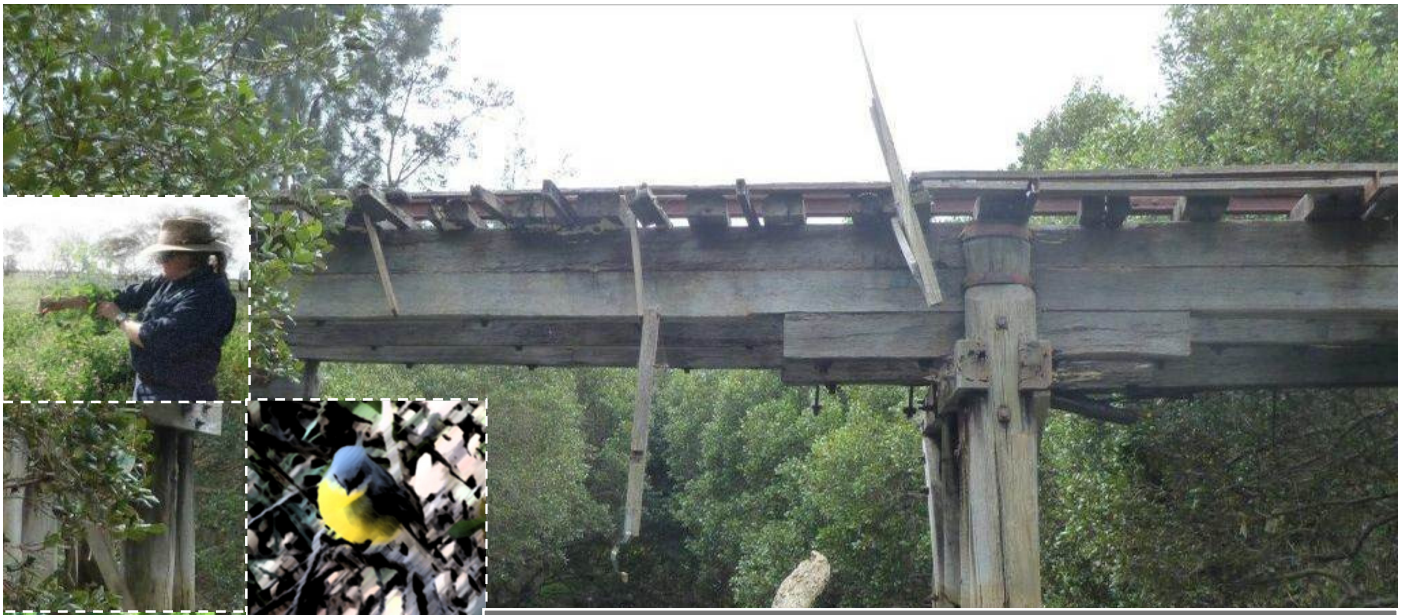

WATERWAYS MAINTENANCE AND REHABILITATION MASTERPLAN FOR THE DUCK RIVER CATCHMENT VOLUMES 1 - 3

Prepared for Parramatta City Council By

Applied Ecology Pty Ltd, October 2012

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THE MASTERPLAN FOR THE DUCK RIVER CATCHMENT

The Masterplan for the Duck River Catchment was prepared in 2012 for Parramatta City Council, and was prepared in conjunction with the Upper Duck River Wetlands and Riparian Corridor Plan of Management, a joint initiative by Parramatta and Auburn Councils.

The Masterplan applies to all of the streams in the Duck River Catchment that fall within the boundaries of Parramatta LGA, including Duck River, Duck Creek, Little Duck Creek, A'Becketts Creek, Smalls Creek, and several unnamed tributaries.

The Masterplan is organised in three volumes:

- Volume One provides a review of existing knowledge, including the legislative framework, previous plans, findings of flora and fauna surveys, and indigenous and non-indigenous cultural heritage assessments.
- Volume Two provides a set of detailed maps that show the nature, location and extent of the catchment's topography, land tenure, stream processes and channel attributes, stormwater pipe networks and treatment devices, vegetation communities and restoration activities, indigenous and non-indigenous cultural heritage, and contaminated lands and associated issues. These maps were also provided to council as GIS layers.
- Volume Three comprises the actual plan, and provides plan objectives, reach apportionment for streams, rehabilitation works and activities, expected waterways corridor responses to works, detailed works plans for each of 28 reaches, with indicative initial and ongoing costs, recommendations for riparian buffers and development setbacks, and timeframe for review of the Masterplan. The appendices include detailed lists of native flora species for revegetation in each of the Endangered Ecological Communities present, description of works activities and guidelines for best practice techniques for these works.

To assist with navigation of the Masterplan, an overview of the contents of each volume is provided below.

VOLUME ONE: PRELIMINARY STUDY OF DUCK RIVER CATCHMENT

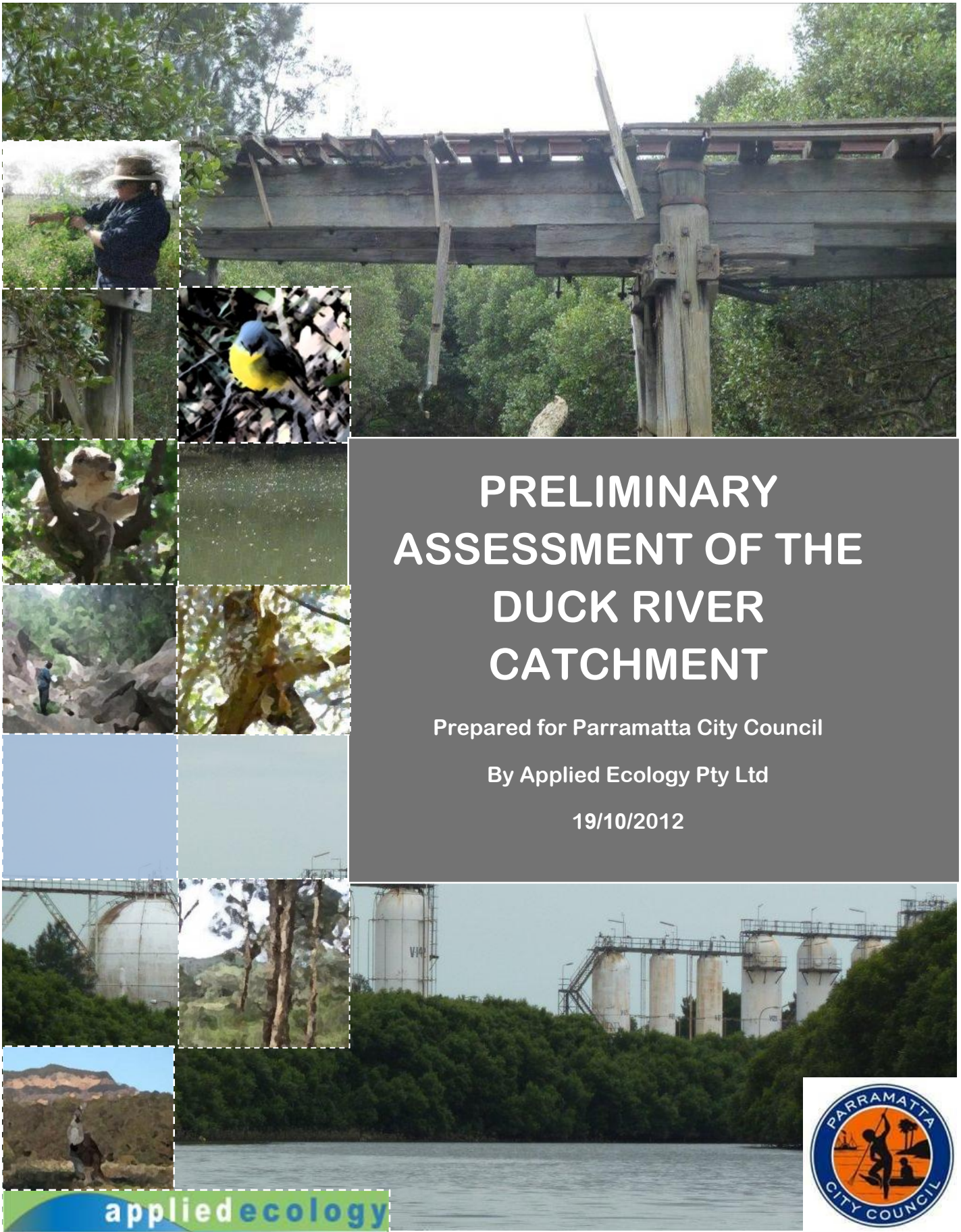
CONTENTS

VOLUME TWO: DETAILED MAPPING OF THE DUCK RIVER CATCHMENT

CONTENTS

VOLUME THREE: A MASTERPLAN FOR DUCK RIVER CATCHMENT

CONTENTS



PRELIMINARY ASSESSMENT OF THE DUCK RIVER CATCHMENT

Prepared for Parramatta City Council

By Applied Ecology Pty Ltd

19/10/2012

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DOCUMENT VERIFICATION

Project Title	**DUCK RIVER CATCHMENT WATERWAYS MAINTENANCE AND REHABILITATION MASTER PLAN**
Document Title	**PRELIMINARY ASSESSMENT OF THE DUCK RIVER CATCHMENT WATERWAYS**
Client	**Parramatta City Council**
Client contact	**Pino Todarello**

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DISCLAIMER

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Pino Todarello Parramatta City Council
Anthony Collins Parramatta City Council

1 Contents

1.1 List of Tables

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2 PURPOSE OF A MASTERPLAN

Parramatta City Council requires Maintenance and Rehabilitation Masterplans for waterways within its jurisdiction. The Masterplan will identify:

- What the waterways were once like
- Their current status
- A vision for the specific waterway corridor
- Future opportunities and current constraints in improving them
- Detailed recommendations of works required (actions)

Actions that are recommended in the Masterplan include estimated budgets, areas of responsibility, priority and type of action. Types of action may include:

- Capital works
- Education
- Research
- Strategic Management
- Maintenance

The Action Plan is not fixed and changes each year as new information is collected and more detailed investigations are undertaken. Actions will then be implemented either through Council's ongoing services or through targeted projects.

2.1 THE NEED FOR THE DUCK RIVER WATERWAYS MASTER PLAN

In order to develop a consistent and agreed maintenance and regeneration program for the Duck River Catchment, a 'Waterways Maintenance and Rehabilitation Master Plan' is required. The Master Plan will be the primary guiding document in the management of the Duck River catchment and will provide a framework and foundation for the necessary collaboration between the relevant state and local government authorities for the associated maintenance and rehabilitation planning and works.

The Master Plan considers the whole of the Duck River catchment in the development of actions and recommendations. These actions and recommendations are primarily for Community Lands within Parramatta LGA that border Duck River and its tributaries. In some cases, specific recommendations may be made with respect to other lands.

This report provides a review of all relevant issues associated with the Duck River Catchment, and seeks to inform the development of the Waterways Maintenance and Rehabilitation Master Plan for the Duck River Catchment.

2.2 CATCHMENT OVERVIEW

The Duck River catchment covers an area of 4056 hectares. Duck River passes through three local government areas, with the upstream section in Bankstown LGA. The river then forms the boundary between Parramatta and Auburn LGAs until it discharges to Parramatta River at Silverwater. Duck River is tidal from its mouth at Parramatta River to the Clyde Weir near the Main Western Railway Line at Granville, and freshwater above the weir. It has several major tributaries, including Duck

Creek, Little Duck Creek, and A'Becketts Creek. Landuse in the Parramatta LGA section of the catchment is predominantly residential, with major areas of industrial and commercial development, and a smaller proportion of open space, which includes sportsgrounds, parks, areas of General Community Use, areas of Cultural Significance and natural areas.

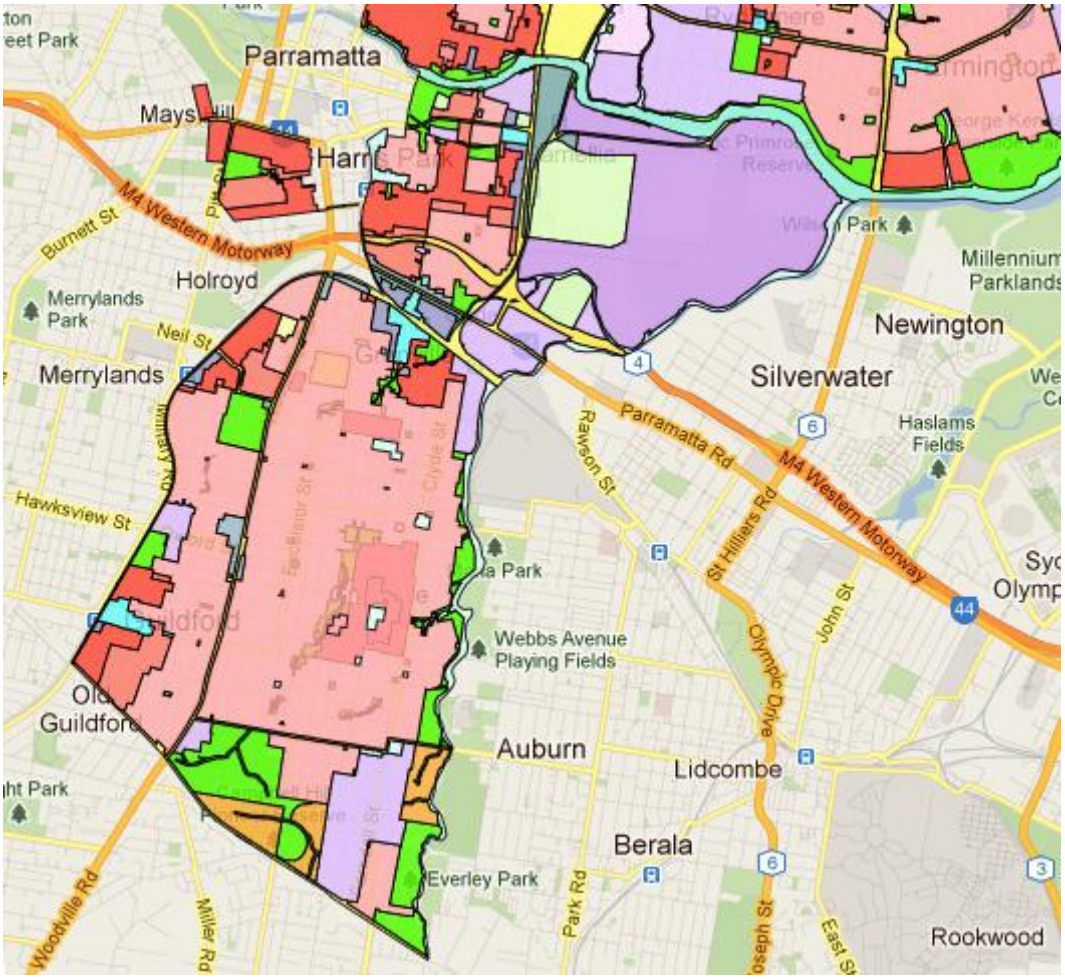


Figure 1. Land tenure in the Duck River catchment section of Parramatta LGA

The Duck Creek subcatchment is approximately 790 hectares and is mainly in Parramatta LGA, with a small upstream section in Holroyd LGA. The main channel of Duck Creek is largely a concrete or brick lined open channel. Little Duck Creek is a major tributary of Duck Creek, and has large sections of concrete lined channel. West of the railway line another stretch of concrete lined channel known as Guildford Rd Branch drains land in Holroyd LGA before being piped to Duck Creek.

A'Becketts Creek subcatchment is approximately 690 hectares, with about half in Parramatta LGA and half in Holroyd LGA. It joins Duck Creek about 1km above the confluence with Duck River. The lower reaches of A'Becketts Creek are tidally affected, and much of the channel has been concrete lined.

2.3 WHAT IS COMMUNITY LAND?

The Local Government Act 1993, herein referred to as the Act, requires Council to take and maintain an inventory of all land owned by Council. This land was then to be classified as either:

- Community Land, or
- Operational Land

The 1999 Regulation (as amended in 2005) has provided Council's with guidelines to ensure all community land is appropriately categorised and managed in accordance with identified management objectives, described in the Act as core objectives.

Community land must now be categorised as one, or more, of the following:

a) Sportsground
b) Park
c) General Community Use
d) Area of Cultural Significance
e) Natural Area

Natural Areas must be further sub-categorised as:

1. Foreshore
2. Bushland
3. Wetland
4. Escarpment
5. Watercourse

2.4 LEGISLATIVE AND POLICY FRAMEWORK

A summary of the relevant state and federal legislation and their applications to management and restoration of wetland ecosystems is provided in Appendix One (Table A1). Any actions that are undertaken that are likely to cause a significant impact on a matter of National Environmental Significance (including threatened species and ecological communities and migratory species) will require a referral to the Federal Minister for consideration.

Under the terms of the NSW TSC Act, Local Government must assess the impacts of any proposed development or activity which might adversely impact on an Endangered Ecological Community, threatened species or populations, including restoration works associated with streambanks and bushland rehabilitation. Where impacts are likely to occur, it must also identify strategies to minimise such impacts. Where a conflict arises, the development proposal must be referred to the NSW Office of Environment & Heritage (OEH) for resolution.

For many communities and species listed under the TSC Act, Threatened Species Recovery Plans have been prepared, while others are addressed more generally in the Priorities Action Statement (PAS). The PAS identifies 36 broad strategies to help threatened plants and animals recover, and establishes relative priorities to implement these strategies. Each of these strategies has more specific priority actions within them, which cover things like:

- surveys to clarify the distribution of a species
- weed and pest management programs
- guidelines for threatened species issues in development assessments
- research into factors influencing the survival of threatened species
- community education programs to raise awareness of a species or threat in a particular area

The PAS also establishes performance indicators to report achievements in implementing recovery and threat abatement strategies and their effectiveness and sets out clear timetables for recovery and threat abatement planning and achievement. A variety of strategies outlined in the PAS can be used to manage a threatening process. One of these strategies is the preparation of a detailed threat abatement plan (TAP) which presents a strategic framework for a targeted threat abatement program. Threat abatement plans have been finalised for a number of key threatening processes, including the following recorded in the Upper Duck River Wetlands:

- Predation by *Gambusia holbrooki* (Plague Minnow)
- Predation by the Red Fox (*Vulpes vulpes*)
- Infestation by Lantana, managed through the national Plan to Protect Environmental Assets from Lantana

2.5 REVIEW OF LITERATURE: EXISTING PLANS

Numerous plans of management have been prepared for the Duck River Catchment in the last 15 years. These cover a range of aspects, from stormwater and flood mitigation to biodiversity management, and have been developed by the three City Councils that manage the main channel of Duck River.

2.5.1 Duck River Management Plan (EDAW, 1996)

The Duck River Management Plan was prepared for the freshwater reach of Duck River. The aim of this plan was to provide a strategy for the restoration of Duck River as a functioning, diverse river system maximising habitat, recreation and aesthetic opportunities. The plan described issues associated with the river, providing a management philosophy for the river and presenting strategies for implementation of the plan's recommendations.

