water quality, stream ecology, soil structure or riparian vegetation • On site wastewater treatment systems or effluent disposal areas will not be permitted within riparian buffers.

1.2 DESIGN GUIDELINES

Performance criteria	Acceptable solutions
Disposal to land will require an effluent (prior to land disposal) with less than 20mg/L BOD and less than 30mg/L suspended solids	▪ aerobic treatment plant ▪ aerobic sand filtration
Disposal direct to waterways will not be permitted unless effluent concentrations are less than the ***lower*** of: ▪ receiving water concentrations (50th percentile), or ▪ receiving water quality objectives	*[Context dependent]*
Cumulative impacts of several on-site systems must be minimised	▪ Maximum density of on-site system capacity - 6 equivalent persons per 2ha
The impacts of on-site effluents on ground and surface waters and terrestrial and aquatic vegetation must not have adverse effects on ecology and public health	Located on land with: ▪ An available disposal area of not less than 5000m^2 ▪ Slope less than 15% or where the disposal area is terraced ▪ No closer than 150m from a potable water supply (ground or surface) ▪ No closer than 100m to a creek or

	wetland ▪ No closer than 25m to bushland ▪ No closer than 25m to a cut or embankment ▪ Above the Q20 flood level The proposed on-site effluent disposal area is not located on soil: ▪ With permeability less than 1.06m/day or greater than 3.5m/day ▪ Within 0.6m of a permanent water table ▪ Within 1m of bedrock ▪ Comprised mainly of sand, gravel, fractured rock or heavy clay

1.3 FURTHER INFORMATION

NSW Septic Safe Program (2001) – *On-Site Sewage Management for Single Households.* Available from NSW Department of Local Government, http://www.dlg.nsw.gov.au/dlg/dlghome/dlg_InformationIndex.asp?areaindex=SEPTIC&index=152

2. INTERIM WATER QUALITY OBJECTIVES DESIGN GUIDELINE

2.1 INTRODUCTION

The General Principle aims to establish water quality objectives for Warringah's creeks.

In the absence of information about in-stream ecosystems, the objectives use relevant trigger levels from the Australian and New Zealand guidelines (ANZECC, 2000), augmented with the objectives set by the EPA for Sydney Harbour

The trigger levels will be reviewed as ecosystem data becomes available. The review should involve stakeholders to ensure that the levels set reflect community values.

GENERAL PRINCIPLE

- No development should result in deterioration of receiving water quality
- Developments in the catchments of creeks that already exceed water quality objectives should contribute to improvements in water quality.

2.2 DESIGN GUIDELINES

Creek	Interim Water Quality Objective[1,5]				
	Total P[2]	**Filtered Reactive P**	**Total N**	**Oxidised N (Nox)**	**Ammonia (NH_4^+)**
Group A (Deep, Wheeler, Curl Curl)	0.010	0.005	0.250	0.030	0.010
Group B (Kierans, Duffys, Bare, Snake/Oxford)	0.010	0.005	0.250	0.030	0.015
Group C (Greendale, Dee Why, Burnt Bridge, Brookvale, Manly, Bantry Bay, Carroll, Frenchs, Middle, South,	0.010	0.005	0.350	0.035	0.015

Creek	**Interim Water Quality Objective**[1,5]				
Collaroy, Narrabeen Foreshores)					
	Dissolved Oxygen (% saturation)[3]	**pH**[3]	**Suspended Solids (mg/L)**	**Faecal Coliforms**[4]	
Group A	90-110	6.5-8.0	2	<150	
Group B	90-110	6.5-8.0	5	<150	
Group C	90-110	6.5-8.0	15	<150	
	Cadmium (mg/L)	**Lead (mg/L)**	**Benzene (mg/L)**	**Chlordane (mg/L)**	
Group A	0.06	1.0	600	0.03	
Group B	0.2	3.4	950	0.08	
Group C	0.4	5.6	1300	0.14	

Notes:

1. Subject to review (see Introduction). All values in mg/L unless otherwise stated.
2. For creeks draining to freshwater lakes and coastal lagoons.
3. Range represents upper and lower limits.
4. To protect contact recreation in receiving waters.
5. In multiple subcatchment localities, the least stringent WQO is nominated. Therefore:
   - Group A WQO – Locality G11;
   - Group B WQO – Localities A2, A3, A4, A7, B9, B12, C7, C10, C11 and
   - Group C WQO – all other localities.

2.3 FURTHER INFORMATION

ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

EPA (1999) Interim Water Quality Objectives for Sydney Harbour and Parramatta River Catchment.

3. NATURAL CHANNEL and CREEK REHABILITATION DESIGN GUIDELINE

3.1 INTRODUCTION

The General Principle aims to incorporate natural features in modified waterways and drains – in new development and in rehabilitation works.

[Note: The guideline is not intended for application to creeks in natural condition because under the proposed LEP changes, channelisation of natural creeks is not permitted]

GENERAL PRINCIPLE
• Modified creeks and drainage lines are to be designed or rehabilitated to achieve structural stability and hydraulic performance through the use of natural features[1] which enhance their ecological, landscape and recreational values

Note:

1. DLWC recommended in commentary on the draft study that "vegetation should be used to stabilise banks and in the interim, biodegradable materials should be utilised to provide support. If biodegradable material is not appropriate, riprap rock is recommended. Wire mesh, concrete, masonry, spray concrete, concrete blankets and such are strongly discouraged."

3.2 DESIGN GUIDELINES

Performance criteria	Key process steps
Channel location and shape is to maximise natural topography and creek forms	▪ Determine local topography and channel fall
Channels are to be designed for long term stability using materials characteristic of the local area	▪ Determine bankfull flow rate ▪ Select type of channel ▪ Determine channel width, depth and slope ▪ Determine typical channel meander radius
Plant selection is to be based on a diversity of locally natural species which are adaptable to habitat in the channel	▪ Review riparian and floodplain vegetation
Habitat diversity is to be included in the channel	▪ Design channel bed and low flow channel ▪ Determine rock riffle dimensions, slope, rock size and placement

	▪ Determine pool geometry (length, width and depth) ▪ Design planting

[Note: the reference Natural Channel Design Guidelines provides valuable information about the practicalities of design, including equations and specifications for the key process steps listed above.]

3.3 FURTHER INFORMATION

Brisbane City Council. 2000. *Natural Channel Design Guidelines*.

LWA. 2000. *Australian Stream Rehabilitation Manual.* Volume 1 part 2: A summary of the stream rehabilitation planning procedure.
Land and Water Australia: http://www.rivers.gov.au/whatsnew.htm

4. COMPENSATORY HABITAT DESIGN GUIDELINE

4.1 INTRODUCTION

The General Principle aims to provide a basis for compensating for unavoidable loss of ecological values. Compensatory habitat should be seen as a last resort, but it can be a valuable approach when there is no other mitigation available.