The Duck River MP states a vision for Duck River's management as "to continually work towards improving the ecological values of the Duck River corridor while enhancing the recreational and educational opportunities and ensuring that landuses within the catchment are developed and managed in line with the principles of Ecologically Sustainable Development." The recommendations covered areas including:

- Vegetation (conservation, restoration and ongoing management)
- Wildlife (control of feral animal, wetlands construction and habitat enhancement)
- Water resources (water quality, WQ control measures, sewer overflows, flooding, flow retardation techniques, stormwater detention techniques, runoff quantity and quality, stream erosion and sedimentation, and irrigation)

Sixteen years later, this MP needs to be reviewed and updated, forming the basis for the current project.

2.5.2 Lower Duck River Foreshores Improvement Plan (EDAW/DUAP, 1998)

The Lower Duck River Foreshores Improvement Plan formed part of the Parramatta River Foreshores Improvement Program, a state government funded initiative. It focused on the lower Duck River, below Clyde Weir to the confluence with Parramatta River, as well as Duck Creek and A'Becketts Creek below the M4 Freeway, and included lands in Parramatta and Auburn LGAs. Following an

extensive consultation process, they developed the following vision statement for the lower Duck River:

"There are five elements of the river that provide the inherent means for its improvement and new appreciation. These are the foundation of a new vision for the river, one that can be realised in the short term but will ensure its value and sustainability for the century ahead. The Duck River Foreshores Improvement Program will:

- Build on the rich Aboriginal and European history of the river system
- Rejuvenate the river through careful stewardship as a dynamic and healthy natural system
- Make the river a place for quiet personal recreation in a varied and interesting setting, encouraging exploration and creating opportunities for relaxation and privacy
- Develop and manage the river as a focus for community life, special events, festivals and tourism
- Establish the river as an expression of the identity of the cities of Sydney and Parramatta, reviving its role as an attractive and useable corridor linking pubic open spaces between the cities"

In many respects, this vision is valid today, and could underpin the current Masterplan.

2.5.3 Duck River Stormwater Management Plan (SKM, 1999)

The Duck River Stormwater Management Plan was prepared for Parramatta, Auburn, Bankstown and Holroyd City Councils in July, 1999. The primary goal of this plan is to: "facilitate the coordinated management of stormwater within the Duck River catchment, to improve the health and quality of the catchment waterways". It makes the following general statements about the catchment condition in 1999:

- Significant erosion and sedimentation in the freshwater reach of Duck River
- A large proportion of the open channel waterways have been replaced with concrete lined channels, including Duck Creek, Little Duck Creek, and A'Becketts Creek
- Poor water quality in Duck River, with microbiological and nutrient levels exceeding the recommended levels for primary contact recreational activities such as swimming and boating. In the freshwater reaches, algal blooms are frequent. During wet weather pollutant concentrations are significantly increased. No water quality data was available for any of the tributary creeks
- Sewer overflows in Duck River contribute significantly to pollutant loads into the river, especially during large storm events
- From sediment sampling the main pollutants tend to be catchment-wide, and are introduced in stormwater runoff from roads, roofs and open space areas
- Mangroves, saltmarshes and mudflats are common in the estuarine reaches, and provide important bird habitat for migratory waders. Little documented information existed on the aquatic habitat within the catchment

Many of these issues are still relevant for the catchment today.

2.5.4 Auburn Council Plan of Management for Duck River Foreshore (2001)

The Plan of Management for Duck River Foreshore was prepared for Auburn Council in 2000/1. It applies primarily to community land along Duck River in Auburn LGA, thus it covers land that is predominantly council's open space areas, but includes Crown Land under the care and control of Council, and some land that is privately owned or owned by other public authorities. This range of land tenure as the subject of the plan is similar to that recommended for the current project on behalf of Parramatta Council.

Management objectives are directed towards conservation of biodiversity and maintenance of ecosystem functions within the Duck River environment. A series of management actions thus aimed to protect the aesthetic, heritage, recreational, educational and scientific values of the Duck River and Foreshore environment. Key activities are directed towards restoration of degraded bushland, reduce high edge effects and poor connectivity, and comply with relevant threatened species recovery plans. Management of water quality, community access and recreational use are also identified as important outcomes in the plan.

2.5.5 Lower Duck River Riparian Management Plan (EP, 2002)

The Lower Duck River Riparian Management Plan was commissioned by the Duck River Steering Committee and completed in November, 2002. It identifies key issues for the catchment to include a lengthy history of degrading processes including weed invasion, clearing, nutrient runoff from adjoining sites, and altered fire regimes. They identify the need to coordinate management among a range of local councils and other organisations.

Management recommendations were directed by the community and environmental values identified during the study. The required outcomes, based on these values, were used to develop strategies and actions that addressed the issues identified, providing the basis to build the resulting RMP. The RMP addressed issues associated with private land, public access, community and social needs, and the natural environment. A range of strategies was proposed to manage these potentially conflicting requirements, so that each identified issue was managed through a series of identified actions. The outcomes included development of a masterplan and a plan of management.

Current requirements for development setbacks were reviewed and recommendation made to improve the management outcomes by modifications to Auburn Council's LEP. The expressed aims were to implement development setbacks that provide stable foreshore banks, riparian vegetation conservation zones (including threatened species and communities), and "regionally significant public foreshore access between the river and wetland edge and riverfront industrial developments". This was further defined as a shared pedestrian/cycle path through open space areas with a range of passive recreation uses. Another key environmental issue addressed was management of mangroves through protection of existing mangrove communities and management of colonisation to retain a range of other vegetation communities and recreational opportunities.

This plan provided a comprehensive series of strategies and management actions that addressed all the identified issues. These covered both banks of the Lower Duck River, encompassing Auburn City Council and Parramatta City Council, and provided an excellent basis for ongoing management.

2.5.6 Duck Creek Sub-catchment Management Plan (Cardno Willing, 2003)

The objectives of the Plan were to:

- Manage stormwater assets in a strategic manner
- Implement a catchment focussed unified approach for stormwater management involving both quality and quantity
- Systematically identify and address stormwater problems
- Ensure ecologically sustainable in social, development principles are achieved
- Maintain and enhance the quality of the waterways and adjoining open space and creek corridors

Typical stormwater issues of concern included the following:

- Flooding of buildings and properties along main watercourses and elsewhere in catchments
- Water quality issues related to the quality of sewer overflows, contaminants in stormwater runoff, siltation and pollution of watercourses and harbours
- Destruction of flora and fauna
- Balancing on-going residential and business development with environmental concerns.

In all cases, recommended measures were based on consideration of economic and ecological factors as well as community aspirations.

2.5.7 Duck River Biodiversity Corridor Masterplan Report for Bankstown LGA (Mather & Associates, 2003)

The implementation of the Duck River Biodiversity Corridor has been identified as one of the key outcomes of Bankstown City Council's (BCC) recently adopted Biodiversity Strategy. The Duck River Biodiversity Corridor is significant in a regional sense, both in terms of its biodiversity values and the recreational opportunities it presents. The purpose of this study is to provide Bankstown City Council with a Masterplan to serve as the basis for planting and habitat creation as well as the enhancement of recreational opportunity in the nominated reserves and neighbourhoods within and adjacent to the Duck River Biodiversity Corridor. The Masterplan provides a management framework and an action list which is to be undertaken in a staged process, to achieve Council's objectives for the Duck River Biodiversity Corridor.

Bankstown City Council's primary objectives are:

- To enhance the biodiversity values of the Duck River Biodiversity Corridor through planting and habitat creation within the reserves.
- To enhance and promote recreational opportunities through the management of the reserves as a discrete corridor.

The Duck River riparian corridor in Parramatta and Auburn LGAs connects with key reserves covered in this plan at the southern, or upstream, end of the catchment. For the Duck River riparian corridor to function effectively as a connectivity corridor, rather than a biodiversity sink, management planning also needs to consider the biological health and capacity of these reserves.

2.5.8 PCC Biodiversity Plan (PCC, 2003)

Parramatta Council's Biodiversity Plan was prepared by council staff in 2003, and comprises two volumes. The first volume provides background information for the plan, an overview of the status of biodiversity in Parramatta LGA, a vision, goals and outcomes, and a set of management actions to achieve these aims. The vision for biodiversity management in Parramatta was stated as "Parramatta is a City that values, protects and conserves its locally occurring native plants, animals and other living things, the environment they live in and the way they interact, so that biodiversity is sustained and enhanced." To realise the Vision, the following key outcomes were identified, and management actions were tailored to meet these:

1. Biodiversity is recognised as a core business of Council.
2. Biodiversity principles are reflected across a range of public and private land uses.
3. Biodiversity principles are applied across Council units.
4. Biodiversity values are optimised while providing for adequate recreational, access, safety and cultural heritage opportunities.
5. Planning instruments are effective in protecting biodiversity.
6. The Parramatta LGA has a system of sustainable, natural corridors as well as ecological communities.
7. Populations of native plant and animal species are sustainable.
8. Council is a recognised leader in biodiversity management.
9. The local community is empowered and involved in biodiversity management and values natural areas and things.
10. Council has in place an effective system to manage, monitor and update biodiversity information.

Volume two of the Biodiversity Plan includes a review of the status of biodiversity in Parramatta LGA, including: ecological communities, native flora and conservation status of rare plants, and native fauna and the conservation status of threatened and other significant species. Considerable community input is summarized in this report, including community values and issues associated with biodiversity management, and the outcomes of several workshops.

This plan is currently being rewritten, with a new draft plan to be completed in the near future.

2.5.9 PCC Open Space Plan (PCC, 2003)

Parramatta Council's Open Space Plan is underpinned by the following vision statement: "From the smallest park to the river foreshore, the City of Parramatta's open space network, will offer its residents, workers and visitors an appealing, accessible and sustainable resource; one that conserves and reflects the landscape's significant natural qualities, offers recreational opportunities for all and builds on the City's rich heritage." Open space establishes a sense of place for the community and is an important contributor to the character of the area.

The principal purpose of the Open Space Plan is to provide a framework to guide the planning, development and management of Parramatta's open space system in the short and long term in line with Council's Strategic Outcomes. This includes ensuring that open space quality is maintained, the availability fits projected population demographics, complies with all the required legislation, and conforms with changing community values and cultural diversity. More importantly it recognises the

need to provide adequate resources to ensure best practice planning and management of open space. The provision of ongoing maintenance is vital to the long term success of any natural area restoration program.

The Open Space Plan discusses the importance of Parramatta's natural heritage and biodiversity and the opportunities for improvement. Issues identified include the lack of awareness in sections of the community of the significance and value of this natural heritage. Public safety and pressure from the urban environment were also highlighted as major issues for natural areas. The Open Space Plan links its recommended management actions with the Parramatta Biodiversity Plan 2003 (currently under review), Parramatta Planting Strategy 2002 and the Parramatta Street Tree Masterplan 2011.

2.5.10 PCC Sport and Recreation Plan (Stratcorp, 2005)

The main purpose of the Plan was to develop a set of guiding principles and strategies that will provide the basis and direction to Council and other stakeholders for the future development of sport and recreation resources within the Parramatta Local Government Area (LGA). Recently, recreation participation has also been linked to the prevention and treatment of other physical and mental illnesses, and as a useful intervention strategy in reducing anti-social behaviour. Further, parks and nature have enormous untapped health potential as they provide an opportunity for people to re-establish and maintain their health in a holistic manner. Most sports reserves have at least one sport being played on them each season, which is maximising the usage and multipurpose nature of the grounds. Sporting facilities for a range of sporting activities are located along the Duck River open space corridor.

Key issues identified for open space management included improved personal security in open space areas is a key issue for residents (e.g. lighting, appropriate planting schedules, location and lighting of car parks). Residents value highly their access to well maintained and well located parks. Emerging importance noted for accommodating the needs of dog owners in relation to the provision of off leash zones that are accessible and strategically located. Sustainable turf management and maintenance practices will become increasingly more important for Council and clubs. Many of these issues have direct impacts for management of the Duck River riparian buffer.

2.5.11 PCC Natural Areas Plan of Management (PCC, 2006)

The Natural Areas Plan of Management complied with changes to the Local Government Act 1993, and established directions for planning, resource management and maintenance of community land, with the community actively involved in decisions affecting management and use. The Plan relates to all community land within the Parramatta City Council LGA categorised as Natural Area (Bushland and Watercourse), with the exception of those that have their own individual Plan of Management. It addresses Natural Areas in their current condition and established clear directions for future management and conservation of this important public resource.

Aspects of community values for Natural Areas include

- Ecological and environmental values, including functional diversity and species richness, capacity to improve water quality, lower air temperatures and improve air quality, especially through removal of carbon dioxide during photosynthesis.

- Educational and scientific values, including opportunities for education and research in areas such as environmental awareness, monitoring processes, bush skills, species lifecycles and ecosystem functions.
- Health values, including increased physical activity and relaxation, leading to improved overall health and wellbeing. Regular participation in these activities allows individuals to improve their overall health and wellbeing through development of mental alertness, stress management, coordination, balance and other functions
- Heritage and cultural values, particularly Aboriginal culture through significant places such as carving trees, shell middens, rock art and campsites. Parramatta LGA was one of the earliest European settlements, and historic structures are often preserved partially intact in natural areas.
- Recreational values, including the health and wellbeing benefits of recreation activities such as walking, fishing, photography, painting, birdwatching and picnicking. Linking Natural Areas greatly increases their recreational value to the community.
- Social values. The outdoors has long been part of the Australian culture, with open space areas highly valued as social venues. These areas are becoming increasingly important to the community, particularly in the city, where increasing urbanisation is leading to the replacement of the traditional 'backyard' with community open space.

All of these core community values for open space and natural areas need to be considered in the preparation of management plans for Duck River catchment.

2.5.12 Wetland Management Plan for the Clyde Wetlands at Shell Clyde Refinery at Rosehill, NSW (UBM Consultants, 2007)

The Wetland Management Plan for Clyde Wetlands applies only to the freshwater wetlands, and does not apply to saltmarsh, mangroves or intertidal/transitional wetland areas. The Plan addressed the rehabilitation and management of the adjoining terrestrial plant communities. The native vegetation within the Refinery comprises three different plant communities:

1. A small Freshwater Wetland;
2. A fringing Low Woodland; and
3. Stands of Swamp Oak Floodplain Forest.

The Wetland, Low Woodland and Swamp Oak Floodplain Forest are located in the north-eastern section of the Refinery.

The plan aims to "clarify the goals and objectives of management" and describes a series of proposed actions and their general sequence, thus providing guidance for bushland restoration and ongoing management strategies. Other works recommended included track construction, fencing, signage, soil remediation and drainage works. The WMP identifies the significant natural areas occurring within the Refinery, and establishes the means of more effectively managing the environmental values of the land. As such, it applies to a very specific part of the catchment which is currently undergoing major changes in management as a result of the decommissioning of the Shell Refinery at Clyde. Shell will retain storage facilities on the site, but will no longer operate the refinery. Implications for the wetland are unclear, and as the plan is now 5 years old, a review is recommended in the near future.

2.5.13 Duck River Remediation Plan for Clyde Marshalling Yards, Auburn, on behalf of Railcorp (PB, 2009)

Douglas Partners Pty Ltd (DP) has been commissioned by the Transport Construction Authority (TCA) to develop this Remediation Action Plan (RAP) for the remediation of contaminated soils at the site of the proposed Auburn Stabling Project (the ASP site). The results of the DP July 2010 contamination assessment have shown that the fill at the site is contaminated with asbestos, medium to heavy fraction petroleum hydrocarbons (TPH C10-C36) and polycyclic aromatic hydrocarbons (PAHs). The TPH C10-C36 and PAHs in the fill were noted to have low leachable concentrations and were found to be associated with the ash, slag, charcoal and cinder that are present sporadically in the fill material. Importantly, the results of the assessment also showed that the contaminated fill had not impacted the groundwater at the site.

In view of the nature of the contaminants and the heterogeneity of the fill, the preferred remedial strategy is the, 'Encapsulation of the Contaminated Soil by Constructing a Properly Designed Physical Barrier System'. The strategy involves the installation of an engineered physical barrier system to limit the exposure of site users and/or off-site receptors to contaminants. The remedial strategy seeks to minimise potential exposure pathways (routes) to the underlying contaminants. Given the anticipated low leachability of the contaminants, the cap does not need to be impermeable. Subject to proper implementation of the RAP it is considered that the site can be rendered suitable for the proposed commercial/industrial land-use.

2.5.14 Parramatta River Estuary Processes Study (AECOM, 2010)

Parramatta City Council, on behalf of the Parramatta River Estuary Committee, commissioned AECOM to deliver the estuary process study. The study is an important stage in the development of an estuary management plan for the river, as guided by State Government processes established for Coastal Management in NSW.

Specific issues investigated, for which management options were presented, included the following:

- Historical land-use changes by way of analysis of aerial photography taken in 1943 and present day: Parramatta and Auburn LGAs contain the greatest areas of contemporary industrial land-use. Historically, Auburn LGA also exhibited large areas of industrial land use, and contains large areas of reclaimed land. Therefore, estuarine areas more likely to be adversely affected by industrial areas and leachate from land reclamation are located in Parramatta and Auburn LGAs (e.g. Parramatta River, Duck River, and Homebush Bay).
- Stormwater management, with a focus on existing stormwater control devices, and catchments where such are required: Duck River subcatchment (4531 ha in total) was identified as being in need of additional gross pollutant management.
- Condition assessment of seawalls and prioritisation of where replacement or repairs of seawalls would provide opportunities for habitat creation: no impacts identified for management as part of this Masterplan.
- Natural shoreline erosion, which included conceptual options for managing erosion of mangroves upstream of Silverwater Bridge due to large vessel impacts: some impacts were identified in lower Duck River.
- Condition assessment of foreshore facilities and prioritisation of where facilities require repairs or replacement: tidal reaches of Duck River are largely unavailable for public access.

- Estuarine vegetation, including seagrass, mangroves, saltmarsh and riparian vegetation communities up to the 40m mean high water mark.

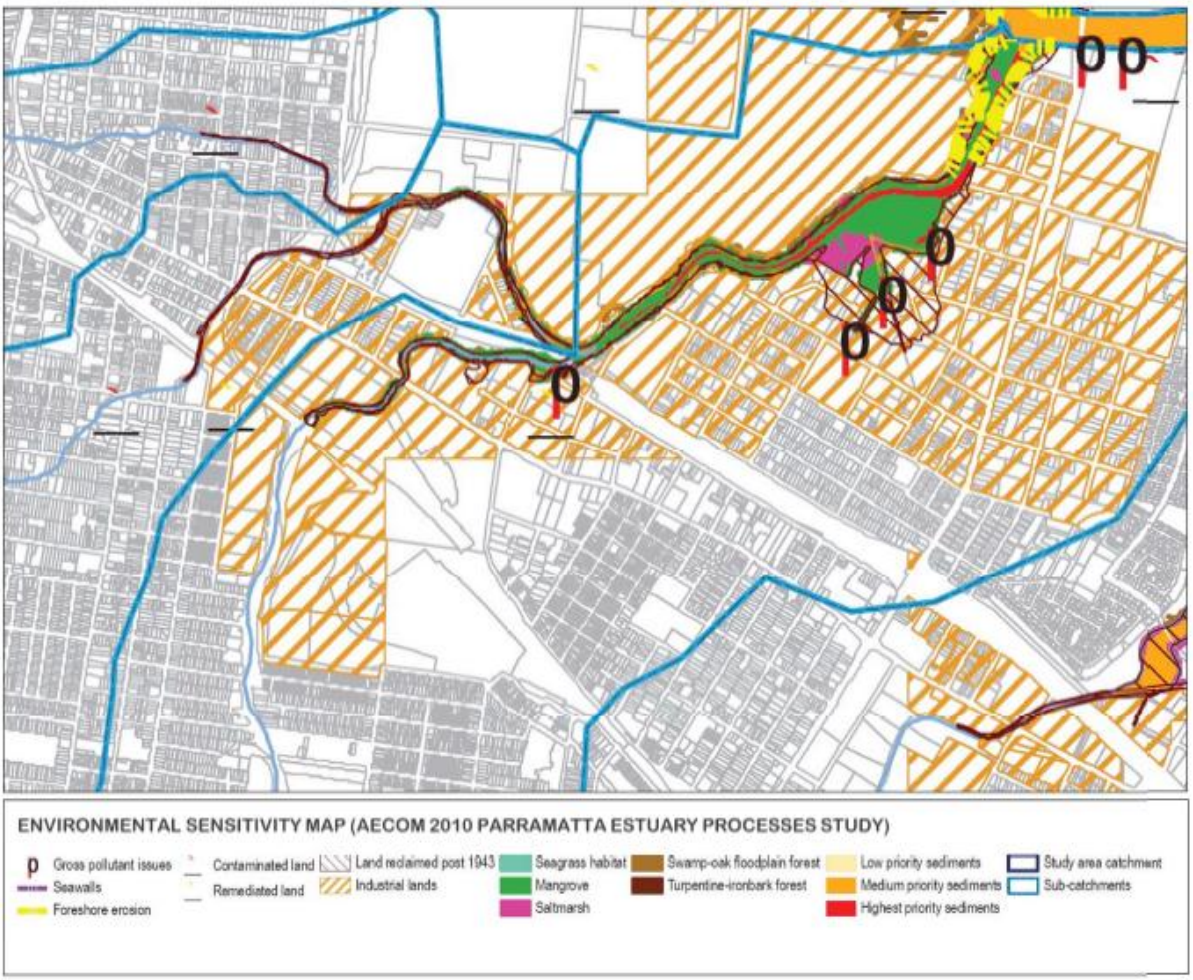


Figure 2. Environmental Sensitivity mapping for Duck River catchment (adapted from Parramatta Estuary Processes Study, AECOM 2010)

The main issues affecting riparian vegetation within the study area are:

- Infestations of introduced tree and shrub species, vines, and encroachment of grass species from adjacent open space areas;
- Access impacts (use of informal walking trails and trampling); and
- Sea level rise, which will also significantly limit the present extent of estuarine riparian vegetation where intertidal vegetation is able to migrate and tidal influences alter soil salinity and inundation frequencies.

An outcome of the study is an environmental sensitivity map of the study area (Figure 2), which identifies values, threats, and areas in which management should be prioritised.

2.5.15 Duck River Floodplain Risk Management Study and Plan (Molino Stewart/WMA, 2011)

The Duck River Floodplain Risk Management Study and Plan applies to the Duck River catchment in Parramatta, Auburn and Bankstown LGAs. This includes Duck Creek, Little Duck Creek and A'Becketts Creek, located in Parramatta LGA. The project included a Flood Study, Floodplain Risk Management Study, Floodplain Risk Management Plan, Plan Implementation, and Review of Plan.

The Floodplain Risk Management Study reviewed flood behaviour and impacts, heritage and environmental issues, emergency management, and community ideas and opinions. Floodplain risk management options were assessed, including response modification measures (local flood plans, predictions and warnings, education and recovery planning), flood modification measures (flood mitigation dams, retardation basins, bypass floodways, levees, channel modification and flood gates), property modification measures (legislative planning, property modification works, flood planning, and hazard categorisation). A number of options were shortlisted based on suitability, and included biodiversity enhancement.

The Floodplain Risk Management Plan detailed management measures based on the assessment of shortlisted options in the Study. For Parramatta Council this included

a) Flood modification, including the use of Woodville Golf Course as a retardation basin, with relevant environmental impact assessments
b) Property modification, including a voluntary buyback scheme, and voluntary house raising scheme, amending open space plans to buy and incorporate high probability flood liable properties into open space areas, and update/amendment of planning instruments to advise local residents accordingly
c) Environmental measures, including maintenance of designated open space areas to improve the passage of flood waters, ongoing management of riparian vegetation, and expansion of riparian corridors through revegetation.

Many of these recommendations are consistent with normal riparian management strategies, and the rest need to be considered in the design of riparian management actions.

3 REVIEW OF STUDY AREA: CATCHMENT CHARACTERISTICS AND CONDITIONS

3.1 ECOLOGY

3.1.1 Geology and soils

3.1.1.1 Soil Landscapes

The Duck River study area lies predominantly on Wianamatta Shales that have been cut in some areas to reveal the underlying Narrabeen Group sandstones. The soil groups in the study area have been described as follows:

Blacktown Soils: This is the predominant soil type within the catchment. These soils occur away from the waterways and join the Birrong Soils at the lower slopes.

Birrong Soils: Typical of floodplains of watercourses such as Duck River. Soils are predominant adjacent to all major water courses in the catchment.

Glenorie Soils: There is little of this soil type in the study area. Small areas of this soil group are present along the lower section of A'Becketts Creek, in the Parramatta LGA.

Disturbed Areas: The landform along the waterways has been altered through progressive infill for land reclamation. These areas of infill are referred to as disturbed soil areas and typically comprise variable, unidentified fill materials. Significant disturbed areas exist adjacent to Duck River, particularly towards the downstream end of the catchment, and around Parramatta River.

Characteristics of each soil landscape are described in Table 1 (DLWC 1:100 000 Soil Landscape Map, 1989).

Table 1. Soil landscape characteristics for soils mapped in the Duck River catchment

SOIL LANDSCAPE	SOIL DEPTH	EROSION HAZARD		URBAN CAPABILITY
		CONCENTRATED FLOWS	NON-CONCENTRATED FLOWS	
Blacktown	<100cm	Moderate to High	Low to Very High (generally Moderate)	High
Birrong	>250cm		Low to Moderate	Not capable without drainage works
Glenorie	<100cm	High	Moderate to Very High	Low to Moderate
Disturbed	40-60cm	Low to High	Low to Extreme	Capable with restrictive conditions

3.1.1.2 Acid Sulphate Soils

Acid Sulphate Soils (ASS) means naturally occurring sediments and soils containing iron sulphides (principally pyrite) or their precursors or oxidation products, whose exposure to oxygen leads to the generation of sulphuric acid, for example by drainage or excavation. ASS potential within the study area is shown in Figure 3.

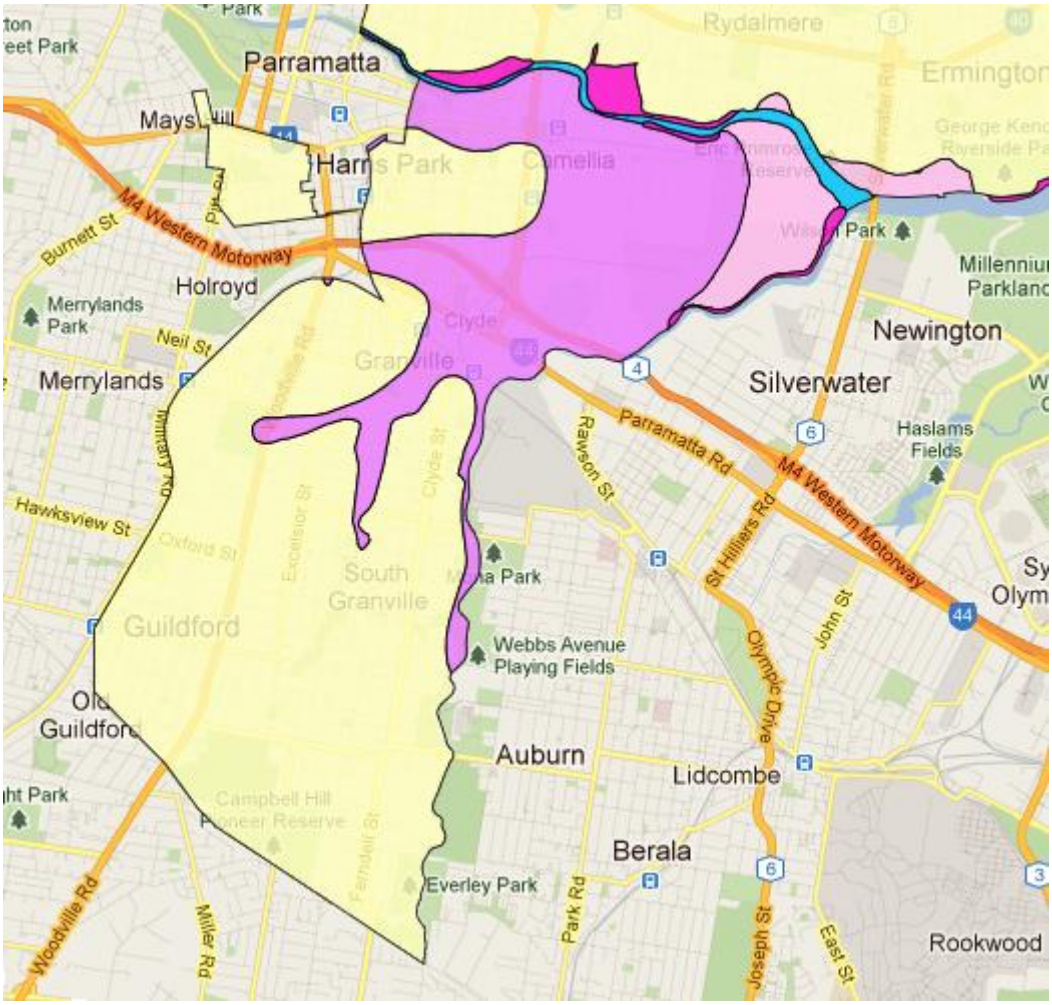


Figure 3. Acid Sulphate Soils probability mapping for Duck River catchment (PCC, 2012)

There is a low probability of ASS 1 to 3m below ground surface adjacent to all waterways, predominantly towards the downstream section of each waterway. There is a high probability of ASS at or near the surface and at depths greater than 3m in the estuarine region of Duck River.

3.1.2 Flora, fauna and vegetation communities

A number of recent surveys have been conducted in the Duck River corridor. These include fauna surveys conducted by Applied Ecology P/L at a number of reserves during 2011/12, and flora lists compiled during bush regeneration works conducted by Bushit P/L during 2010/11. These lists are indicative of catchment condition, rather than exhaustive, and include few areas downstream from Clyde Weir. The section of Duck River below the weir is tidal, and would reasonably be expected to support a quite different suite of animals and plants.

3.1.2.1 Fauna

In recent surveys Applied Ecology P/L staff recorded 58 species of birds in the Duck River catchment riparian corridors and associated reserves (Appendix Two, Table A2), focussing on the area upstream of Clyde Weir. This included 9 species of introduced birds, and 3 threatened species. Distribution across the catchment was not consistent, with more birds recorded along the main Duck River corridor (28 species south of Ray Marshall Reserve, and 43 between Clyde Weir and Ray Marshall Reserve), and at Campbell Hill-Waddangalli Reserves (31 species). Avian diversity was considerably lower in all of the tributaries surveyed.

In addition, 5 species of frog were recorded, 7 lizards and one snake species, 7 bats (including 3 threatened species), 4 introduced mammals, 2 fish, a turtle and one significant invertebrate, the endangered Cumberland Plain Land Snail (Figure 3; Appendix Three, Table A3). Once again, areas of higher diversity were concentrated in the larger bushland reserves, and considerably lower in all of the tributaries surveyed.

3.1.2.2 Threatened Fauna

Six species of threatened fauna have been recorded from the Duck River riparian corridor. These include:

Green and Golden Bell Frog (*Litoria aurea*)

A relatively large, stout frog, ranging in size from approximately 45 mm to approximately 100 mm snout to vent length. Diagnostic features are a gold or creamish white stripe running along the side, extending from the upper eyelids almost to the groin, with a narrow dark brown stripe beneath it, from nostril to eye. It also has blue or bluish-green colour on the inside of the thighs.The colour of the body varies. Usually a vivid pea-green, splotched with an almost metallic brassy brown or gold. The backs of some individuals may be almost entirely green; in others golden-brown markings may dominate.

Inhabits marshes, dams and stream-sides, particularly those containing bullrushes (*Typha* spp.) or spikerushes (*Eleocharis* spp.). Optimum habitat includes water-bodies that are unshaded, free of predatory fish such as Plague Minnow (*Gambusia holbrooki*), have a grassy area nearby and diurnal sheltering sites available. Some sites, particularly in the Greater Sydney region occur in highly disturbed areas. Several records from around Camelia, one from Duck Creek in Granville, and several records from A'Becketts Creek upper reaches in Holroyd LGA.

Main threats for this species include destruction of wetlands; alteration of drainage patterns and stormwater runoff; a fungal pathogen known as Frog Chytrid Fungus; predation by feral animals such as foxes; herbicides and other weed-control measures; road mortality, where populations are already small due to other threats; predation by exotic fish such as Plague Minnow; and loss of suitable breeding habitat through alteration by infilling and destruction of wetlands.

Little Eagle (*Hieraetus morphnoides*)

The Little Eagle is a medium-sized bird of prey that occurs in two colour forms: either pale brown with an obscure underwing pattern, or dark brown on the upperparts and pale underneath, with a rusty head and a distinctive underwing patter of rufous leading edge, pale 'M' marking and black-

barred wingtips. Both forms have a black-streaked head with a slight crest, a pale shoulder band on the upperwings, a rather short and square-tipped barred tail, and feathered legs.

Occupies open eucalypt forest, woodland or open woodland. Sheoak or acacia woodlands and riparian woodlands of interior NSW are also used. One record from Duck River Bushland Reserve in 2007. Main threats for this species include clearing and degradation of foraging and breeding habitat; urban expansion; rural-residential subdivision and associated land uses (e.g. horse and goat grazing); and secondary poisoning from rabbit baiting.

Spotted-tailed Quoll (*Dasyurus maculates*)

The Spotted-tailed Quoll is about the size of a domestic cat, from which it differs most obviously in its shorter legs and pointed face. The average weight of an adult male is about 3500 grams and an adult female about 2000 grams. It has rich-rust to dark-brown fur above, with irregular white spots on the back and tail, and a pale belly. The spotted tail distinguishes it from all other Australian mammals, including other quoll species. However, the spots may be indistinct on juvenile animals.

Mostly nocturnal, although will hunt during the day; spends most of the time on the ground, although also an excellent climber and may raid possum and glider dens and prey on roosting birds. Recorded across a range of habitat types, including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline. Individual animals use hollow-bearing trees, fallen logs, small caves, rock crevices, boulder fields and rocky-cliff faces as den sites.

Main threats for this species include loss, fragmentation and degradation of habitat; accidental poisoning during wild dog and fox control programs; deliberate poisoning, shooting and trapping may also be an issue; competition with introduced predators such as cats and foxes. One record from the vicinity of Mona St in 1993.

Grey-headed Flying Fox (*Pteropus poliocephalus*)

The Grey-headed Flying-fox is the largest Australian bat, with a head and body length of 23 - 29 cm. It has dark grey fur on the body, lighter grey fur on the head and a russet collar encircling the neck. The wing membranes are black and the wingspan can be up to 1 m. It can be distinguished from other flying-foxes by the leg fur, which extends to the ankle.

Occur in subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths and swamps as well as urban gardens and cultivated fruit crops. Roosting camps are generally located within 20 km of a regular food source and are commonly found in gullies, close to water, in vegetation with a dense canopy. Individual camps may have tens of thousands of animals and are used for mating, birth and the rearing of young. A camp is located on Duck River immediately upstream from Clyde Weir.

Main threats for this species include loss of foraging habitat; disturbance of roosting sites; unregulated shooting; and electrocution on powerlines. A number of records from Clyde Weir, Granville to the confluence with Parramatta River.

Eastern Bentwing Bat (*Miniopterus schreibersii oceanensis*)

The Eastern Bent-wing Bat has chocolate to reddish-brown fur on its back and slightly lighter coloured fur on its belly. It has a short snout and a high 'domed' head with short round ears. The wing membranes attach to the ankle, not to the base of the toe. The last bone of the third finger is much longer than the other finger-bones giving the "bent wing" appearance.

Caves are the primary roosting habitat, but also use derelict mines, storm-water tunnels, buildings and other man-made structures. Form discrete populations centred on a maternity cave that is used annually in spring and summer for the birth and rearing of young. Breeding or roosting colonies can number from 100 to 150,000 individuals. Hunt in forested areas, catching moths and other flying insects above the tree tops.

Main threats for this species include damage to or disturbance of roosting caves, particularly during winter or breeding; loss of foraging habitat; application of pesticides in or adjacent to foraging areas; and predation by feral cats and foxes. One record from Duck River Bushland Reserve, and one from nearby at Campbell Hill Pioneer Reserve.

Cumberland Plain Land Snail (*Meridolum corneovirens*)

Superficially similar to the familiar exotic Garden Snail. It differs most obviously in its 25 - 30 mm diameter shell. While this shell may be almost any shade of brown, it is always uniform in colour, while that of Helix consists of dark patches on a pale background. The Cumberland Land Snail also has a more flattened shell that is very thin and fragile, compared with the thick shell of the Garden Snail.

Figure 4. Cumberland Plain Land Snails at Duck River Bushland Reserve, a threatened species

Primarily inhabits Cumberland Plain Woodland (an endangered ecological community). This community is a grassy, open woodland with occasional dense patches of shrubs. Lives under litter of bark, leaves and logs, or shelters in loose soil around grass clumps. Occasionally shelters under rubbish. Can dig several centimetres into soil to escape drought. Is a fungus specialist. Unlike the Garden Snail, does not eat green plants.

Main threats for this species include clearing and degradation of Cumberland Plain Woodland remnants. There is generally a poor understanding of other threats to this species. One record from Duck River Bushland Reserve.