GENERAL PRINCIPLE
• Development which results in loss of ecological values **may** be required to compensate for the loss through the provision of compensatory habitat

4.2 DESIGN GUIDELINES

Performance criteria	Acceptable solutions
Investigate feasible project alternatives	Key process steps include: ▪ Assess development impacts ▪ Can impacts be avoided? ▪ Can impacts be reduced to acceptable levels? ▪ Investigate compensation options ▪ Compare costs and benefits ▪ Recommend impact management strategy
The type of compensation must be of comparable value, with viable management arrangements	Key process steps include: ▪ Assess ecological values of land to be affected ▪ Identify potential compensatory habitat options (see below) ▪ Assess ecological values of land options ▪ Compare ecological values (see below) ▪ Review land tenure an management considerations (see below) ▪ Recommend compensatory habitat
Compensatory habitat should have similar biophysical features to the habitat which will be lost	▪ Land within the same sub-catchment, with similar vegetation, slope, aspect, drainage ▪ Land with similar ecological values (based on criteria of naturalness, representativeness, rarity, diversity, special features)

The form of compensation and management arrangements must be in the public interest and offer long term security	Subject to Council approval, one or more of: ▪ Voluntary conservation agreement ▪ Dedication of land as open space or reserve ▪ Donation of land to Council ▪ Fencing to exclude livestock ▪ Financial compensation to support Council land acquisition or management ▪ Rehabilitation of degraded areas, provided that the area is substantially larger to compensate for the habitat quality

4.3 FURTHER INFORMATION

Sanders, N.R. 2000. *Guideline for Determining Compensatory Habitat*.

LWA. 2001. *Guidelines for Protecting Australian Waterways – Ecological Value Guideline*. Land and Water Australia: http://www.rivers.gov.au/whatsnew.htm

5. STORMWATER QUALITY INTERCEPTION DEVICES DESIGN and OPERATIONAL GUIDELINE

5.1 INTRODUCTION

The General Principle aims to integrate the design and management of stormwater quality improvement devices (SQIDs) with the overall goals for creek management. In planning for stormwater improvement, SQIDs should be viewed as part of an overall approach, which also includes at source controls and non-structural elements (such as education and regulation).

GENERAL PRINCIPLE

- Stormwater quality improvement devices should be selected on the basis of their overall benefit to creek values, in particular they should be off-line and outside the riparian zone and should maintain variability of low flows;
- Management and maintenance should be consistent with creek values and the principles and performance criteria in Schedule 18 of the Warringah LEP.

5.2 DESIGN GUIDELINES

Performance criteria	Acceptable solutions
Match SQID design objectives with desired outcomes for the creek	▪ Whole of catchment comparison of options – including at sources and non-structural solutions ▪ Base options selection on consistent criteria – e.g. cost effectiveness, local and regional benefit, environmental impacts, re-use opportunities, local amenity, ease of maintenance
Select SQIDs on the basis of overall benefit to creek values	▪ Off line installation and outside riparian zones ▪ Minimise storage of polluted water (which may re-enter creek) ▪ In ground structures, particularly near waterways of higher visual or recreation value; or adjacent to housing ▪ Structures with natural elements (such as wetlands) serving multiple objectives are preferable to single purpose structures (such as sediment basins)
Maintain fish passage and aquatic habitat in creeks	▪ Locate structures off-stream or within the piped drainage network

	▪ Avoid in-stream installations where riparian zones and in-stream habitat of high ecological value will be directly affected.
Minimise any adverse environmental impacts	▪ Prepare a *Creek Management Study* and management plan for proposed installations, covering both construction and operation ▪ During design and construction, ensure that the sediment and erosion control plan minimises risks and has built in contingencies – particularly for floods ▪ Post-construction, monitor structures to ensure that dissolved oxygen level, metal, suspended solids and nutrient concentrations are not more than 10% different from ambient ▪ Increase maintenance frequencies if monitoring data do not meet the above criteria ▪ Prevent runoff or 'leachate' from excavated sediments or litter returning to the creek ▪ Design outlets to minimise local erosion or sedimentation

5.3 FURTHER INFORMATION

Hunter, G.J. (Undated). *Stormwater Quality Improvement Devices – Issues for Consideration*.

NSW EPA. 1997. *Managing Urban Stormwater – Treatment Techniques*.

Brisbane City Council. 2000. *Design Guidelines for Stormwater Quality Improvement Devices*.

6. WORKS WITHIN CREEKS AND RIPARIAN ZONES DESIGN and OPERATIONAL GUIDELINE

6.1 INTRODUCTION

The General Principle aims to minimise the number and extent of works within creeks and riparian zones.

GENERAL PRINCIPLE
• Works within creeks and riparian zones which impact adversely on creek values should be avoided unless they provide an overall community benefit; and • All works, whether development or rehabilitation, should minimise adverse environmental impacts • Design, construction and operation should be consistent with the principles and performance criteria in Schedule 18 of the Warringah LEP

6.2 DESIGN GUIDELINES

Performance criteria	Acceptable solutions
Avoid placing infrastructure within riparian zones	▪ Relocate or redesign infrastructure outside designated riparian zones ▪ Off stream temporary controls for sediments and other pollutants ▪ Remove temporary structures and rehabilitate the creek as soon as practicable after construction
Maintain fish passage and aquatic/riparian habitat in creeks	▪ Locate structures outside aquatic and riparian zones ▪ Avoid in-stream structures where riparian zones and in-stream habitat of high ecological value will be directly affected
Minimise any adverse environmental impacts	▪ Prepare a *creek impact study* and management plan for proposed installations, covering both construction and operation ▪ Contingency plans in the event of spills or other damage ▪ Design structures to minimise local erosion or sedimentation (through turbulence or discharge of stormwaters)
Revegetate riparian areas	▪ Provide compensatory habitat for irreversible losses

and buffers	▪ Revegetate with local, natural species

6.3 FURTHER INFORMATION

Brisbane City Council. 1997. *Erosion Treatment for Urban Creeks: Guidelines for selecting remedial works.*

Brisbane City Council. 2000. *Natural Channel Design Guidelines*.

7. DEVELOPMENT NEAR CREEKS, RIPARIAN ZONES AND BUFFERS DESIGN GUIDELINE

7.1 INTRODUCTION

The General Principle aims to minimise the number and extent of works within creeks and riparian zones.

GENERAL PRINCIPLE
The goal of creek planning and management in Warringah is to ***protect creek values and maintain healthy ecosystems.***

7.2 DESIGN GUIDELINES

Principles and performance criteria in the tables below are drawn from Schedule 18 of the Warringah LEP

Principle: ***Support the health of target species/communities*** *(e.g. migration routes, habitat, streamflow, water quality)*	
Performance criteria	**Acceptable solutions**
Maintain natural habitats	- No disturbance of riparian vegetation OR - Compensatory habitat provided for any disturbance
Provide fauna movement routes	- No disconnection of riparian zone AND - No barriers to fish movement OR - Install fishways on any temporary or permanent barriers
Prevent unnatural erosion or sediment deposition	- No increase in peak flows AND - No increase in total sediment loads
Maintain acceptable water quality	- Council approved sediment and erosion control plan AND - Discharge concentrations less than water quality objectives
Maintain connectivity between creeks and floodplains	- No construction of barriers between creeks and floodplains

Principle: ***Protect rare or threatened species and natural features***	
Performance criteria	**Acceptable solutions**
Prevent the loss of any rare or threatened natural features	- No loss of any species, community or habitat listed under relevant conservation legislation - No loss of natural features identified in the LEP as rare or threatened

Maintain existing protected creek areas	- No development within the riparian buffer of creeks within protected areas
Maintain the total area of creeks designated as high value	- Maintain the integrity of all areas with high ecological value
Protect downstream protected areas, such as National Parks	- No more than 10% site imperviousness for site development in Group B catchments

Principle: *Prevent serious loss of natural diversity*

Performance criteria	Acceptable solutions
Avoid introducing plants or animals which may displace natural species	- Construction activities must not introduce new weeds species or allow weeds to spread AND - New housing subdivisions adjacent to riparian buffers must have an approved management plan for domestic animals
No increase in nutrient loads to riparian soils and creeks	- Use of wetlands, vegetated strips, swale drainage etc. designed to capture net increase in nutrient loads following development AND - Use of best practices in subdivision, building and stormwater design
Avoid displacing species by habitat changes	- No development within the riparian buffer OR - Provision of compensatory habitat
Protect natural areas from contamination	- No activities within the riparian buffer zone which may contaminate soils or vegetation
	- No storage of chemicals, fuels or oils within riparian buffers OR - Adequate bunding of stored materials

Principle: *Maintain and enhance creek landscapes*

Performance criteria	Acceptable solutions
Avoid development which is visible from riparian areas in Group A catchments	- Maintain a 10m width of screening vegetation between the development and riparian zones AND - Design the scale, setbacks and colour to minimise visual impact
Avoid development which obscures views of natural valleys in Group A or B catchments	- Design the scale and location of structures so that important views are not obscured (e.g. from roads, walking trails, lookouts, adjacent housing, commercial and public areas)

Principle: *Minimise damage to public and private property through creek processes*

Performance criteria	Acceptable solutions
Avoid increases in peak channel flows and sediment exports for events smaller than 2 year ARI.	- On-site detention or infiltration (e.g. through rainwater tanks, subsurface storage, swale drains, infiltration basins) AND - On-site sediment capture (e.g. through GPTs, wetlands, vegetated buffer strips)
Avoid local erosion at stormwater outlets	- Energy dissipation at stormwater outlets entering creeks AND - Infiltration and on site detention with minimal use of pipes or lined drains AND - Stabilisation of actively eroding banks using Natural Channel Design principles

Avoid export of weeds from private properties into creeks	- Householder education to control and dispose of invasive weeds on private property

Principle: ***Create opportunities for public access and recreation in waterway corridors***	
Performance criteria	**Acceptable solutions**
Provide public access along creek corridors	Set back developments to allow public access within riparian buffers

Note: private land within riparian areas may need to be acquired by Council where public access is desirable. Mechanisms for acquisition may be by purchase, exchange or donation. Council may also be able to negotiate easements or access agreements where acquisition is not possible.

Principle: ***Ensure that people are safe in and around waterways***	
Performance criteria	**Acceptable solutions**
Channel banks are not oversteepened	- Maximum 1:4 slopes
Channel banks are stable	- Revegetate with a combination of groundcover and deeper rooting species - Reinforce toes of bank and other areas prone to erosion or slippage, preferably using natural materials

Principle: ***Preserve cultural heritage values***	
Performance criteria	**Acceptable solutions**
Avoid the loss of indigenous cultural heritage values	- No development within an a distance acceptable to the Director General NPWS from listed sites AND - Undertake cultural heritage survey where there is a likelihood of finding artefacts - on natural bush land, land previously undisturbed or subject to little disturbance; land containing sandstone outcrops, rock shelters, old growth trees, sand bodies and land adjacent to creeks, rivers, lakes and swamps; land adjacent to known archaeological sites or areas of importance to Aboriginal people such as story places, missions and relocation reservations AND - Approval for a cultural heritage management plan from Director General NPWS, following consultation with the Metropolitan LALC.
Avoid the loss of non-indigenous cultural heritage values	- No development within 50m – or a distance acceptable to Council and NSW Heritage Office - from listed sites AND - Approval by Council and the NSW Heritage Office for any activity which may adversely affect a site or object of significance

Principle (only for Group A and B creeks): ***Preserve all natural components that contribute to ecological value – particularly streamflow, water quality and flora/fauna.***	
Performance criteria	**Acceptable solutions**
Streamflow and water quality are natural	- No artificial barriers to capture water - No removal of water for consumptive use (except riparian use rights) - Site imperviousness is less than 10% AND - Site design adheres to WSUD principles AND

	- On-site uses do not involve specific risks to water quality (e.g. chemicals, organic materials, exposed soil, effluent generation)
Aquatic and riparian vegetation are undisturbed and unmodified	- All development is outside riparian zone and riparian buffer zone
Aquatic and riparian fauna habitat and movement corridors are retained	- No disturbance to stream bed or banks

Note: Groups A and B creeks are listed in Schedule 18 of the Warringah LEP

7.3 FURTHER INFORMATION

Warringah Council. 2003. *Local Environmental Plan, Schedule 18: Guiding Principle for Environmentally Sensitive Catchments and Waterways*.

8. WATERWAY MANAGEMENT PLAN GUIDELINE

8.1 INTRODUCTION

The guideline aims to provide a consistent framework for the structure and content of creek management plans. The purpose of the plans is to provide a long term basis for creek management which incorporates catchment, floodplain, riparian and aquatic components.

The plans will draw from the information and broad recommendations in the Creek Management Study (2001) as well as data collected subsequently.

GENERAL PRINCIPLE
• Creek Management Plans will provide a 5-15 year action plan for achieving an agreed set of outcomes.