3.1.2.3 Flora

As part of their works report, Bushit P/L compiled a list of all native species recorded on work sites along Duck River between November, 2010 and October, 2011, providing an up to date snapshot of floristic diversity in the riparian corridor. Bushland restoration sites covered by this report comprised:

- Site 1 – Parramatta Road (both sides)
- Site 2 – Duck River Reserve (Clyde Station to Mona Street)
- Site 3 – Horlyck Reserve (Mona St to Mons St)
- Site 4 – Duck River Reserve (Mons St to Chiswick St)
- Site 5 – Clyde St Reserve (Bennett St)
- Site 6 – Ray Marshall Reserve (Chiswick St to Wellington Rd)
- Site 7 – Everley Park and Norford Park

They recorded 259 native plant species, including one threatened species (Appendix 3). Ironically this list doesn't include the Duck River Bushland Reserve, where the most intact bushland is conserved.

Native flora species was recorded in a single survey for Duck River Bushland Reserve during recent flora and fauna surveys conducted by Applied Ecology P/L. This survey recorded 100 species of native flora in the reserve (Appendix 3), a number of which were not reported elsewhere by Bushit in 2011.

Key outcomes for this project were to ground-truth the extent of vegetation community mapping compiled by SMCMA, and species were ranked against the indicative species lists provided for each vegetation community in the reserve. Based on this, minor adjustments were made to the distribution boundaries for Cumberland Ironbark Forest (CIF) and Cumberland River Flat Forest (CRFF). Species present and distribution among vegetation communities is shown in Table 2. Species were recorded as diagnostic, listed or additional when present. Diagnostic species are those that are important for defining the community, while listed species are often encountered but not considered to separate this community from others. Additional species are those that were not reported as being commonly found for that community, and frequently include species from adjoining communities in transitional areas.

Table 2. Summary of flora species recorded in Duck River Bushland Reserve and their relationship with mapped vegetation communities (for a full list of species see Appendix Four, Table A4).

SPECIES NAME	CIF	CRFF
Species listed for community	**69**	**36**
Species diagnostic for community	**28**	**12**
Additional species	**16**	**21**
Total species recorded in community	**85**	**57**
Total species recorded in reserve	**100**	

3.1.2.4 Threatened Flora

Three species of threatened flora have been recorded along the Duck River riparian corridor. These include:

Acacia pubescens

A spreading shrub, 1 - 5 m high with brilliant yellow flowers, bipinnate leaves (divided twice pinnately) and conspicuously hairy branchlets. Occurs on alluviums, shales and at the intergrade between shales and sandstones. The soils are characteristically gravely soils, often with ironstone. Occurs in open woodland and forest, in a variety of plant communities, including Cooks River/ Castlereagh Ironbark Forest, Shale/ Gravel Transition Forest and Cumberland Plain Woodland. Main threats for this species include habitat loss; habitat degradation (through weed invasion, mechanical damage, rubbish dumping, illegal track creation, and inappropriate fire regimes); disease; and hybridisation. Recorded from a number of locations in Duck River Bushland Reserve.

Tetratheca glandulosa

Small, spreading shrub which grows 20 - 50cm in height. Stems often become entwined among other small shrubs, sedges and grasses. Leaves are opposite 5 - 10 mm long and 1 mm wide with recurved (rolled under) margins. Leaf margins have small stiff hairs that give them a “toothed” appearance. The flower stalk and sepals (leaf-like structure at base of flower) are covered with dark-red gland-tipped hairs, which distinguishes *T. glandulosa* from other *Tetratheca* species. Associated with shale-sandstone transition habitat where shale-cappings occur over sandstone Topographically, the plant occupies ridgetops, upper-slopes and to a lesser extent mid-slope sandstone benches. Vegetation structure varies from heaths and scrub to woodlands/open woodlands, and open forest. Vegetation communities correspond broadly to Benson & Howell’s Sydney Sandstone Ridgetop Woodland. Common woodland tree species include: C*orymbia gummifera, C. eximia, Eucalyptus haemastoma, E. punctata, E. racemosa*, and/or *E. sparsifolia*, with an understorey dominated by species from the families Proteaceae, Fabaceae, and Epacridaceae. Main threats for this species are habitat loss through vegetation clearing and habitat degradation; fire control activities, particularly frequent prescribed burning and mechanical fuel reduction and the construction/maintenance of fire access

tracks; and habitat fragmentation of small, isolated populations. A single record from the vicinity of Horlyck Park in 1887.

Wilsonia backhousei

Narrow-leafed Wilsonia is a perennial, sprawling, matted shrub less than 15 cm tall. The narrow, pointed, dark green, stalkless leaves are succulent and less than 20 mm long. The single white flowers are also stalkless. This is a species of the margins of salt marshes and lakes. Main threats to this species are trampling, weed competition, rubbish dumping, poor water quality in runoff, and habitat loss through development. Recorded from tidal mudflats around Camelia industrial area.

3.1.2.5 Vegetation communities

Vegetation communities along Duck River have been mapped recently by SMCMA as part of the draft Native Vegetation of the Sydney Metropolitan Catchment Management Authority Area (2010). Most of the communities identified have been listed as Endangered Ecological Communities (Figure 5 and 6), and are described in the following section. Additional vegetation has been described as Urban Exotic/Natives and Weeds & Exotics. Both of these communities are dominated by introduced species. The first is a highly degraded form of native vegetation that retains limited representation of the original species, often with only canopy species remaining, but may include areas where revegetation has commenced but is still challenged by weed invasion. In the second community local native species may be completely absent, and this community is much harder to rehabilitate.

Figure 5. Coastal Freshwater Reedlands EEC with a backdrop of Cumberland Riverflat Forest EEC in reach DUCK RIVER 5B

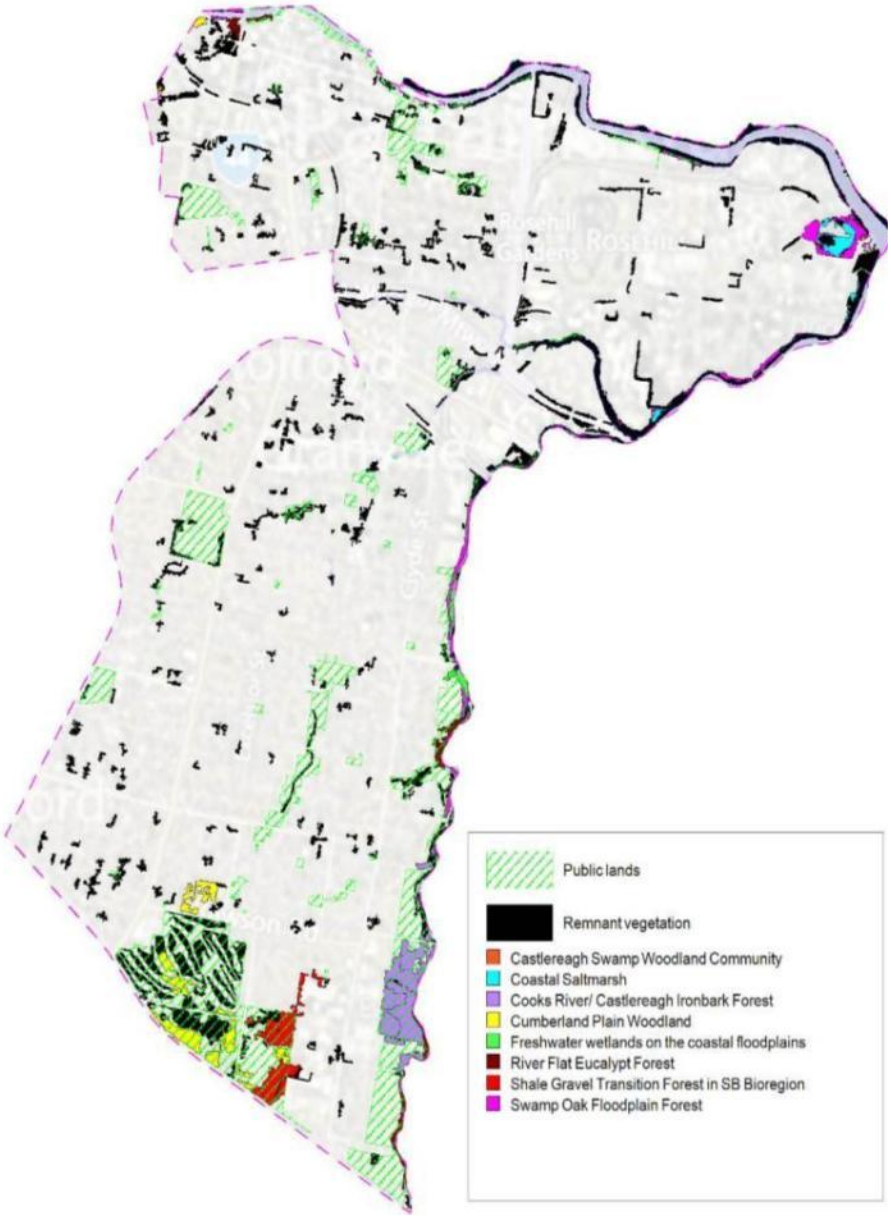


Figure 6. Vegetation communities along the Duck River catchment riparian corridor (SMCMA, 2010)

3.1.2.6 Endangered Ecological Communities

Five Endangered Ecological Communities (EECs) have been recorded from the Duck River catchment. These include:

Coastal Saltmarsh EEC

Coastal Saltmarsh occurs in the intertidal zone on the shores of estuaries and lagoons that are permanently or intermittently open to the sea. It is frequently found as a zone on the landward side of mangrove stands. Characteristic plants include *Baumea juncea, Juncus krausii, Sarcocornia quinqueflora, Sporobolus virginicus, Triglochin striata, Isolepis nodosa, Samolus repens, Selliera radicans, Suaeda australis* and *Zoysia macrantha*. Occasionally mangroves are scattered through the saltmarsh. Tall reeds may also occur, as well as salt pans.

This community occurs in the intertidal zone along the NSW coast. Species composition varies with elevation and latitude, with Saltmarsh in southern NSW being generally more species-rich than further north. Along Duck River these species include threatened species *Wilsonia backhousei* (vulnerable). Main threats for this community include:

- In-filling for development, including roads, residential, industrial, recreational, waste disposal and agricultural purposes.
- Modification of tidal flows as a consequence of artificial structures being erected.
- Alteration of salinity and increasing nutrient levels resulting from the discharge of stormwater into saltmarshes.
- Weed invasion, particularly by Juncus acutus.
- Physical damage from human disturbance, domestic and feral animals.
- Dumping of rubbish and pollution from oil or chemical spills from shipping or road accidents; catchment runoff of nutrients and agricultural chemicals.
- Invasion by mangroves.
- Inappropriate fire regimes.

Cumberland Swamp Oak Riparian Forest (Swamp Oak Floodplain Forest EEC)

This community is found on the coastal floodplains of NSW. It has a dense to sparse tree layer in which *Casuarina glauca* (swamp oak) is the dominant species. Other trees including Acmena smithii (lilly pilly), Glochidion spp. (cheese trees) and Melaleuca spp. (paperbarks) may be present as subordinate species, and are found most frequently in stands of the community northwards from Gosford. The understorey is characterised by frequent occurrences of vines, *Parsonsia straminea, Geitonoplesium cymosum* and *Stephania japonica* var. *discolor*, a sparse cover of shrubs, and a continuous groundcover of forbs, sedges, grasses and leaf litter.

The composition of the ground stratum varies depending on levels of salinity in the groundwater. Under less saline conditions prominent ground layer plants include forbs such *Centella asiatica, Commelina cyanea, Persicaria decipiens* and *Viola banksii*; graminoids such as *Carex appressa*, *Gahnia clarkei, Lomandra longifolia, Oplismenus imbecillis*; and the fern *Hypolepis muelleri*. On the fringes of coastal estuaries, where soils are more saline, the ground layer may include *Baumea juncea, Juncus kraussii, Phragmites australis, Selliera radicans* and other saltmarsh species.

Main threats for this community include:

- Clearing for urban and rural development, and the subsequent impacts from fragmentation
- Flood mitigation and drainage works
- Grazing and trampling by stock and feral animals (eg. pigs)
- Activation of acid sulfate soils
- Landfilling and earthworks associated with urban and industrial development
- Pollution from urban and agricultural runoff
- Rubbish dumping
- Climate change
- Localised areas, particularly those within urbanised regions, may also be exposed to frequent burning which reduces the diversity of woody plant species.

Cumberland Riverflat Forest (Riverflat Eucalypt Forest EEC)

As the name suggests, this EEC is found on the river flats of the coastal floodplains. It has a tall open tree layer of eucalypts, which may exceed 40 m in height, but can be considerably shorter in regrowth stands or under conditions of lower site quality. While the composition of the tree stratum varies considerably, the most widespread and abundant dominant trees include *Eucalyptus tereticornis* (forest red gum), *E. amplifolia* (cabbage gum), *Angophora floribunda* (rough-barked apple) and *A. subvelutina* (broad-leaved apple).

A layer of small trees may be present, including *Melaleuca decora, M. styphelioides* (prickly-leaved teatree), *Backhousia myrtifolia* (grey myrtle), *Melia azaderach* (white cedar), *Casuarina cunninghamiana* (river oak) and *C. glauca* (swamp oak). Scattered shrubs include *Bursaria spinosa* , *Solanum prinophyllum, Rubus parvifolius, Breynia oblongifolia, Ozothamnus diosmifolius, Hymenanthera dentata, Acacia floribunda* and *Phyllanthus gunnii*.

The groundcover is composed of abundant forbs, scramblers and grasses including *Microlaena stipoides, Dichondra repens, Glycine clandestina, Oplismenus aemulus, Desmodium gunnii, Pratia purpurascens, Entolasia marginata, Oxalis perennans* and *Veronica plebeia* . The composition and structure of the understorey is influenced by grazing and fire history, changes to hydrology and soil salinity and other disturbance, and may have exotic shrubs, grasses, vines and forbs.

Main threats for this community include:

- Further clearing for urban and rural development, and the subsequent impacts from fragmentation
- Flood mitigation and drainage works
- Landfilling and earthworks associated with urban and industrial development
- Grazing and trampling by stock and feral animals (particularly pigs)
- Changes in water quality, particularly increased nutrients and sedimentation
- Weed invasion
- Climate change
- Activation of acid sulfate soils
- Removal of dead wood
- Rubbish dumping
- Frequent burning which reduces the diversity of woody plant species

Coastal Freshwater Reedland (Freshwater Wetlands on the Coastal Floodplain EEC)

Associated with coastal areas subject to periodic flooding and in which standing fresh water persists for at least part of the year in most years. Typically occurs on silts, muds or humic loams in low-lying parts of floodplains, alluvial flats, depressions, drainage lines, backswamps, lagoons and lakes but may also occur in backbarrier landforms where floodplains adjoin coastal sandplains. Generally occur below 20 m elevation on level areas. They are dominated by herbaceous plants and have very few woody species. The structure and composition of the community varies both spatially and temporally depending on the water regime: Those that lack standing water most of the time are usually dominated by dense grassland or sedgeland vegetation, often forming a turf less than 0.5 metre tall and dominated by amphibious plants including *Paspalum distichum* (water couch), *Leersia*

hexandra (swamp rice-grass), *Pseudoraphis spinescens* (mud grass) and *Carex appressa* (tussock sedge). Where they are subject to regular inundation and drying the vegetation may include large emergent sedges over 1 metre tall, such as *Baumea articulata, Eleocharis equisetina* and *Lepironia articulata*, as well as emergent or floating herbs such as *Hydrocharis dubia* (frogbit), *Philydrum lanuginosum* (frogsmouth), *Ludwigia peploides* subsp. *montevidensis* (water primrose), *Marsilea mutica* (nardoo) and *Myriophyllum* spp. (milfoils). As standing water becomes deeper or more permanent, amphibious and emergent plants become less abundant, while floating and submerged aquatic herbs become more abundant.

Main threats for this community include:

- Land clearing, continuing fragmentation and degradation
- Flood mitigation and drainage works
- Filling associated with urban and industrial development
- Pollution and eutrophication from urban and agricultural runoff
- Weed invasion
- Overgrazing, trampling by livestock
- Soil disturbance by pigs
- Activation of acid sulfate soils
- Dumping of landfill, rubbish and garden refuse
- Native fauna is threatened by predation, particularly by mosquito fish and cane toads
- Anthropogenic climate change

Cooks River/Castlereagh Ironbark Forest EEC

Ranges from open forest to low woodland, with a canopy dominated by Broad-leaved Ironbark *Eucalyptus fibrosa* and Paperbark *Melaleuca decora*. The canopy may also include other eucalypts such as Woolybutt *E. longifolia*. The dense shrubby understorey consists of *Melaleuca nodosa* and Peach Heath *Lissanthe strigosa*, with a range of 'pea' flower shrubs, such as *Dillwynia tenuifolia*, *Pultenaea villosa* and *Daviesia ulicifolia* (can be locally abundant). The sparse ground layer contains a range of grasses and herbs.

Has a very restricted natural distribution and mainly occurs on clay soils derived from the deposits of ancient river systems (alluvium), or on shale soils of the Wianamatta Shales. Can intergrade into Shale-Gravel Transition Forest (where the alluvium is shallow), Castlereagh Swamp Woodland (in moist depressions) and Castlereagh Scribbly Gum Woodland (on more sandy soils). Most species in the community are able to regenerate from lignotubers and buds beneath the bark as well as seeds stored in the soil.

The main threats for the community include:

- Further clearing for urban/rural residential development or clay/shale extraction, and the subsequent impacts from fragmentation.
- Urban run-off, which leads to increased nutrients and sedimentation.
- Weed invasion.
- Inappropriate fire regimes, which have altered the appropriate floristic and structural diversity.

3.2 CATCHMENT RUNOFF AND WATER QUALITY

3.2.1 Hydrology

The Duck River catchment receives approximately 950mm of rainfall per year (1950 to present) and evaporation of approximately 1490mm/year (SILO, 2010). Rainfall can vary significantly from year to year, but generally ranges between 600 and 1300mm/yr (Figure 7).