8.2 GUIDELINES

Content	Inclusions
Scope and Purpose	▪ geographic area (catchment, sub-catchment) ▪ planning horizon ▪ linkages to other activities (such as LEP reviews, stormwater management programs, reserve management plans)
Catchment characteristics	▪ current and future land use, demographics ▪ catchment condition ▪ soils, geology, ▪ surface drainage networks and groundwater ▪ development controls ▪ infrastructure (stormwater, sewerage, water supply, roads)
Creek characteristics	▪ water quality ▪ geomorphology ▪ aquatic flora and fauna ▪ riparian and aquatic vegetation ▪ floodplain area and land uses ▪ riparian widths and buffers (confirm validity of LEP mapping) ▪ environmental values ▪ management units
Issues	▪ planning and land use constraints/opportunities

	▪ community involvement ▪ community values (existing and future) ▪ risks to values
Current and Desired Values, Objectives and Targets	▪ social, ecological, economic ▪ long term ▪ short term ▪ SMART targets (specific, measurable, achievable, realistic, timebound)
Options	▪ review of current and emerging best practice ▪ options to achieve future values ▪ costs and benefits ▪ staging and timing ▪ criteria for assessing options ▪ assessment of options
Planning and regulatory recommendations	▪ LEP amendments (primarily locality statements and mapping) ▪ Regulatory amendments ▪ Water quality objectives
Operational recommendations	▪ Additional stormwater management infrastructure ▪ Additional facilities ▪ Creek and riparian rehabilitation ▪ Maintenance
Non-structural recommendations	▪ Education and awareness programs ▪ Council officer training ▪ Incentive schemes
Financial recommendations	▪ costings ▪ funding sources
Implementation plan	▪ actions and timings ▪ responsibilities ▪ cost estimates

The support of the community will become increasingly critical for setting achievable goals. The behaviour of landholders has a major influence on creek quality and the limited availability of funding means that direct community involvement in the actions is essential.

8.3 FURTHER INFORMATION

LWA. 2002. *Guidelines for Protecting Australian Waterways – Planning Guideline*
Land and Water Australia: http://www.rivers.gov.au/whatsnew.htm

LWA. 2000. *Australian Stream Rehabilitation Manual – Volume 1 part 2: A summary of the stream rehabilitation planning procedure*
Land and Water Australia: http://www.rivers.gov.au/whatsnew.htm

Appendix G

Summary of River Styles in the Warringah LGA

Warringah Council
Creek Management Study - Appendix G

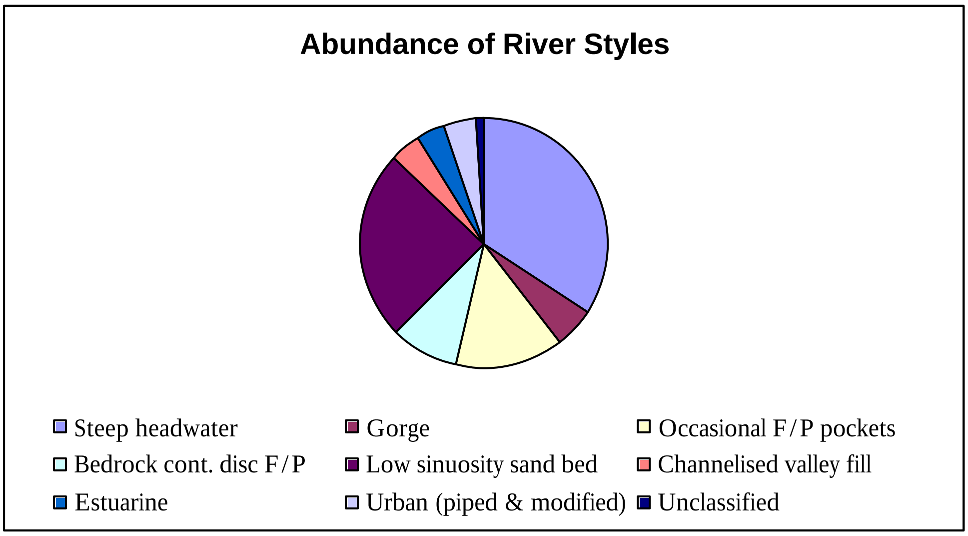
Contents

1. Geomorphic attributes of River Styles in Warringah LGA

	River Style	Valley setting, configuration and shape	Floodplain	Textural Control	Channel Characteristics	Geomorphic Units
Confined	Steep Headwater	Confined, V shaped valley. Located in the upper reach of the catchment	No floodplain	Bedrock, boulder, some minor sand accumulations	High sloped, straight channel	Cascades, bedrock steps , short pseudo pool-riffle systems imposed between bedrock steps, occasional waterfalls and plunge pools.
Confined	Gorge	Confined, U shaped valley located in the upper to middle reaches of the catchment. Tends to occur immediately downstream of a major step in the valley profile	No floodplain	Bedrock, boulder, some minor sand accumulations	High –moderate sloped, straight to low sinuosity channel	Waterfalls, plunge pools, cascades, bedrock steps , pool-riffle systems
Confined	Confined with occasional floodplain pockets	Confined, irregular shaped valley occurring in upper to middle reaches of the catchment. Occurs when valley start s to open intermittently.	Small, narrow pockets of floodplain.	Bedrock and sand. Occasional presence of colluvially derived boulders	Moderately sloped, straight to low sinuosity channel	**Channel-** Pool-riffle sequences, occasional bedrock steps creating small cascades. Some sand accumulation in pools and attached to banks **Floodplain**- Comprised of coarse sand, scour marks and cut with flood channel where it attaches to valley wall
Partly-confined	Bedrock controlled, discontinuous floodplain	Partly confined, irregular shaped valley, occurring within the middle reaches of the catchment. Channel abuts approximately 70-80% of length. Occurs where valley starts to widen.	Discontinuou s floodplain varying in width. Majority have been turned into parkland.	Predominantly sand with minor clay.	Moderate-low slope, low-moderate sinuosity.	**Channel-** Pool-riffle sequences, benches, some bedrock steps, bedrock outcrops, occasional mid channel and bank attached bars (dependent on sediment load), point bars apparent in more sin uous reaches. **Floodplain**- Generally highly modified and capped with fill. Where remnant pockets exist characteristics include, terracing, stripping, pseudo leveeing, occasional chute channels
Alluvial	Low sinuosity sand bed	Alluvial, irregular-shaped valley occurring where valley has widened in the middle to lower reaches of the catchment.. Channel abuts valley margin for < 10% of its distance.	Continuous floodplain on either side of the channel. Floodplain width increases downstream.	Predominantly sand with minor clay.	Low slope, low sinuosity. Examples tend to be in poor condition or highly modified.	**Channel**- Pool-riffle sequences, mid channel bars and bank-attached bars, erosional benches. **Floodplain**- All examples highly modified. Remnant characteristics include occasional flood channels, scouring. Most features have been destroyed or extensively reworked.
Alluvial	Channelised valley fill	Alluvial, occurs on top of escarpment at the apex of the drainage divide.	Very shallow continuous valley fill occurs on either side of the channel	Clayey sand. Some areas are organic rich.	Moderate sloped, sinuosity is variable. Most of these areas have been modified for grazing /agistment or parkland.	**Channel**- short pool-riffle sequences, shallow bedrock steps creating small cascades. **Valley Fill**- no real geomorphic units apparent.. Given the upstream drainage area and slope it is unlikely that there would be a high enough degree of channel-"floodplain" interaction to create geomorphic features.
Alluvial	Estuarine	Alluvial, occurs at terminus of catchment.	Continuous floodplain on either side of the channel.	Sand	Broad brackish tidal channel. Sometimes drains into lagoon	**Channel**- broad constantly reworked by tides. Some narrow beaches occurring on channel margins. **Floodplain**- broad, highly modified into parkland or built upon. Would have historically been comprised of sand dunes.
Urban	Urban piped	Can occur anywhere in catchment. Channel has been removed and flow has been piped underground to accommodate urbanisation.				
Urban	Urban modified	Can occur anywhere in catchment. Channel has been modified to the extent that it no longer functions as a river. These are generally open drain that's purpose is to transport flow.				
	Unclassified	A reach is labelled unclassified when further information (ie: historical data) is required to assign it a River Style. This classification is used to avoid inaccuracies until the information becomes available to make an accurate classification.				