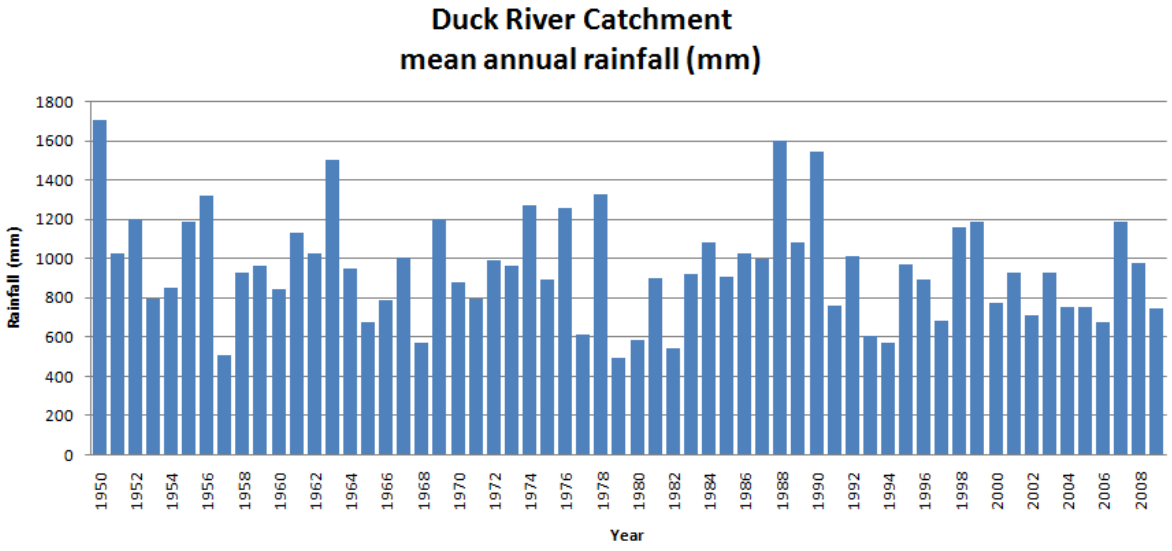


Figure 7. Duck River Catchment Annual Rainfall (SILO 2010)

3.2.2 Catchment Runoff

Catchment runoff does not appear to be systematically monitored on the Duck River. However, a surface water monitoring station at Mackay Road, South Granville (ID 213209) is reported in the Australian Natural Resources Atlas (ANRA 2009) indicating that at some time, water flows may have been recorded at this site. This site is located approximately mid way between the upper and lower bounds of this study. In the absence of stream flow records, a recent catchment modeling study has been reviewed to provide insight to the Duck River hydrology.

The Duck River catchment hydrology has recently been modeled (SMCMA Draft in progress) and draft hydrology results for the Duck River before the confluence with Duck Creek have been made available for this review. This modeling covers only a relatively short period between 2003 and 2008 and cannot be interpreted as being indicative of the entire range of conditions in the Duck River. Nevertheless, this modeling provides insight to the responsiveness of the catchment to rainfall and volume of runoff generated from rainfall in this highly urbanised catchment. The draft modeled daily flow hydrograph and associated rainfall for the Duck River is presented in Figure 8. The model results indicate a runoff coefficient of approximately 30%, which, when applied to average catchment rainfall equates to approximately 285mm of runoff per year.

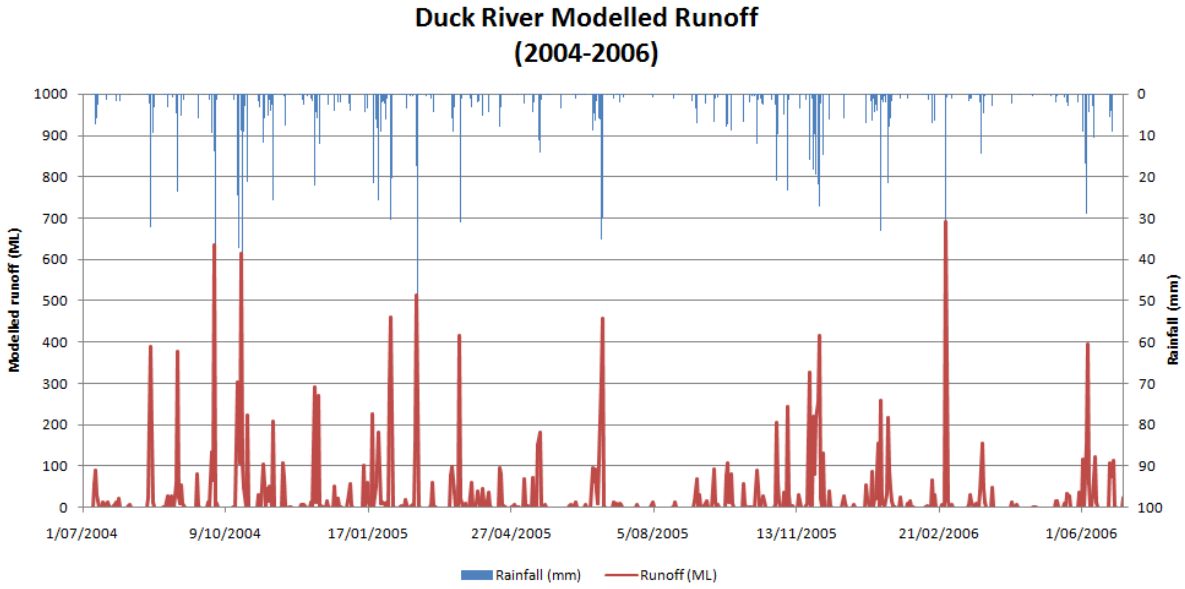


Figure 8. Daily Rainfall and Modeled Flows in the Duck River, 2004-2006. (Data provided by SMCMA 2012)

The runoff response to rainfall in the Duck River Catchment is generally swift with sharp rises in flows typical of urbanised catchments with significant portions of directly connected impervious areas. Figure 9 shows a typical runoff hydrograph (modeled data, 30 minute time step) showing the sharp increase in flows and relatively short hydrograph recession with little or no baseflow. The modeled flow duration curve (Figure 10) shows that for approximately 50% of the time, flows in the Duck River are less than 0.02ML/d.

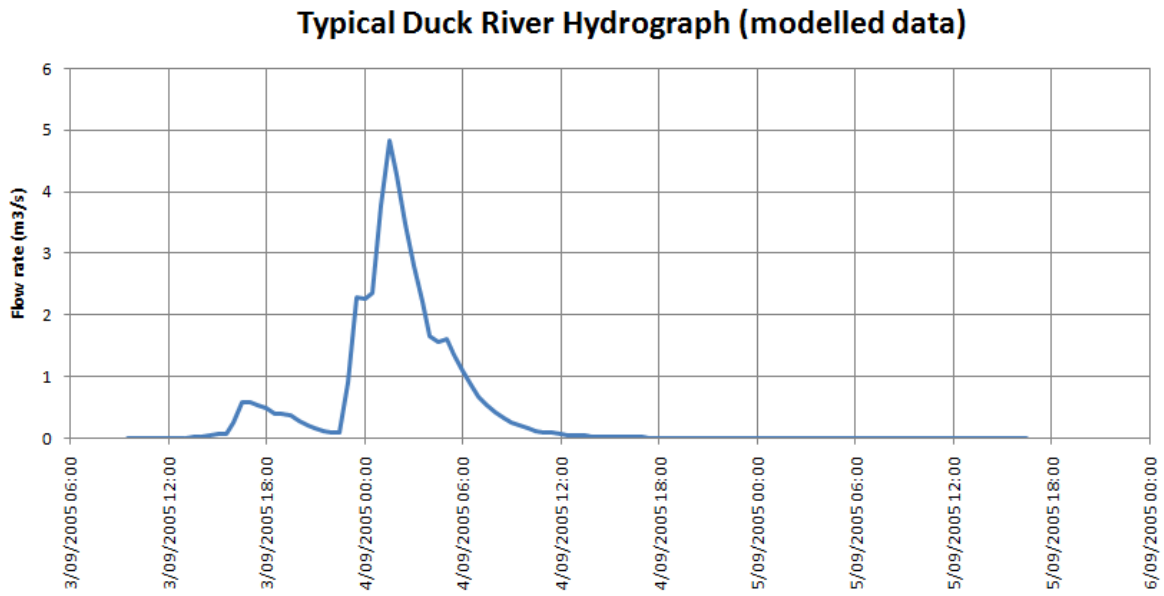


Figure 9. Typical Modeled Hydrograph for the Duck River, (Data provided by SMCMA 2012)

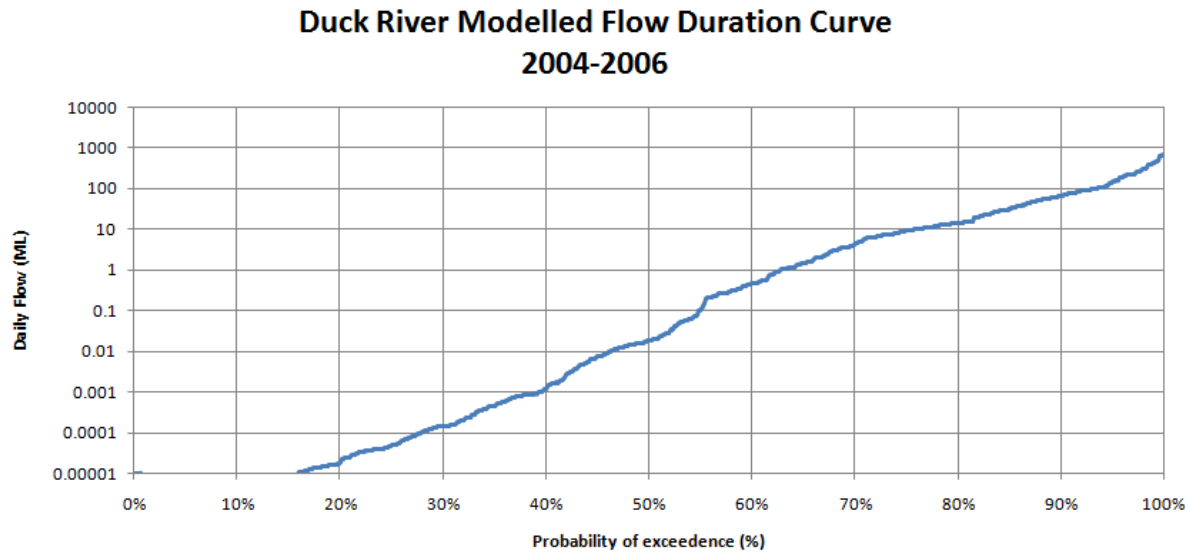


Figure 10. Flow Duration Curve in the Duck River, 2004-2006. (data provided by SMCMA 2012)

3.2.3 Water quality

Water Quality on one site in the Duck River has been systematically sampled and analysed for a wide range of water quality constituents between 1995 and 2007 and the results have been presented in Laxton et al (2008). The Duck River site is located at Parramatta Road, just outside the study area and is tidally influenced in dry weather. A nearby site on Duck Creek which is not tidally influenced has also been included in this review as this site is probably more indicative of freshwater conditions in the Duck River.

Figure 11 summarises nutrient water quality at Duck River related monitoring sites with red figures indicating non-compliance against water quality guidelines (protection of aquatic ecosystems). 50th percentile values are exceeded for all nutrient species during 2007 and Laxton et al (2008) reports that this is the case for any of the previous years sampled. Furthermore, Laxton et al (2008) reports that in the upper Duck Creek, nutrient concentrations increased substantially in 2005/2006 due to a suspected sewage leak.

Freshwater - Upper Duck Creek (2007)

Nutrient	50 percentile	90 percentile
Ammonia	0.109 mg-N/L	0.178 mg-N/L
Oxidised nitrogen	0.471 mg-N/L	0.718 mg-N/L
Total nitrogen	1.685 mg-N/L	3.246 mg-N/L
Orthophosphate	0.0436 mg-P/L	0.1798 mg-P/L
Total phosphorus	0.1355 mg-P/L	0.3389 mg-P/L

Saltwater - Parramatta River and Duck River (2007) Surface water

Nutrient	50 percentile	90 percentile
Ammonia	0.110 mg-N/L	0.330 mg-N/L
Oxidised nitrogen	0.179 mg-N/L	0.378 mg-N/L
Total nitrogen	0.987 mg-N/L	1.771 mg-N/L
Orthophosphate	0.0446 mg-P/L	0.0926 mg-P/L
Total phosphorus	0.1612 mg-P/L	0.3378 mg-P/L

Figure 11. Water Quality in Duck Creek -2007. (Laxton et al 2008)

High nutrient concentrations in the Duck River correspond with high chlorophyll-a concentrations indicating an over-productive system that has resulted in fish kills in the estuarine section of the Duck River in the past (Laxton et al 2008).

The water quality monitoring program and data reported by Laxton et al (2008) is generally representative if baseflow conditions, rather than event based conditions, therefore estimating catchment pollutant loads in the Duck River catchment is not possible without the use of a model. The SMCMA Upper Parramatta River Source Catchments Model (SMCMA 2012) has been used to estimate pollutant loading rates in the Duck River catchment.

In Spring 2009 and Autumn 2010, biological surveys were undertaken at 20 representative sites in the Parramatta LGA, including two sites on Duck River (Cardno Ecology Lab, 2010). The primary objective of these surveys was to determine the biological health of each waterway as indicated by water quality, the condition of aquatic habitats and their associated fauna and flora. The secondary objective was to determine whether the biological health of each waterway was related to the level of effective imperviousness (the proportion of the catchment that consists of impervious surfaces connected directly to streams by stormwater pipes).

Of the two sites, one (DR2BG2) was located just upstream from the stepping stones weir, and the other (DRXX01) near Seventh St, upstream of Clyde Weir. DRXX01 was found to be very depauperate for macroinvertebrates in edge habitats. DR2BG2 had a very high percentage of exotic macrophytes (>50%). Duck River had the highest percentage effective imperviousness of the four Parramatta catchments investigated. The diversity of diatoms and fish tended to increase as % effective imperviousness increased.

The study found that there was no obvious relationship between the condition of the aquatic habitat and that of the biological assemblages, nor was there much link between the different biological components. The lack of consistency reflects the differential responses of the biological indicators to the environmental disturbances associated with urbanisation (Cardno Ecology Lab, 2010).

3.3 STREAM AND CHANNEL MORPHOLOGY,

3.3.1 Changes in the Catchment Since European Settlement

The Duck River catchment and river have undergone significant changes since European settlement including:

- Extensive urbanisation and industrialisation resulting in catchment hardening;
- Land clearing;
- Channelisation and lining of sections of the Duck River and side creeks resulting in hydraulically efficient drainage system;
- Construction of barrages and weirs along the Duck River including the Clyde Weir and Mackay Road causeway; and
- Introduction of additional pollutant sources such as agriculture, and now urbanisation and sewage infrastructure.

The landscape and river prior to European settlement has been captured in maps, journals and paintings and a selection of these historic sources relating to the estuarine environment have been

collated and reviewed by McLoughlin (2000). These sources and descriptions are reproduced in Figure 12.

Table 1. Description of the Foreshore Vegetation of the Parramatta River, 1788–1933.

	Observation	Location	Year	Observer and Source
1	*…about 4 mile higher than where the ships lay, the country was open and improved the farther we went up & in most places not any underwood, grass very long.*	Upper harbour	1788	Lt. William Bradley, Bradley 1969, p. 75
2	*…along the bank the grass was tolerably rich and succulent, and in height nearly up to the middle, interspersed with a plant much resembling the indigo.*	Above Duck River	1788	Surgeon John White, White 1962, p. 127
3	*The banks of it were now pleasant, the trees immensely large, and at a considerable distance from each other; and the land around us flat and rather low, but well covered in the kind of grass just mentioned.*	Above Clay Cliff Creek	1788	Surgeon John White, White 1962, p. 128
4	*About two miles below this settlement, the harbour becomes quite narrow, being not more than ten or twelve yards across, and the banks are about six feet high: here the country has the appearance of a park. In rowing up this branch, we saw a flock of about thirty kangaroos or paderong, but they were only visible during their leaps, as the long grass hid them from our view...*	3–4 km down-stream from Parramatta	1790	Lt. Phillip Gidley King, King 1968, p. 402

Figure 12. Collation of landscape description of the Upper Parramatta River, extracted from McLoughlin (2000)

Aerial photographs provide a more objective means of gauging catchment change and a selection of photographs from 2008 and 1943 showing the same river stretches are shown in Figures 13-16. The photographs show that by 1943, much of the Duck River catchment either had already undergone urbanisation or was in the process of doing so. Large sections of the upper catchment remained rural with some stands of trees still present.

Figure 13. 2008 and 1943 Aerial Photography:. Source: LPI NSW, Spatial Information Exchange

Figure 14. 2008 and 1943 Aerial Photography:. Source: LPI NSW, Spatial Information Exchange

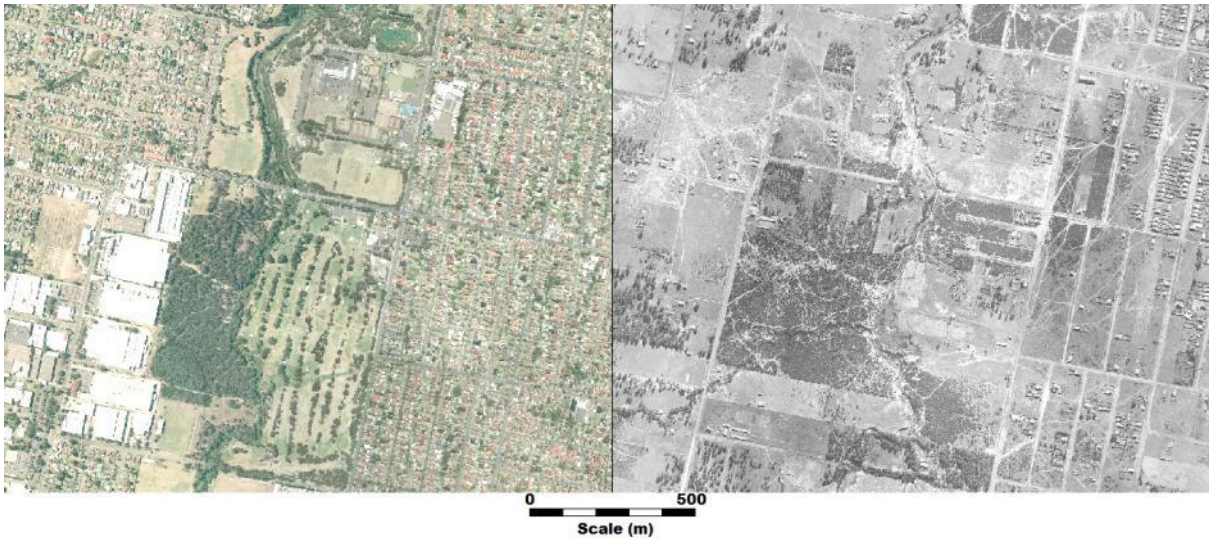


Figure 15. 2008 and 1943 Aerial Photography:. Source: LPI NSW, Spatial Information Exchange

Figure 16. 2008 and 1943 Aerial Photography:. Source: LPI NSW, Spatial Information Exchange

3.3.2 Stream and Channel Morphology

The changes in the catchment since European Settlement are likely to have resulted in:

- Larger runoff volumes, higher peak flow rates and higher frequency of surface runoff;
- Decreased low flow volumes;
- Increased channel erosion and incision and sedimentation in dead zones/pools;
- Higher nutrient loads and more sunlight; and
- Lower water tables delivering subsurface flows and baseflows to the stream.

These impacts are typical of urban developments in Eastern Australia. These changes typically would have begun following land settlement and are not necessarily very recent changes. Closer aerial photograph inspection of selected Duck River sections indicate extensive riverbank erosion in 1943 that has since undergone partial revegetation (Figure 17a and 17b). The aerial photographs of 1943 show a number of similar areas of apparent riverbank erosion indicating that substantial changes to catchment hydrology and bank stability had occurred prior to this time.

Figure 17(a) Upper Duck River Wellington Road 1943; (b) 2008:. Source: LPI NSW, Spatial Information Exchange

Pre and post urbanisation conceptual models of catchment responses to rainfall and channel morphology are provided in Figures 18 and 19 (extracted from Walsh et al 2004). Pre and post development of the highly urbanised Duck River catchment are likely to exhibit many of the features shown in these conceptual models.

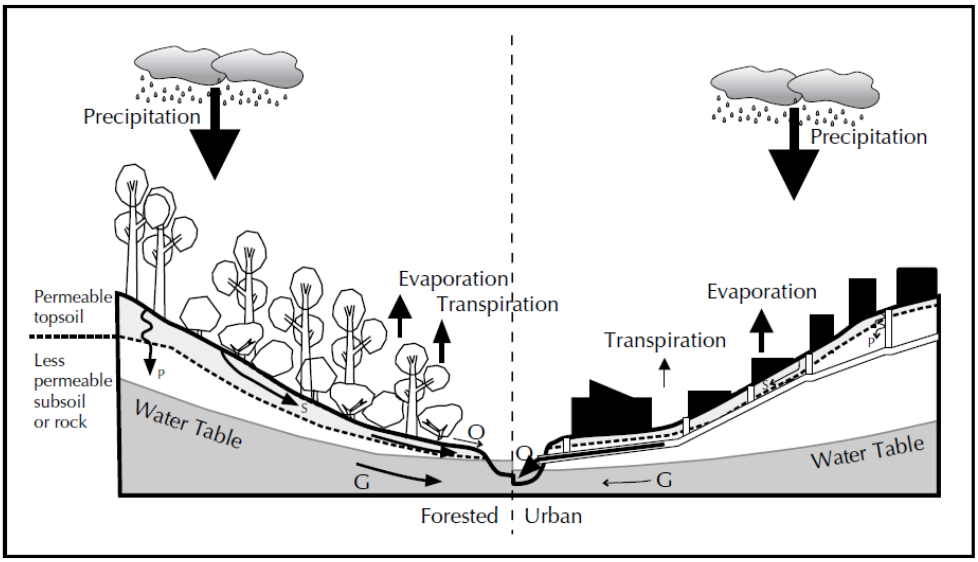


Figure 2. The water cycle in a forested catchment and in an urbanized catchment with a conventional stormwater drainage system (not considering imports of water supply or export of wastewater). The size of arrows indicates qualitative differences in the relative size of annual water volumes through each pathway in a typical south-eastern Australian coastal catchment. Water that falls on the catchment and is not evaporated or transpired may reach the stream by three possible paths: overland flow (O: almost all of which is transmitted to the stream by stormwater pipes in the urban catchment), subsurface flow through permeable topsoil (S), or percolation (P) into groundwater flow (G). (Partly adapted from Dunne & Leopold, 1978.)

Figure 18. Water cycle changes for pre and post catchment urbanisation

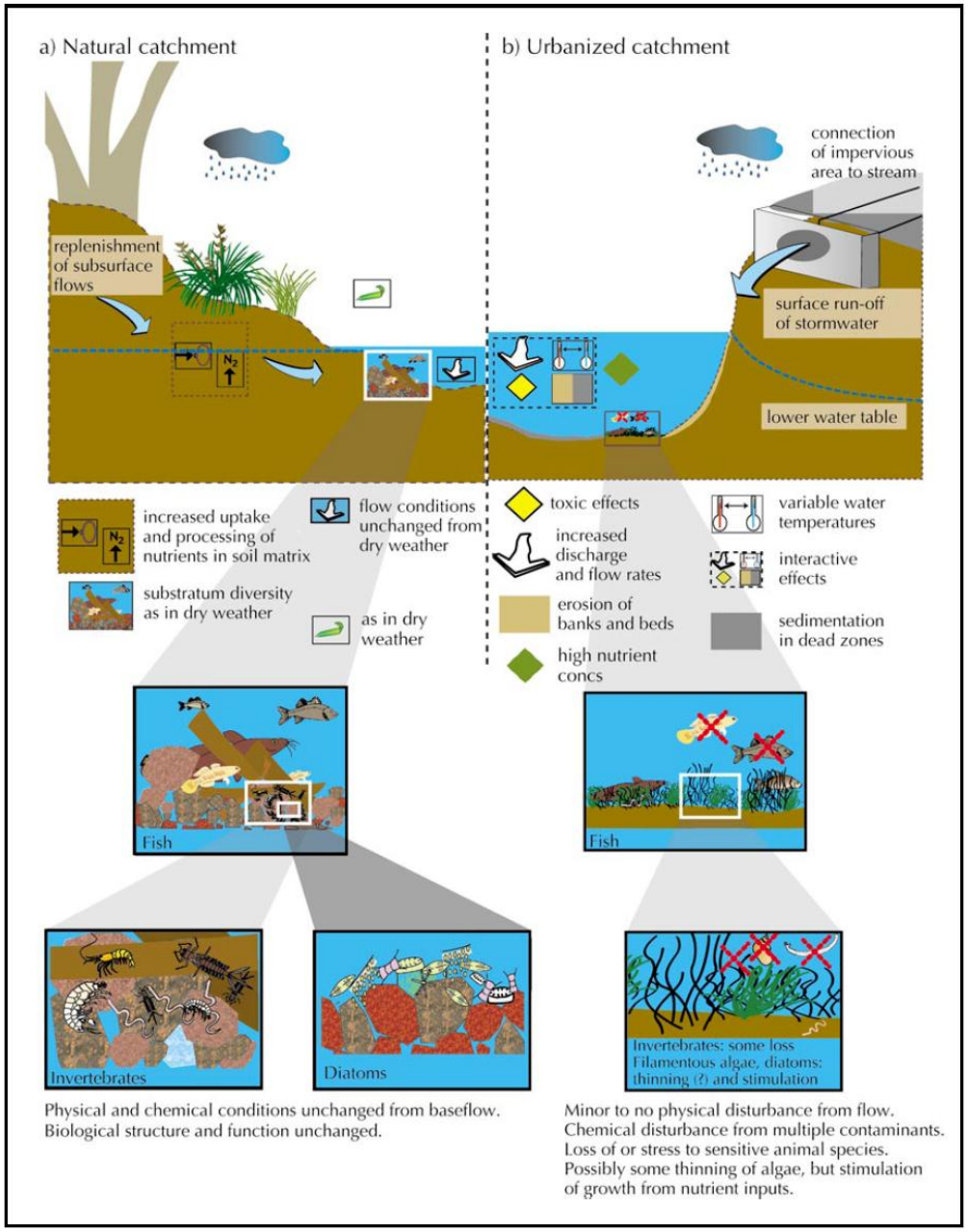


Figure 19. Conceptual processes in natural and urbanised streams following moderate rainfall events (Walsh et al 2004).

3.3.3 Sydney Water's Concrete Channel Assets

Both the Duck Creek, including Little Duck Creek, and A'Becketts Creek concrete lined channel systems (Figure 20 and 21) were initially constructed by the Department of Public Works in the 1930s and then transferred to Sydney Water in 1948 (Figure 22). Sydney Water's role today is to maintain the assets as they were constructed. This means that they repair the assets as required, clean the system of any obstructions, including the build-up of sediments in some spots and repair and maintain any Sydney Water fences along those channels.

Sydney Water works with local council through their floodplain coordination committees. These committees determine whether any works are required and Sydney Water then negotiates with Councils to facilitate outcomes. While some concrete lined channels in the Cooks River catchment

have been broken out and replaced with “naturalized” channels, there are no plans for this type of action in the Duck River catchment.

Figure 20. Larger channels in the lower catchment include reach A’BECKETTS 1, with an open space corridor

Figure 21. In many cases there is little room between the channel and surrounding development (UNNAMED 8 GUILDFORD RD)

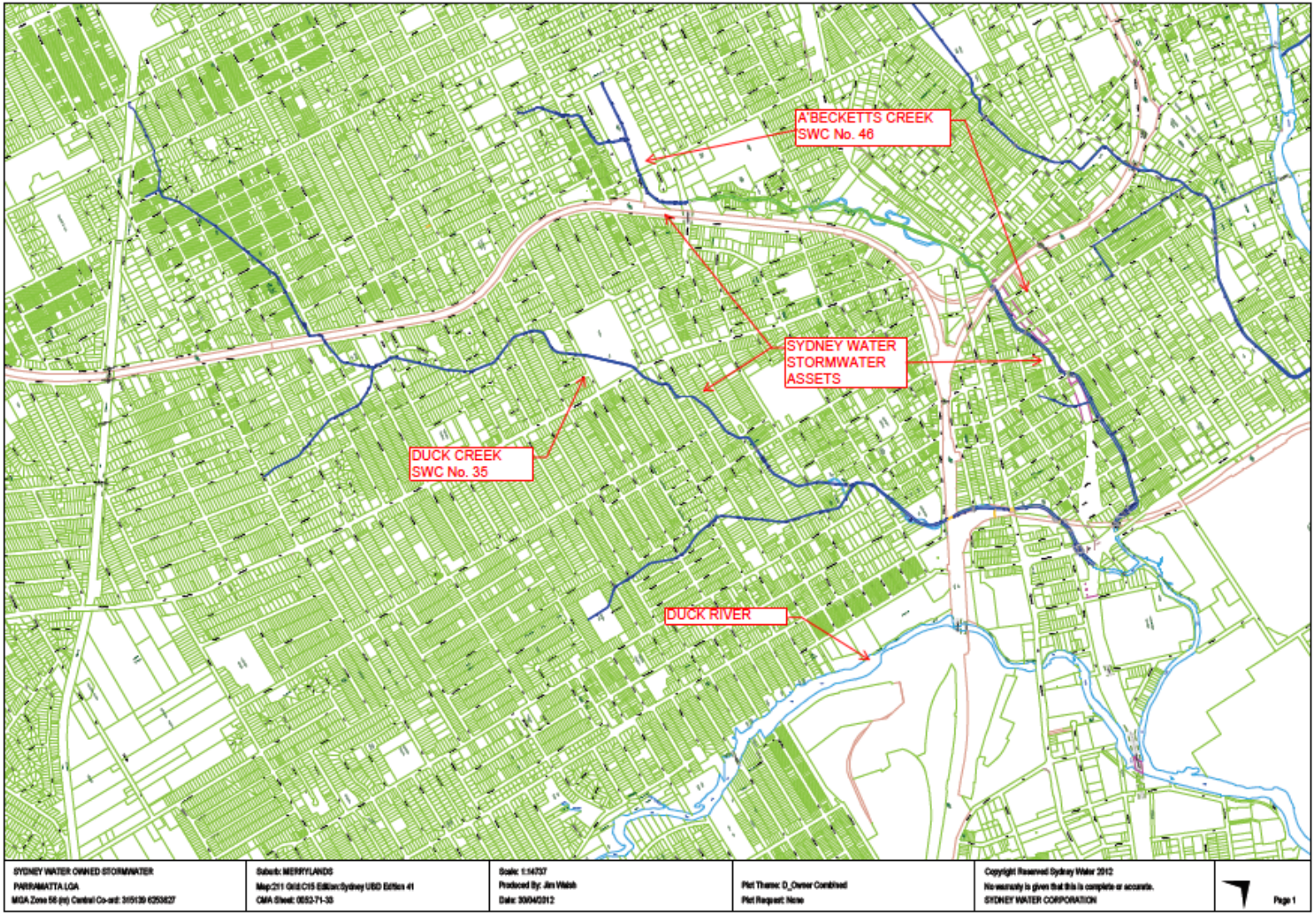


Figure 22. Sydney Water's stormwater asset network in Duck River catchment (Sydney Water, 2012)

3.3.4 Duck River Rehabilitation, Maintenance and Restoration Activities

The management and maintenance of the Duck River corridor is primarily guided by principles outlined in the Parramatta City Council Natural Areas Plan of Management (2006). This document only contains general actions to be undertaken or encouraged across all open space areas in the LGA and does not contain specific management actions for the Duck River corridor. Nevertheless, this plan can be used as a guide for the present study to confirm the identified areas of importance for rehabilitation and maintenance.

In recent years considerable effort has been directed towards improving the health of aquatic ecosystems in Duck River. Two major Environmental Trust Grants have supported this:

(i) **TBL in the Duck River Catchment – a model for Industrial Sustainability (2007-2011) $1.3M** – joint with Auburn Council, Parramatta the lead Council. The grant focussed on working with businesses in the Camellia and Silverwater Industrial areas (lower Duck River) to improve their environmental sustainability across energy, water, travel, waste and biodiversity. The grant also included a capital improvement component associated with cycle way upgrades, riparian weed removal, installation of stormwater pollutant traps and interpretive signage regarding natural and built heritage.

(ii) **Sustainable Water Management in the Duck River Catchment (2009-2012) $1.8M** – joint with Auburn, Bankstown and Parramatta Councils, Auburn the lead Council. The objective was to improve the management of water supply (and seek alternative supply options) to open space and recreational assets across the three Council areas within the catchment. Works within Parramatta Council include: River water extraction licence, storage tanks, treatment technology and new irrigation system for Horlyck Reserve Granville; amplification of existing dam capacity at Woodville Golf Course; supply of recycled effluent to Granville Park; and studies on future works at Granville Pool and Ray Marshall Reserve.

Table 3. Stormwater improvement devices installed in the Duck River catchment in 2009-2012

LOCATION	DESCRIPTION OF WORKS
GPTS INSTALLED	
Clyde St, South Granville (opp Dellwood St, in park)	Channel net and sediment basin
Dixmude St, South Granville (in park)	Channel net
Mackay Rd (corner Dixmude St) South Granville	Nettech, sediment basin and channel armouring (10m)
Mons St, South Granville (end of park)	Channel net, sediment basin and channel armouring (12m)
Wellington Rd, South Granville (creek crossing)	Nettech, sediment basin and channel armouring/ planting (25m)
Shirley St, Rosehill (end of private road)	Ecosol – underground sump
Shirley St, Rosehill (start of private road)	2 x Nettechs

Additional works to improve the health and water quality in the catchment include installation of a range of gross pollutant traps at key points in the catchment (Table 3). A number of on-ground projects and programs aimed at maintaining, restoring and enhancing the health of vegetation around Duck River have been identified through this review (Table 4).

Table 4. Bush regeneration activities in the Duck River catchment from 2007/8 to 2011/2.

LOCATION	YEAR	DESCRIPTION OF WORKS
CONTRACT REGENERATORS		
Prince St capping	2011/12	Planting 400 tubes, maintain plantings on capped asbestos contamination site, spray and mulch
Parramatta Rd	2007/08	Planting 500 tubes, control vines and woody weeds
	2008/09	Planting 500 tubes, control vines and woody weeds
	2009/10	Planting 400 tubes, control vines and woody weeds
	2010/11	Planting 440 tubes, direct seed, maintain plantings and mulch, control vines and woody weeds
	2011/12	Planting 295 tubes, install silt fencing, control vines, mulch, spot spray and direct seed
Duck River Reserve: rear Australia Post	2007/08	Planting 500 tubes, reduce vines and woody weeds
	2008/09	Planting 200 tubes, control vines and woody weeds
	2009/10	Planting 200 tubes, secondary weeding
	2010/11	Manage habitat for snakes and security, control vines and woody weeds
	2011/12	Planting 200 tubes, maintain drainage line, reduce woody weeds
Duck River Reserve: Bangor St to Neilson St	2007/08	Planting 500 tubes, secondary weeding and control vines
	2008/09	Planting 1600 tubes, secondary weeding and control vines
	2009/10	Planting 1760 tubes, secondary weeding, and mulching, install log barrier and fencing
	2010/11	Planting 280 tubes, spot spray, direct seed
	2011/12	Planting 580 tubes, secondary weeding, target woody weeds, spot spray and maintain plantings
Duck River Reserve: Heath St	2007/08	Planting 280 tubes, target woody weeds
	2008/09	Planting 280 tubes, secondary weeding
	2009/10	Planting 280 tubes
	2010/11	Planting 80 tubes, maintain plantings, followup woody weeds
	2011/12	Planting 420 tubes, control woody weeds
Horlyck Reserve: Mona St	2007/08	Planting 200 tubes, target woody weeds and vines
	2008/09	Planting 200 tubes, target weeding for vines and woody weeds
	2009/10	Planting 200 tubes, target vines and woody weeds,

LOCATION	YEAR	DESCRIPTION OF WORKS
		reduce large woody weed infestation
	2010/11	Planting 80 tubes, target woody weeds, spot spray groundcover weeds
	2011/12	Planting 100 tubes, spot spray and maintain plantings
Horlyck Reserve: Riverside remnants	2007/08	Secondary weeding
	2008/09	Secondary weeding
	2009/10	Target weeding for vines and woody weeds
	2010/11	Planting 20 tubes, target vines and woody weeds
	2011/12	Planting 20 tubes, target weeding
Duck River Reserve: Mons St to Chiswick Rd	2007/08	Planting 1770 tubes, maintain plantings
	2008/09	Planting 1100 tubes, restaking boundary logs after flooding, secondary weed control
	2009/10	Planting 1180 tubes, secondary weed control for vines and grasses
	2010/11	Planting 390 tubes, spot spray, control Morning Glory and reduce woody weeds
	2011/12	Planting 280 tubes, maintain plantings
Clyde St Reserve	2007/08	Planting 200 tubes
	2008/09	Planting 400 tubes
	2009/10	Planting 400 tubes, maintain plantings
	2010/11	Planting 80 tubes, maintain plantings
	2011/12	Planting 220 tubes, maintain plantings
Ray Marshall Reserve	2007/08	Planting 1000 tubes, mulch edges
	2008/09	Planting 700 tubes
	2009/10	Planting 700 tubes
	2010/11	Planting 300 tubes, spot spray and direct seed
	2011/12	Planting 340 tubes, maintain plantings
Everley Park and Norford Park	2007/08	Planting 200 tubes, secondary weeding
	2008/09	Planting 1000 tubes, spot spray around plantings
	2009/10	Planting 1000 tubes, spot spray around plantings
	2010/11	Planting 80 tubes, maintain plantings, spot spray
	2011/12	Planting 280 tubes, maintain plantings, spot spray
Campbell Hill Pioneer Reserve	2007/08	Planting 1120 tubes, target noxious and woody weeds, maintain core bushland areas
	2008/09	Planting 1020 tubes, control vines, blackberry and woody weeds, maintain core bushland areas
	2009/10	Planting 1520 tubes, spot spray around plantings, control vines, woody weeds and blackberry
Waddangalli Woodland	2007/08	Planting 60 tubes, control Blackberry and woody weeds, maintain core bushland areas
	2008/09	Planting 1000 tubes, reduce woody weeds

LOCATION	YEAR	DESCRIPTION OF WORKS
	2009/10	Planting 1000 tubes, maintain core bushland areas, reduce blackberry and woody weeds
Duck River Bushland Reserve	2007/08	Planting 1100 tubes, maintain plantings, target weeding, control exotic grasses
	2008/09	Planting 4000 tubes, control vines and woody weeds along creekline, spot spray and maintain plantings
	2009/10	Planting 1200 tubes, spot spray and maintain plantings, maintain core bushland areas
VOLUNTEER GROUPS		
MDRRC, Duck River Reserve between Seventh Ave and Mona St	monthly, ongoing	Aim: to widen the riparian corridor Maintenance of plantings, spot spray, mulch and plant, maintenance weed control
Friends of Duck River Bushcare	monthly, ongoing	Aim: to encourage native regeneration through edge weeding Maintenance of core bushland edges, some planting

- Duck River Icon Project (SMCMA 2006-2008). Rehabilitation of riverbanks and an island adjacent to Webb Avenue playing fields and Mackay Road, South Granville. A green corridor linking existing remnant vegetation including Castlereagh Ironbark Forest was established
- Mighty Duck River Restoration Collective (MDRRC). Protection of endangered remnants and wetland along the Duck River. NSW Government 2002 Restoration and Rehabilitation - community grants
- Mighty Duck River Restoration Collective (MDRRC) Stage 2. Protection of endangered remnants and wetland along the Duck River. NSW Government 2003 Restoration and Rehabilitation - community grants

Revegetation and Expansion management options in the Duck River catchment listed by Molino Stewart (2011) include:

- The northern bank of Duck River at the confluence with Duck Creek, adjacent to a factory on Shirley Street
- Duck River Reserve (additional revegetation west of existing vegetation toward pathway)
- Ray Marshall Reserve (small area suitable for revegetation at the end of Chiswick Road)
- Norford Park (triangle area at the southern end suitable for revegetation)

4 REVIEW OF LITERATURE AND SITE SURVEYS: CULTURAL HERITAGE

4.1 INDIGENOUS HERITAGE

The Duck River appears to have been the boundary between two major groups of indigenous people prior to European occupation of New South Wales.