2. Abundance of River Styles

The pie chart below demonstrates the abundance of River Styles determined by total length within the Warringah study area. Steep Headwaters are the dominant River Style, while unclassified streams make up the smallest proportion of streams. Note the dominance of confined reaches in the LGA, in which streams have limited capacity to adjust, and the very low proportion of alluvial reaches which have self-adjusting streams.



3. Patterns of River Styles in Warringah LGA, using Middle, Oxford and South Creeks as examples

The distribution of River Styles in the study area is largely determined by the topography of the catchment. As valley slope and width are imposed by the topography, they act as key determinants of rivers character and behaviour.

3.1 Middle Creek

Middle Creek drains from confined, relatively Steep Headwaters. As the valley opens and slope is reduced pockets of floodplain develop on the valley floor. These reaches are characterised by two River Styles: Confined with occasional floodplain pockets and partly confined, bedrock controlled with discontinuous floodplain patterns. As the valley continues to widen and slope is further reduced, Low sinuosity sand bed rivers with continuous floodplain are able to develop on the relatively wide valley floor. It is at this point that a large step occurs in the valley profile, creating Oxford Falls. Downstream of this step, valley width constricts into a confined asymmetrical Gorge.

As valley width increases and pockets of floodplain are able to form, Confined with occasional floodplain pockets and Partly confined, bedrock controlled with discontinuous floodplain River Style again dominate. Downstream of the confluence with Oxford Creek the valley opens and a Low sinuosity sand bed pattern of River Style develops within a broad floodplain. This River Style continues until Middle Creek drains into Narrabeen Lagoon.

3.2 Oxford Creek

Oxford Creek drains the top of the escarpment through a Channelised valley fill. The transition from the low sloped channelised valley fill as it flows into the valley is marked by a series of broad bedrock steps creating cascades. Downstream of this point, confined Steep Headwaters dominate. The valley systematically widens downstream of this point, accommodating floodplain development. As this occurs, Confined with occasional floodplain pockets and Partly confined, bedrock controlled with discontinuous floodplain patterns of River Style develop. As with Middle Creek, a large step occurs in the valley profile on Oxford Creek, a waterfall that drains into a constricted Gorge pattern of River Style marks this point. As the valley widens the channel becomes partly confined, bedrock controlled with discontinuous floodplain until its confluence with Middle Creek.

3.3 South Creek

South Creek drains from a narrow low sloped, Partly confined, bedrock controlled with discontinuous floodplain headwater. As with Middle and Oxford Creeks, a step occurs in the valley profile. On South Creek this point is characterised by a series of broad bedrock steps that create cascades. Downstream of this step, the channel moves into a confined gorge setting. As the valley opens, floodplain pockets occur on the floodplain and the dominant River Style returns to Partly confined, Bedrock controlled with discontinuous floodplain. Downstream of the confluence with Wheeler Creek, the valley opens and a Low sinuosity sand bed pattern of River Style develops within a broad floodplain. This River Style continues until South Creek drains into Narrabeen Lagoon.

Appendix H

Breakdown of Implementation Plan Costs and Prioritisation of Reaches and Activities for Each Time Period