The Auburn area was located on the border between the Darug inland group and the Eora/Dharawal coastal group of Aboriginal people. The Wangal and Wategoro, sub-groups or clans, are the groups most often recognised as the original inhabitants of the Auburn / Homebush Bay region. Bennelong, one of the most famous Aborigines of the time, was a member of Wangal, as was his wife, Barangaroo. Pemulwuy, who organised tribes to resist the white settlement of the Sydney region from 1790 to 1802 was also a member of the Wangal. The agreed boundary between Burramattagal country and their neighbours, the Wategora clan, seems to have been the Duck River (McClymont, 2008). The Auburn area was once used by Aboriginal people as a market place for the exchange of goods, a site for ritual battles and a 'Law Place' for ceremonies.

Further to the west, the original inhabitants of the area that is now Parramatta belonged to the Darug (Dharug, Daruk) language group. The clan that occupied the area was known as the Burramattagal. The Bidjigal occupied the areas to the north and west. The Burramattagal relied on the mixed food sources available from the river and the surrounding woods (Kass, 2008). The southern riverbank and the mostly freshwater stream now known as Clay Cliff Creek were vital sources of their food and living resources. In their seasonal rotation of campsites around their territory, the clan would have found that the reasonably abundant fish, shellfish, bird life, reptiles and marsupials large and small contributed greatly to their daily quest for food (McClymont, 2008).

A number of searches were conducted to identify whether there were Aboriginal heritage items, places or other relevant information for the Upper Duck River area. These included searches of the National Native Title Tribunal (Table 5) with the following results.

Table 5. National Native Title Tribunal search results

TRIBUNAL DATABASE SEARCHED	SEARCH RESULT
Schedule of Applications	no relevant entries
Register of Native Title Claims	no relevant entries
National Native Title Register	no relevant entries
Register of Indigenous Land Use Agreements	no relevant entries
Notified Indigenous Land Use Agreements	no relevant entries

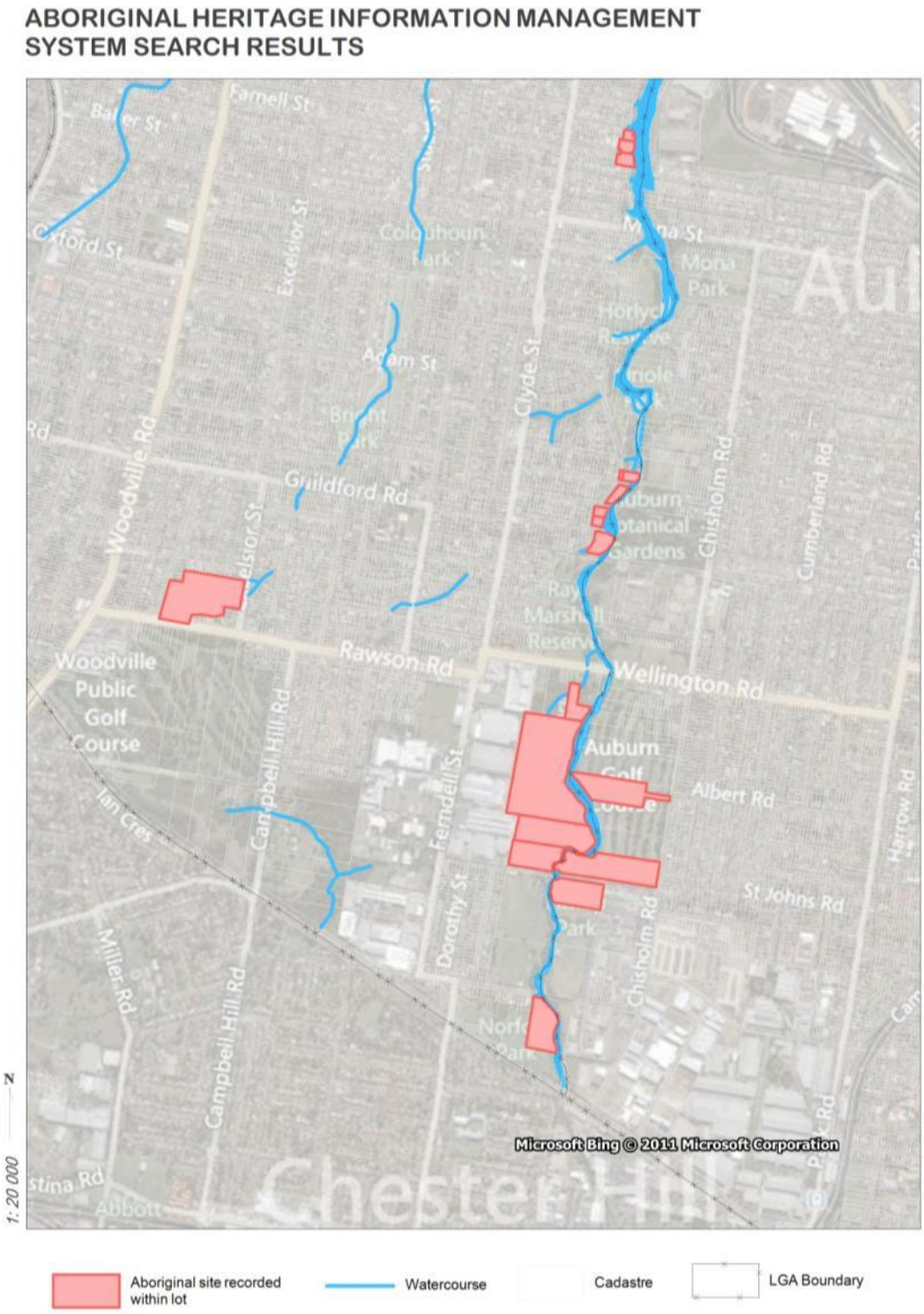


Figure 23. Indicative locations of indigenous heritage items along Upper Duck River

Further searches were conducted with the Aboriginal Heritage Information Management Service (AHIMS database; Appendix 5, Table A5). Basic searches for heritage items on properties by individual lot numbers revealed that there are numerous indigenous heritage items located at various points along the Upper Duck River (Figure 23). Mary Dallas Consulting (2002) identified a number of these heritage item locations, but also reported that all of the Upper Duck River Wetlands

and Riparian Corridor was classified as high sensitivity for indigenous heritage potential. Before any works can be conducted in these areas a full search of the AHIMS database should be conducted, and if heritage items are located then Aboriginal Heritage Impact Permit must be obtained under Part 6 of the National Parks and Wildlife Act 1974.

4.2 NON-INDIGENOUS HERITAGE (MUSECAPE, 2012)

On 5 February 1788, soon after the landing of Captain Arthur Phillip at Sydney Cove, Captain John Hunter and Lieutenant William Bradley sailed up what is now known as the Parramatta River, as far as Homebush Bay. Captain Hunter was the first white person to set foot within what is now the Auburn LGA.

Ten days later, Governor Phillip, along with a well-armed party in three boats, reached Homebush Bay. They ventured about 3 kilometres inland. The following day a party of explorers traced the river in a westerly direction, coming to the place where the Duck River enters the Parramatta River. They explored the tributary as far as the depth of water permitted. The party entered the mouth of Duck River while exploring the Parramatta River. Seeing a group of wild ducks taking flight from a reed bed, and thinking it might be a breeding ground for ducks, Governor Phillip named the waterway Duck River. The ducks were most likely specimens of *Porphyrio porphyrio* (Eastern Swamp Hen), but the name Duck River stuck.

Granville remained relatively untouched by European colonisation for many years. Early governors did make land grants to soldiers, officials and a handful of families who had established themselves as the elite of Parramatta. The Wentworths (D'Arcy Wentworth and his son William Charles) held land on the Duck River. The largest landowner in the district was the merchant Garnham Blaxcell, who snapped up some small grants given to members of the New South Wales Corps, and then received a massive consolidated grant of 1,125 acres (455 hectares) in 1806. This area is now bounded by Clyde Street and Parramatta, Woodville and Rawson roads. The forest was a resort for timber-getters, charcoal burners and men who trapped the prevalent native dogs; the original name for Woodville Road was Dog Trap Road.

The soil in what is now Auburn LGA proved too poor for agriculture, but early industries included timber-getting, and brick-making, which began with the establishment of the Duck River Brickworks by Charles Linney. In the 1850s, the construction of the Sydney-Parramatta railway brought large-scale deforestation and much of the useable timber was cut out by 1860. The railway line, opened with much ceremony in 1855, actually terminated on Dog Trap Road at a station called Parramatta Junction. In 1860 the railway was extended into Parramatta proper. The opening of the railway made suburban development possible, and the township of Auburn emerged from subdivisions by John Yelverton Mills near the railway station.

During the 1860s, subdivision of the old Jamieson estate began. Although James Bergan established a tweed mill close to the railway, many of the first buyers were orchardists and farmers. There was room also for middle-class villas, occupied by men who were responsible for renaming, not just the disreputable Dog Trap Road, but the whole area. In the 1880s it became Granville, in honour of the then British Foreign Minister, Lord Granville. Five years later, the Municipality of Granville was declared: it encompassed all or part of the modern suburbs of Camellia, Rosehill, Harris Park,

Granville, Clyde, and South Granville. The municipality – which took in Guildford in 1906 – lasted until 1949 when it was subsumed in the enlarged City of Parramatta.

Granville municipality grew quickly in the 1880s and 1890s, as industrialists were attracted by its road, rail and water access: the municipality also gained gas street lighting and a connection to the metropolitan water supply in this period. Hudson Brothers, manufacturers of railway rolling stock, chose a site on the Duck River at Granville to establish works, which opened in 1883 and covered 14 acres (5.6 hectares). Other new enterprises in Granville included James Brunton's six-storey flour mill and William Ritchie's factory producing agricultural machinery. The workers in these large factories – along with those in smaller tanneries and brickworks – boosted the area's population and stimulated the subdivision of existing farm lots.

During the 1920s, developments in building and the growth of motor transport brought more manufacturers to the Municipality of Granville. Private developers and the War Services Homes Commission tried to meet the resulting demand for housing: between 1921 and 1933 the number of 'occupied dwellings' in Granville municipality rose by 54 per cent. By 1933, however, the Depression was devastating the area. Male unemployment was over 20 per cent and the Granville Council struggled to provide relief works.

After World War II, state planning policies – which designated Parramatta as a growth centre – and federal immigration programs impacted on Granville, which had been reduced in size and status to become one of many suburbs of the City of Parramatta. At first, industrial expansion continued, but mainly in South Granville, while the Housing Commission built estates to accommodate an urban population growing as a result of the baby boom and immigration. The area was developed with an unusually high proportion of low income and/or non-English-speaking families.

In the immediate post-war period, growth was boosted by government initiatives. But it was the gazettal of the Strata Title Act of 1961 that had the greatest impact throughout the suburb, permitting the erection of multi-unit housing blocks. By the 1960s and 1970s, the number of Middle Eastern immigrants settling in Auburn had grown, making Auburn one of the main Arabic / Middle Eastern centres in Sydney, vying only with Canterbury. In the 1991 census, 47 per cent of the population of the municipality had been born overseas.

A cultural precinct and associated structures have been recorded around the Duck River catchment (Table 6, Figure 24). Preservation of these is an important part of the conservation process for the wetlands and riparian corridor.

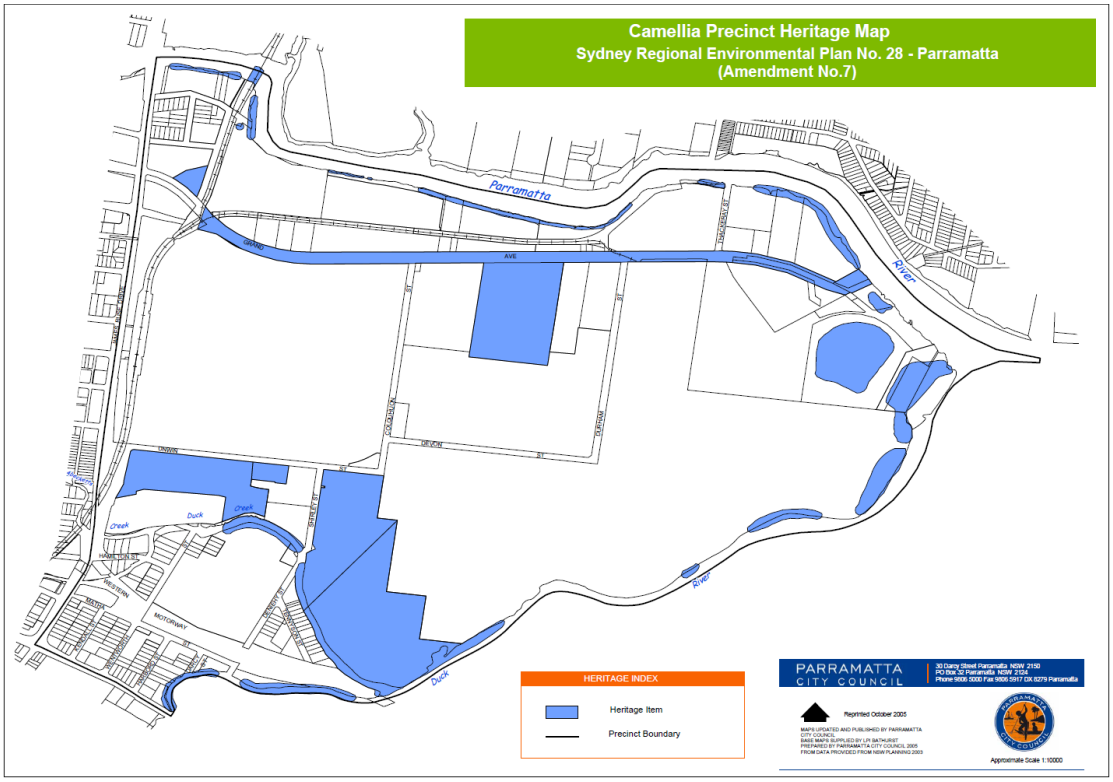


Figure 24. Camellia Precinct Heritage Map from Sydney Regional Environmental Plan No.28 – Parramatta (Amendment No.7), with listed Heritage Items shown in blue. (Source: Parramatta City Council).

A desktop survey of currently listed heritage items within the heritage precinct has revealed a number of items, including historic industrial sites, archaeological sites and landscape areas (Table 6; Musecape, 2012).

Table 6. List of heritage items derived from Schedule 6 (Heritage Items) within the area covered by Sydney REP No 28 Parramatta Amendment No.7, Schedule 3 Amendment of Parramatta Local Environmental Plan 1996 (Heritage and Conservation) and Schedule 5 (Heritage Items) in Parramatta LEP 2011

ITEM NO.	ADDRESS	SUBURB	ITEM	PROPERTY DESCRIPTION	LEVEL OF SIGNIFICANCE
I1	Parramatta River	Camellia	Wetlands		Local
I6	Grand Avenue	Camellia	Tram alignment		Local
I3	1 Grand Avenue	Camellia	Grave of Eliner Magee & child	Lot 1, DP 226202	Local
I2	1A Grand Avenue (north of)	Camellia	Clyde Carlingford Rail Bridge abutments		Local
I01643	1B Grand Avenue	Camellia	Sewage Pumping Station 67	Lot 2 DP 430623	State
I5	39 and 41 Grand Avenue	Camellia	Pumping Station	Lots 1 and 2, DP 615549	Local
SREP	3 Grand Avenue	Camellia	Wunderlich	Lot 4 DP 623497	Regional

ITEM NO.	ADDRESS	SUBURB	ITEM	PROPERTY DESCRIPTION	LEVEL OF SIGNIFICANCE
SREP	Unwin Street	Camellia	RTA Depot	Lot 120 DP 817742	Regional
SREP	2 Unwin Street (4a James Ruse Drive)	Camellia	Capral Aluminium	Lot 1 DP 818736	Regional

Further literature reviews revealed additional heritage items listed elsewhere in the catchment (Table 7; Molino Stewart, 2011). These sites have been extracted from the Australian Heritage Places Inventory, items listed under the NSW Heritage Act, items listed by State Agencies and items/locations listed in the various LEPs.

Table 7. Additional heritage items and their locations (Molino Stewart, 2011 and others)

ITEM NO.	ITEM NAME	ADDRESS	SUBURB
	Crest Theatre	157 Blaxcell Street	Granville
	Cottage (1)	1 Salisbury Road	Guildford
	Uniting Church	104 South Street	Granville
	Cottage (2)	54 Stuart Street	Granville
	Monuments	29 William Street	Granville
	Homes for the unemployed cottage	46 Bertha Street	Merrylands
	Wunderlich	10 Grand Avenue	Rosehill
	RTA Depot	4a James Ruse Drive	Rosehill
	Capral Aluminium	Unwin Street	Rosehill
	Former shop and dwelling	15 Abbott Street	Granville
	Terraces	5 – 23 Arthur Street	Granville
	Cottage (4)	29 Bertha Street	Merrylands
	Colquhuon park and monument t	196 Blaxcell Street	Granville
	Electrical substation	417 Blaxcell Street	Granville
	Electrical substation	2 Bright Street	Granville
	Cottage (5)	10 Bury Street	Guildford
	East St residences	21-23 East Street	Parramatta
	Granville pool	1a Enid Avenue	Granville
	Scout Hall	1A Glen Street	Granville
	Electrical substation	133 Guildford Road	Guildford
	Cottage (7)	2 Lisgar Street	Granville
	Sandstone bridge	The Avenue	Granville

Location of European heritage items and conservation precincts around the Duck River catchment is shown in the following map (Figure 25).