Breakdown of Indicative Costs for Each Reach		
Reach/Creek	**Activity**	**Cost ($)**
Kierans Creek (upper)	Preparation of Creek Management Plan consistent with Dundundra Falls Reserve Plan of Management **(1-2 years)**	20000
	Negotiate with SWC to supply sewage reticulation to the Myora Road area **(1-2 years)**	N/A
	Incentive Scheme to progressively replace septic tanks with aerobic sand filtration systems **(1-2 years)**[ab]	50000
	Conduct a risk assessment of stormwater runoff from different land uses **(1-2 years)**	20000
	Consider the proposed LEP amendments in evaluating development proposals in the upper reaches **(1-2 years)**	N/A
	Work with rural and commmercial landholders (e.g. with incentive schemes, education, regulation, audit) to improve site management practices **(2-5 years)**	50000
	Incentives for upgrading on-site wastewater systems to effect nutrient removal **(2-5 years)**[b]	10000
Sub-total		**150000**
Duffys Creek (upper)	Preparation of Creek Management Plan, with particular reference to stormwater management and water sensitive design **(1-2 years)**	20000
	Incentive Scheme to progressively replace septic tanks with aerobic sand filtration systems **(1-2 years)**[ab]	50000
	Conduct a risk assessment of stormwater runoff from different land uses **(1-2 years)**	20000
	Consider the proposed LEP amendments in evaluating development proposals in the upper reaches **(1-2 years)**	N/A
	Work with rural and commmercial landholders (e.g. with incentive schemes, education, regulation, audit) to improve site management practices **(2-5 years)**	50000
	Incentives for upgrading on-site wastewater systems to effect nutrient removal **(2-5 years)**[b]	10000
Sub-total		**150000**
Greendale Creek (upper)	Consider the proposed LEP amendments in evaluating development proposals in the upper reaches **(1-2 years)**	N/A
Sub-total		**N/A**
Greendale Creek (lower)	Limit further development (including impervious surfaces) within the riparian zone **(1-2 years)**[c]	N/A
	Investigate the costs and benefits of options to intercept and/or treat landfill leachate entering the creek **(2-5 years)**	40000
Sub-total		**40000**
Dee Why Creek	Repair erosion around the concrete creek invert by stabilising soil and revegetating with groundcover **(1-2 years)**	20000
	Continue revegetating riparian areas **(1-2 years)**	30000
	Investigate potential pollution from Cromer industrial estate (also applicable to South Creek) **(1-2 years)**	N/A
	Investigate the construction of an artificial wetland habitat adjacent to the creek **(2-5 years)**	30000
Sub-total		**80000**
Brookvale Creek	Control weeds in Allenby Park and educate landholders about garden waste management **(1-2 years)**	20000
	Continue weed management in the reaches below Warringah Mall **(1-2 years)**	20000
Sub-total		**40000**
Curl Curl Creek	Preparation of Creek Management Plan **(1-2 years)**	30000
	Revegetate riparian zone and buffers **(1-2 years)**	30000
	Investigate the performance of existing stormwater quality controls and augment if necessary **(2-5 years)**	40000
Sub-total		**100000**
Manly Creek	Continue weed management **(1-2 years)**	20000
	Stabilise banks and revegetate **(2-5 years)**	80000
Sub-total		**100000**
Burnt Bridge Creek (in cooperation with Manly Council)	Continue implementation of erosion control and revegetation works **(1-2 years)**	20000
	Investigate the costs and benefits of an in-stream wetland **(2-5 years)**	10000
	Improve the recreeational and access trail network **(2-5 years)**	100000
Sub-total		**130000**
Bare Creek	Undertake weed management in riparian zone **(1-2 years)**	10000
	Educate residents about plant selection and garden waste management **(1-2 years)**	10000
	Investigate sediment trapping opportunities **(1-2 years)**	20000
	Enforce sediment and erosion control measures for new construction **(1-2 years)**	N/A
	Preparation of a Creek Management Plan **(2-5 years)**	10000
Sub-total		**50000**
Frenchs Creek	Undertake weed management in riparian zone **(1-2 years)**	15000
	Educate residents about plant selection and garden waste management **(1-2 years)**	10000
	Investigate sediment trapping opportunities **(1-2 years)**	20000
	Preparation of a Creek Management Plan with particular attention to retrofitting WSUD and stormwater quality control devices **(2-5 years)**	20000
Sub-total		**65000**

Reach/Creek	Activity	Cost ($)
Carroll Creek	Undertake weed management in riparian zone **(1-2 years)**	20000
	Educate residents about plant selection and garden waste management **(1-2 years)**	10000
	Require WSUD principles in all new development **(1-2 years)**	N/A
	Investigate retrofit of WSUD in existing development **(5-15+ years)**	15000
	Install additional stormwater quality control devices **(5-15+ years)**	200000
Sub-total		**245000**
Bantry Bay Creek	Undertake weed management in riparian zone **(1-2 years)**	15000
	Educate residents about plant selection and garden waste management **(1-2 years)**	10000
	Require WSUD principles in all new development **(1-2 years)**	N/A
	Investigate retrofit of WSUD in existing development **(5-15+ years)**	15000
	Install additional stormwater quality control devices **(5-15+ years)**	200000
Sub-total		**240000**
Deep Creek (upper)	Preparation of a Creek Management Plan **(1-2 years)**	15000
	Progressively eliminate weed sources from the upper catchment to the National Park boundary **(1-2 years)**	50000
	Restrict access vehicle and riding trails within riparian buffers **(1-2 years)**	30000
	Investigate causes of elevated nutrient concentrations downstream of Kimbriki Recycling and Waste Disposal Centre **(1-2 years)**	N/A
Sub-total		**95000**
Deep Creek (lower) (In cooperation with Pittwater Council)	Preparation of a Creek Management Plan (as above) **(1-2 years)**	15000
	Continue revegetation around the reserve **(1-2 years)**	10000
	Encourage Pittwater Council to continue the program of development controls and stormwater infrastructure **(1-2 years)**	N/A
Sub-total		**25000**
Middle Creek (upper)	Limit catchment development on undeveloped tributaries **(1-2 years)**[c]	N/A
	Require WSUD in new development **(1-2 years)**	N/A
	Preparation of a Creek Management Plan (in conjunction with Snake and Oxford Creeks) **(2-5 years)**	40000
	Recreational trail in public land from Narrabeen Lagoon to Oxford Falls **(2-5 years)**	300000
	Commence riparian revegetation in upper reaches (including removal and replacement of the engineered channel running through the Australian Tennis Academy with stream stabilisation measures) **(2-5 years)**	50000
	Educate residents about plant selection and garden waste management **(2-5 years)**	20000
	Riparian revegetation and weed removal in middle and lower reaches **(5-15+ years)**	200000
Sub-total		**610000**
Snake Creek / Oxford Creek	Limit catchment development **(1-2 years)**[c]	N/A
	Require WSUD in new development **(1-2 years)**	N/A
	Preparation of a Creek Management Plan (in conjunction with Middle Creek) **(2-5 years)**	40000
	Educate residents about plant selection and garden waste management **(2-5 years)**	10000
	Riparian revegetation and weed removal **(5-15+ years)**	150000
Sub-total		**200000**
South Creek	Preparation of a Creek Management Plan **(1-2 years)**	40000
	Progressively revegetate riparian zone (upper reaches) **(1-2 years)**	50000
	Stabilise eroding banks in upper reaches **(1-2 years)**	50000
	Construct a wetland at the Wheeler Creek confluence **(1-2 years)**	See Wheeler Creek
	Introduce at-source controls (retrofit WSUD, etc) to reduce peak flows **(1-2 years)**	100000
	Educate residential, commercial and industrial landholders about at-source stormwater management **(1-2 years)**	20000
	Educate residents about plant selection and garden waste management **(1-2 years)**	20000
	Progressively revegetate riparian zone (middle and lower reaches) **(2-5 years)**	200000
	Recreational trail in public land from Narrabeen Lagoon to Beacon Hill **(2-5 years)**	300000
	Continue retrofit of WSUD in catchment **(2-5 years)**	200000
	Continue retrofit of WSUD in catchment **(5-15+ years)**	300000
Sub-total		**1280000**
Wheeler Creek	Strictly limit catchment development **(1-2 years)**[c]	N/A
	Preparation of a Creek Management Plan **(1-2 years)**	30000
	Negotiate with property owners to revegetate disturbed riparian zones **(1-2 years)**	30000
	Remove weeds and sediment in lower channel near South Creek confluence **(2-5 years)**	30000
	Install a wetland, fishway and erosion controls at South Creek confluence **(2-5 years)**	200000
Sub-total		**290000**
Grand Total		**3890000**
Note:		
a = approx. $500 per upgrade		
b = may be achieved by rate reductions		
c = costs may be required for compensation/acquisition		

Prioritisation of Reaches and Activities for Each Timeframe Period

Timeframe	Reach/Creek[a]	Activity	Cost ($)
1-2 years	Wheeler Creek	Strictly limit catchment development	N/A
		Preparation of a Creek Management Plan	30000
		Negotiate with property owners to revegetate disturbed riparian zones	30000
	Curl Curl Creek	Preparation of Creek Management Plan	30000
		Revegetate riparian zone and buffers	30000
	Deep Creek (upper)	Preparation of a Creek Management Plan	15000
		Progressively eliminate weed sources from the upper catchment to the National Park boundary	50000
		Restrict access vehicle and riding trails within riparian buffers	30000
	Deep Creek (lower) (In cooperation with Pittwater Council)	Preparation of a Creek Management Plan (as for upper reaches)	15000
		Continue revegetation around the reserve	10000
		Encourage Pittwater Council to continue the program of development controls and stormwater infrastructure	N/A
	Snake Creek / Oxford Creek	Limit catchment development	N/A
		Require WSUD in new development	N/A
	Duffys Creek (upper)	Preparation of Creek Management Plan, with particular reference to stormwater management and water sensitive design	20000
		Incentive Scheme to progressively replace septic tanks with aerobic sand filtration systems	50000
		Conduct a risk assessment of stormwater runoff from different land uses	20000
		Consider the proposed LEP amendments in evaluating development proposals in the upper reaches	N/A
	Kierans Creek (upper)	Preparation of Creek Management Plan consistent with Dundundra Falls Reserve Plan of Management	20000
		Negotiate with SWC to supply sewage reticulation to the Myora Road area	N/A
		Incentive Scheme to progressively replace septic tanks with aerobic sand filtration systems	50000
		Conduct a risk assessment of stormwater runoff from different land uses	20000
		Consider the proposed LEP amendments in evaluating development proposals in the upper reaches	N/A
	Bare Creek	Undertake weed management in riparian zone	10000
		Educate residents about plant selection and garden waste management	10000
	Deep Creek (upper)	Investigate causes of elevated nutrient concentrations downstream of Kimbriki Recycling and Waste Disposal Centre	N/A
	Burnt Bridge Creek (in cooperation with Manly Council)	Continue implementation of erosion control and revegetation works	20000
	South Creek	Preparation of a Creek Management Plan	40000
		Progressively revegetate riparian zone (upper reaches)	50000
		Stabilise eroding banks in upper reaches	50000
		Construct a wetland at the Wheeler Creek confluence	See Wheeler Creek
		Introduce at-source controls (retrofit WSUD, etc) to reduce peak flows	100000
		Educate residential, commercial and industrial landholders about at-source stormwater management	20000
		Educate residents about plant selection and garden waste management	20000
	Middle Creek (upper)	Limit catchment development on undeveloped tributaries	N/A
		Require WSUD in new development	N/A
	Dee Why Creek	Repair erosion around the concrete creek invert by stabilising soil and revegetating with groundcover	20000
	Bare Creek	Investigate sediment trapping opportunities	20000
		Enforce sediment and erosion control measures for new construction	N/A
	Carroll Creek	Undertake weed management in riparian zone	20000
		Educate residents about plant selection and garden waste management	10000
		Require WSUD principles in all new development	N/A
	Frenchs Creek	Undertake weed management in riparian zone	15000
		Educate residents about plant selection and garden waste management	10000
	Manly Creek	Continue weed management	20000
	Bantry Bay Creek	Undertake weed management in riparian zone	15000
		Educate residents about plant selection and garden waste management	10000
		Require WSUD principles in all new development	N/A
	Greendale Creek (upper)	Consider the proposed LEP amendments in evaluating development proposals in the upper reaches	N/A
		Limit further development (including impervious surfaces) within the riparian zone	N/A
	Frenchs Creek	Investigate sediment trapping opportunities	20000
	Brookvale Creek	Control weeds in Allenby Park and educate landholders about garden waste management	20000
		Continue weed management in the reaches below Warringah Mall	20000
	Dee Why Creek	Continue revegetating riparian areas	30000
		Investigate potential pollution from Cromer industrial estate (also applicable to South Creek)	N/A
Sub-total			**970000**

Timeframe	Reach/Creek[a]	Activity	Cost ($)
2-5 years	Wheeler Creek	Remove weeds and sediment in lower channel near South Creek confluence	30000
		Install a wetland, fishway and erosion controls at South Creek confluence	200000
	Curl Curl Creek	Investigate the performance of existing stormwater quality controls and augment if necessary	40000
	Duffys Creek (upper)	Work with rural and commmercial landholders (e.g. with incentive schemes, education, regulation, audit) to improve site management practices	50000
		Incentives for upgrading on-site wastewater systems to effect nutrient removal	10000
	Kierans Creek (upper)	Work with rural and commmercial landholders (e.g. with incentive schemes, education, regulation, audit) to improve site management practices	50000
		Incentives for upgrading on-site wastewater systems to effect nutrient removal	10000
	Bare Creek	Preparation of a Creek Management Plan	10000
	Snake Creek / Oxford Creek	Preparation of a Creek Management Plan (in conjunction with Middle Creek)	40000
		Educate residents about plant selection and garden waste management	10000
	South Creek	Progressively revegetate riparian zone (middle and lower reaches)	200000
		Continue retrofit of WSUD in catchment	200000
	Burnt Bridge Creek (in cooperation with Manly Council)	Investigate the costs and benefits of an in-stream wetland	10000
		Improve the recreeational and access trail network	100000
	Frenchs Creek	Preparation of a Creek Management Plan with particular attention to retrofitting WSUD and stormwater quality control devices	20000
	South Creek	Recreational trail in public land from Narrabeen Lagoon to Beacon Hill	300000
	Manly Creek	Stabilise banks and revegetate	80000
	Middle Creek (upper)	Preparation of a Creek Management Plan (in conjunction with Snake and Oxford Creeks)	40000
		Recreational trail in public land from Narrabeen Lagoon to Oxford Falls	300000
		Commence riparian revegetation in upper reaches (including removal and replacement of the engineered channel running through the Australian Tennis Academy with stream stabilisation measures)	50000
		Educate residents about plant selection and garden waste management	20000
	Dee Why Creek	Investigate the construction of an artificial wetland habitat adjacent to the creek	30000
	Greendale Creek (lower)	Investigate the costs and benefits of options to intercept and/or treat landfill leachate entering the creek	40000
Sub-total			**1840000**
5-15+ years	Snake Creek / Oxford Creek	Riparian revegetation and weed removal	150000
	South Creek	Continue retrofit of WSUD in catchment	300000
	Middle Creek (upper)	Riparian revegetation and weed removal in middle and lower reaches	200000
	Carroll Creek	Investigate retrofit of WSUD in existing development	15000
		Install additional stormwater quality control devices	200000
	Bantry Bay Creek	Investigate retrofit of WSUD in existing development	15000
		Install additional stormwater quality control devices	200000
Sub-total			**1080000**
Grand Total			**3890000**
Note:			

a = Order reflects overall priority (within each time frame period) from highest to lowest, based on creek classification (A, B or C - Section 5.3), value Vs risk matrix (Section 7.2) and action priorities within each reach (Section 7.2).

Appendix I

Hierarchical Numbering System for Identifying Creeks and Reaches

ID Code	Catchment	Subcatchment/Creek	Tributary	Sub-Tributary	Sub-Sub-Tributary	Access Point
1	**Cowan Creek**					
1.1		**Kierans Creek**				Cnr. Aumuna Rd & Larool Rd
1.1.1			**Tributary**			Birramal Rd
1.1.2			**Tributary**			Kulgoa Cr
1.1.2.1				Sub-tributary		Cnr. Kulgoa Cr and Tooronga Rd
1.1.2.2				Sub-tributary		Tooronga Rd
1.1.3			**Tributary**			Golf Paradise Driving Range - Myoora Rd
1.1.4			**Neverfail Creek**			Kinma State School - Coolowie Rd
1.1.5			**Tributary**			Aumuna Rd
1.2		**Duffy's Creek**				Booralie Road
2	**Curl Curl Lagoon**					
2.1		**Greendale Creek**				John Fisher Park - Harbord Rd
3	**Dee Why Lagoon**					
3.1		**DY Creek**				Campbell Av
4	**Manly Lagoon**					
4.1		**Burnt Bridge Creek**				Cr Eileen St and Worrobil St
4.1.1			**Tributary**			Birrima St
4.2		**Manly Creek**				David Thomas Reserve - Solane Cr
4.2.1			**Tributary**			Carinya Cl
4.2.2			**Curl Curl Creek**			Manly Warringah War Memorial Park - Wakehurst Parkway
4.3		**Brookvale Creek**				Warringah Golf Course - Condamine St (lower) and Doulton Av (upper)
4.3.1			**Tributary**			Allenby Park - Owen Stanley Av
4.3.1.1				Sub-tributary		Owen Stanley Av
4.3.2			**Tributary**			Margaret St
5	**Middle Harbour Creek**					
5.1		**Bantry Bay**				Killarney Dr
5.1.1			**Tributary**			Forestville Park - Pildra Pl
5.1.2			**Bates Creek**			Starkey St
5.2		**Carroll Creek**				Merrilee Cr
5.2.1			**Tributary**			Prahran Av
5.3		**Sub-catchment**				Mathews St
5.4		**Frenchs Creek**				Haigh Av
5.4.1			**Tributary**			Borgnis Reserve - Stone Pde
5.4.2			**Tributary**			Ralston Av
5.4.3			**Tributary**			Pringle Av
5.5		**Bare Creek**				
5.5.1			**Tributary**			Mona Vale Rd
5.5.2			**Tributary**			Narabang Way

Note: Highlighted access points indicate site survey locations.

ID Code	Catchment	Subcatchment/Creek	Tributary	Sub-Tributary	Sub-Sub-Tributary	Access Point
6	**Narrabeen Lagoon**					
6.1		**Middle Creek**				Wakehurst Parkway Bridge and side road (lower) Oxford Falls - Oxford Falls Rd (mid), Dreadnought Rd (mid-upper) and Carnarvon Rd (upper)
6.1.1			**Tributary**			NSW Academy of Sport - Wakehurst Parkway
6.1.1.1				Sub-tributary		NSW Academy of Sport - Wakehurst Parkway
6.1.2			**Tributary**			Dee Why West Recreation Reserve - Cromer Valley Rd
6.1.3			**Oxford Creek**			Cr Oxford Falls Rd and Morgan Rd
6.1.3.1				Sub-tributary		Oxford Falls Rd
6.1.3.2				Sub-tributary		Oxford Falls Rd
6.1.3.3				Snake Creek		Cr Morgan Rd and Hilversum Cr
6.1.3.3.1					Sub-sub-tributary	Morgan Rd
6.1.3.3.2					Sub-sub-tributary	Perentie Rd
6.1.3.4				Sub-tributary		East of main channel near Dawes Rd
6.1.3.5				Sub-tributary		West of main channel near Dawes Rd
6.1.4			**Tributary**			Spicer Rd N
6.1.5			**Tributary**			Wakehurst Parkway
6.1.6			**Tributary**			Wakehurst Parkway
6.1.6.1				Sub-tributary		Meatworks Av
6.1.6.2				Sub-tributary		Maybrook Av
6.1.7			**Tributary**			Oxford Falls Grammar School - Dreadnought Rd
6.1.8			**Tributary**			Jindabyne St
6.2		**South Creek**				Kirkstone Rd (lower), Carcoola Rd (mid-lower), Lillihina Av (mid) and Willandra Rd (mid and upper)
6.2.1			**Tributary**			Cromer Golf Course - Cromer Rd
6.2.2			**Wheeler Creek**			Little Willandra Rd (lower) and Maybrook Manor (upper)
6.2.3			**Tributary**			Nalya Rd
6.3		**Deep Creek**				Wakehurst Parkway
6.3.1			**Tributary**			North of Warringah Radio Control Society
6.3.2			**Tributary**			Kamber Rd
6.3.2.1				Sub-tributary		JJ Melbourne Hills Memorial Reserve - Mona Vale Rd
6.3.3			**Tributary**			Madang Rd (east)
6.3.3.1				Sub-tributary		Madang Rd (west)
6.3.3.1.1					Sub-sub-tributary	Madang Rd (west)
6.3.3.1.2					Sub-sub-tributary	Forest Way
6.3.3.1.3					Sub-sub-tributary	Hilversum Cr
6.3.3.2				Sub-tributary		Bush Tr
6.3.3.2.1					Sub-sub-tributary	Bush Tr
6.3.3.3.				Sub-tributary		West of Warringah Radio Control Society
6.3.3.3.1					Sub-sub-tributary	West of Warringah Radio Control Society
6.3.3.4				Sub-tributary		Bush Tr
6.4		**Sub-catchment**				James Wheeler Pl
6.5		**Sub-catchment**				War Veterans Homes - Lantana Av
6.6		**Sub-catchment**				Jamieson Park - Coolooli Rd
7	**Collaroy Beach**					
7.1		**Sub-catchment**				Alexanda St
7.2		**Sub-catchment**				Cr Hendy Av and Kent St
7.3		**Sub-catchment**				The Avenue

Note: Highlighted access points indicate site survey locations.