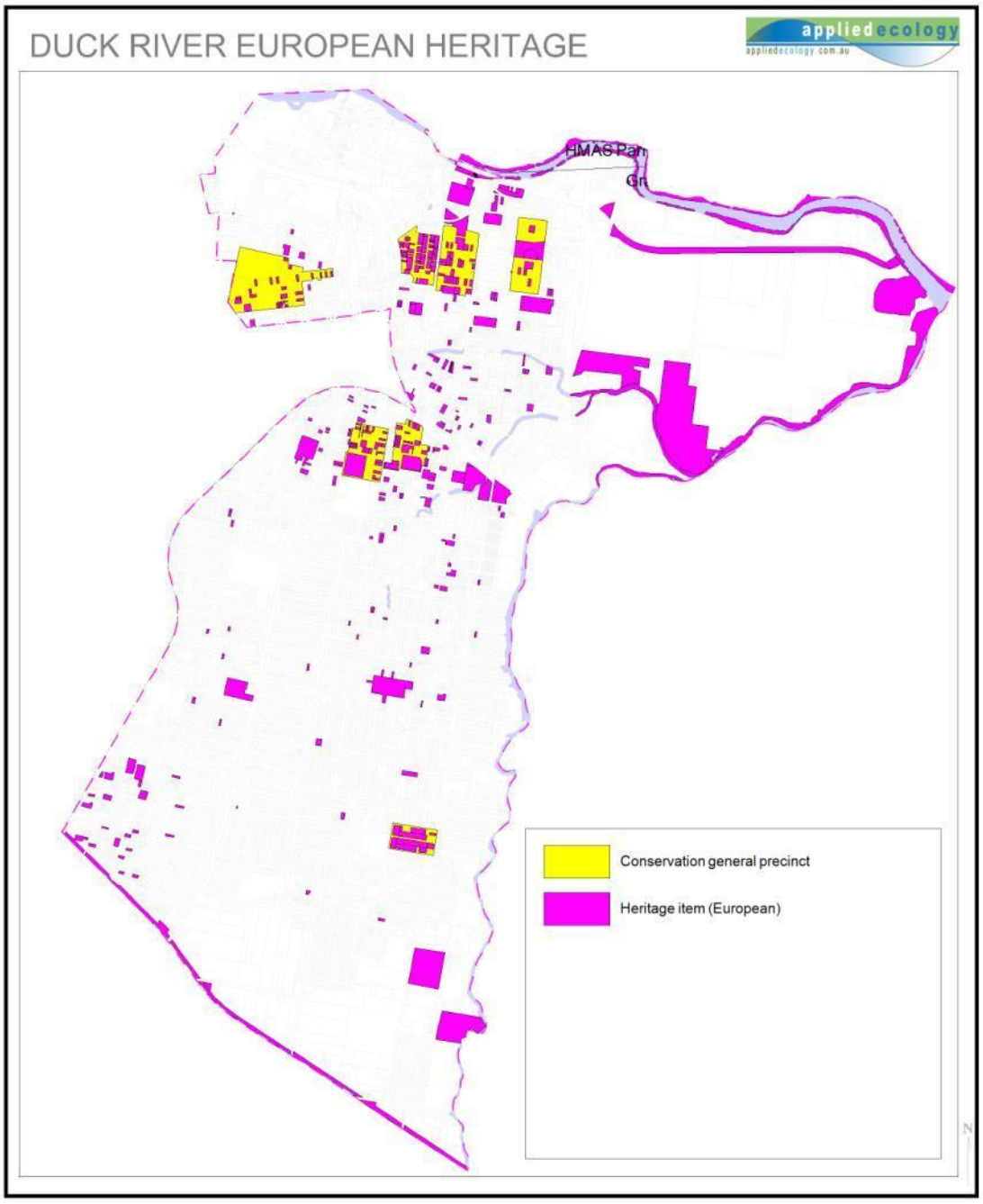


Figure 25. European heritage items and conservation precincts around the Duck River catchment

Analysis of documentary and physical evidence relating to the Study Areas has revealed a number of potential heritage items, archaeological sites and areas worthy of further investigation (Musecape, 2012).

1. Sandstone block crossing and stone “bridge” over piped outflow point for stormwater, both near Mackay Road, South Granville (Figure 26).
2. Low sandstone block retaining wall and possible road formation located next to the wetlands off Randolph Street, South Granville.

3. Remaining piles and other possible archaeological evidence from former Mona Street bridge (Figure 27).
4. Low weir across Duck River just upstream of the Main Western Railway Line bridge over the river.
5. Old abutments of Main Western Railway Line bridge over the river, just east of Clyde Railway station.
6. Brick arched former railway bridge over Duck River immediately downstream of existing Main Western Railway Line bridge.
7. Remains of timber former railway bridge over Duck River just upstream of Parramatta Road bridge. This bridge appears to have carried a spur line from near Clyde Railway Station to industrial sites on the western side of the river.
8. Possible archaeological evidence of wharf for former Parramatta Tramway on western side of confluence of Duck River and Parramatta River.

Figure 26. Sandstone block crossing and stone "bridge" over stormwater pipe, near Mackay Road, South Granville

Figure 27(a) Remaining piles from former Mona St bridge; (b) Original Mona St bridge in 1915 (Source: Auburn City Council Local Studies collection image 839)

5 REVIEW OF LITERATURE: BUFFER ZONES AND SETBACK

5.1 REVIEW OF SCIENTIFIC KNOWLEDGE

5.1.1 The importance of the riparian zone

A riparian zone is broadly defined as "the area of land that forms the banks of a waterbody and the adjacent land it directly affects, including the vegetation". Riparian systems play an important role in maintaining the ecological and geomorphic health of ecosystems, particularly in urban areas where the last remaining remnant vegetation often exists adjacent to streams within a catchment. Riparian systems also have disproportionately high levels of biodiversity in relation to the surrounding area because of their position at an interface between fluvial and terrestrial environments.

Riparian zones contain biota with various adaptations used to survive in a frequently changing environment with a diverse range of habitats. The value of connected wildlife corridors especially in maintaining biodiversity is widely recognised by scientists and environmental managers. They are considered to be of great importance for the movement of both flora and fauna across environmental gradients as well as helping to maintain high levels of genetic diversity especially in urban areas. Riparian vegetation also contributes large woody debris to the channel which is important for in stream habitat for fish and macroinvertebrates and affecting the flow of water.

Riparian vegetation plays a significant role in influencing the geomorphic condition of a stream by preventing bank erosion, aiding rainfall and runoff infiltration and contributing to soil, bank and channel stability. Riparian zones are sources of nutrients to the stream through leaf litter and organic matter and also nutrient sinks, storing nutrients from upslope, which is particularly significant in nutrient rich urban catchments. Riparian zones act also as a filter and a buffer against pollutants which may be derived from upslope urban or industrial areas. In addition to the ecosystem services they provide, riparian zones provide valuable social value due to their usefulness as aesthetic visual buffers, flood mitigation, property protection and enhanced economic value as well as amenity.

5.1.2 Riparian zones in an urbanised environment

Unfortunately, the highly productive nature of riparian land makes it a prime target for intensive cropping, intensive grazing and intensive irrigation, and this was the early history of land use change in the Duck River catchment. Further modification involved changes relating to industry establishment in areas that were accessible by water transport. Today, the scenic values associated with waterways can make adjacent land a prime target for development. Past patterns of modification along Duck River will drive the direction of more recent changes in land use. Tradeoffs will exist, depending on the relative importance of development and waterway improvement to the community.

In a disturbed catchment, once the nutrient levels in the water of the creek and creekbank soils become too high, the natural vegetation becomes out-competed by weeds. Consequently, relying solely on protection from clearing or erosion is insufficient to protect the integrity of the riparian vegetation. As a consequence of the high ecological and social value of riparian zones, there are often conflicting interests between conservation and development. Although some studies have

examined the relationship between buffer width and biodiversity, there remains a paucity of research in that area particularly with respect to urban environments.

5.1.3 Riparian buffers and zone boundaries

Current literature generally accepts 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
- geomorphologic protection generally defines a minimum riparian zone (see Rutherfurd et al, 1999).

The use of nominated riparian buffer distances is common in planning and development regulation (e.g. a 40m protection zone applied 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, for example a range from 5m to 400m is used in a selection of Australian planning documents.

A more effective approach to defining the riparian zone was to use both structural (channel geomorphology, vegetation type) and functional (geomorphologic, 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 8 (adapted from Montgomery Watson Harza (MWH) Australia P/L, 2003).

Table 8. 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.

BASIS FOR WIDTH	METHOD	COMMENTS
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 9 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. Draft Duck River Floodplain Risk Management Study and Plan (Molino Stewart/WMA, 2011).

Table 9.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: (see next page)

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.

Determining values associated with fauna movement can also be complex, although such considerations may be useful, especially if a creek's value would increase through the provision of a basic corridor linkage (i.e. ecological connectivity).

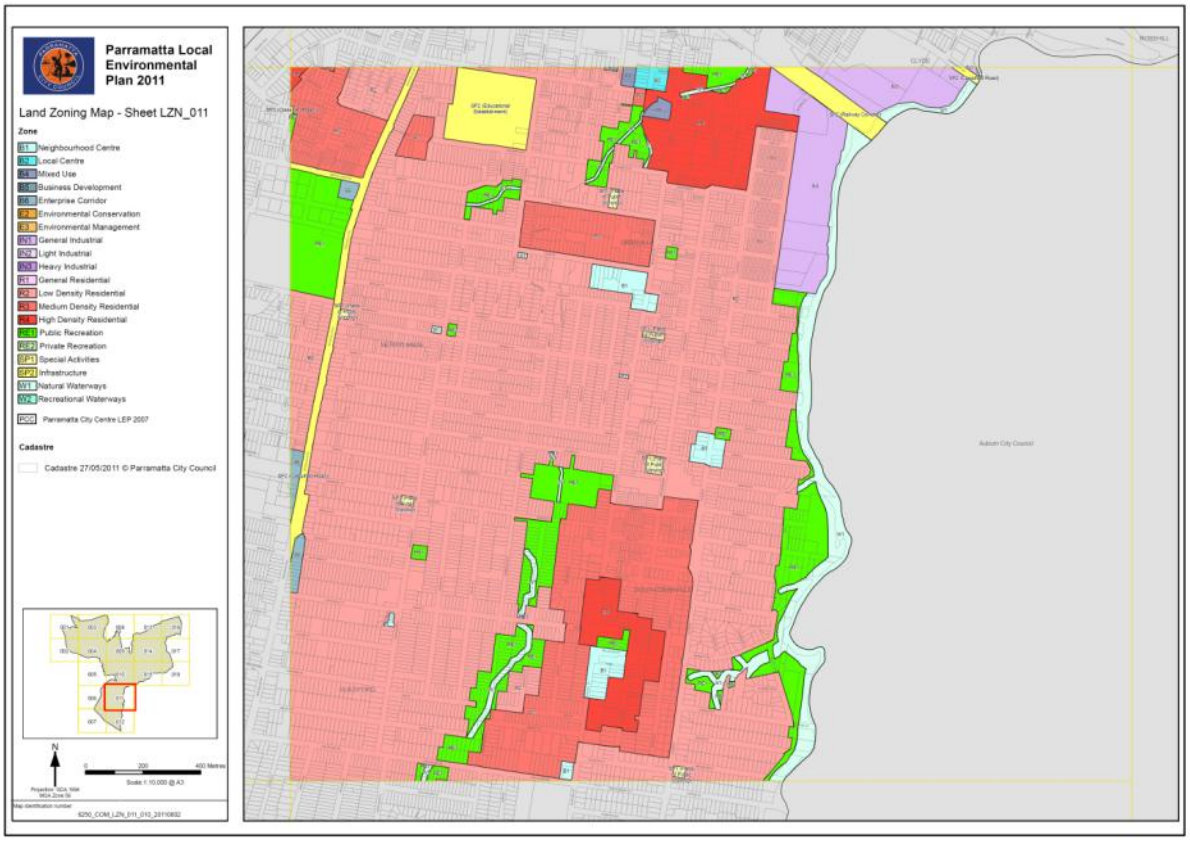
The implication of this approach is that the riparian zone may include existing developed areas – such as sporting fields, ovals, fences and even small buildings. In effect, these are part of the functional riparian zone, even though they are unnatural. From a land use management perspective, we suggest 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).

5.2 REVIEW OF CURRENT LEGISLATION

5.2.1 Planning Instruments and Controls (Buffer Zones and Setbacks)

Land zoning surrounding the Duck River is provided in the Parramatta Local Environment Plan (2011) and reproduced below. The Duck River itself is generally classified as Natural Waterway (W1). Land zoning surrounding the Duck River primarily consists of (see Figure 28):

- I1, General Industrial. Northern section of the study area;
- RE1, Public recreation;
- R2, Low density residential (limited areas adjacent to the waterway); and
- E2, Environment Conservation.



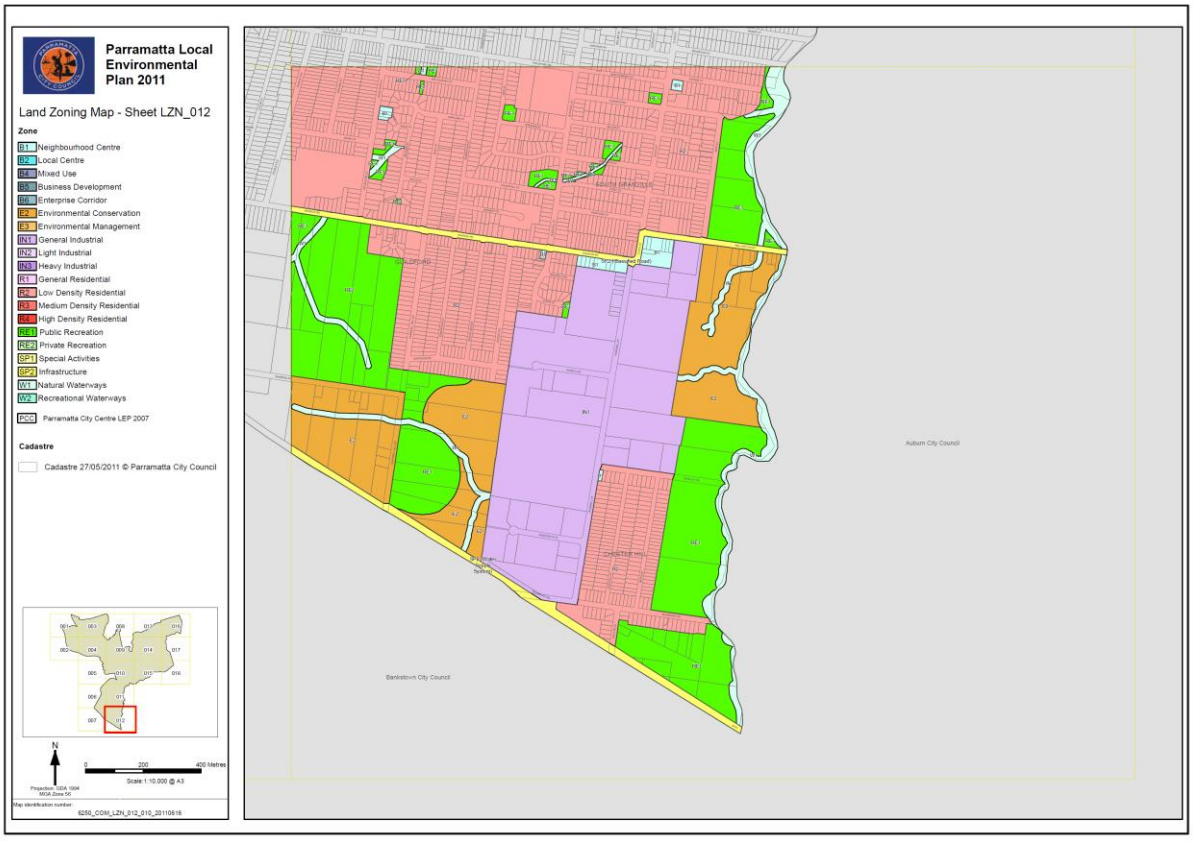


Figure 28. Land Use Zoning along the Duck River. PCC LEP 2011

Design principles regarding development that may apply to these land use zones adjacent to the Duck River in the LEP relating to the protection of waterways are:

- P.1 Development is to make provision for buffer areas for the preservation and maintenance of floodway, riparian corridors and habitat protection. Refer to Clause 6.7 Foreshore Building Line and Clause 6.5 Water Protection in the Parramatta LEP 2011.
- P.2 Development on land subject to Clause 6.5 Water Protection in the Parramatta LEP 2011 or that abuts a waterway is to be landscaped with local indigenous species, to protect bushland and wildlife corridors and soften the interface between the natural landscape and the urban environment. Riparian vegetation also plays an important role in stabilising bed and banks and attenuating flood flows.
- P.3 The piping, enclosing or artificial channelling of natural watercourses and drainage channels is not permitted. Consideration is to be given to re-opening piped or lined drainage systems wherever feasible.
- P.4 Development is to ensure that natural channel design principles are incorporated in any works on or in waterways.
- P.5 Ongoing maintenance costs are to be considered in the design of any waterway protection features.

The specific reference to provision of buffers in design principle P1 (above) refers to Clause 6.7 Foreshore Building Line and Clause 6.5 Water Protection in the Parramatta LEP 2011. The foreshore building line is outside of the study area and generally applies to foreshore downstream of the M4 motorway crossing. There is no specific reference to buffers or setbacks under Clause 6.5, Water Protection that may otherwise suggest a specific buffer distance or setback to riparian land and waterways.

Biodiversity design principles for development of land abutting land zones E2 and W1 in the LEP (2011) also recognise the need for "the requirement for provision of a buffer zone on the abutting land to protect the bushland area" although a specific distance/width is not specified. Molino Stewart (2011) suggests a riparian zone of between 20m and 40m on both sides of the Duck River based on the need for three specific zones:

1. Core riparian zone – land in and adjacent to the channel;
2. Vegetated buffer to protect the integrity of the core riparian zone; and
3. An asset protection zone for protection against bushfire damage.

5.2.2 Flooding

Flooding impacts to property on the Duck River between the Sydney Water pipeline and railway crossing appear to be limited as shown in Figure 29 (Molino Stewart 2011). This study showed that no properties are likely to be impacted in the 1 in 100yr ARI runoff event (or smaller events) and relatively few properties may be impacted in the PMF event. This study indicates that much of the development in the Duck River catchment between the pipeline and railway can be classified as low risk. The Duck River itself and surrounding lands may be considered high to medium risk attracting a wide range of planning controls and building restrictions for new developments, however much of the riparian corridor is already zoned for open space and non-urban land use.

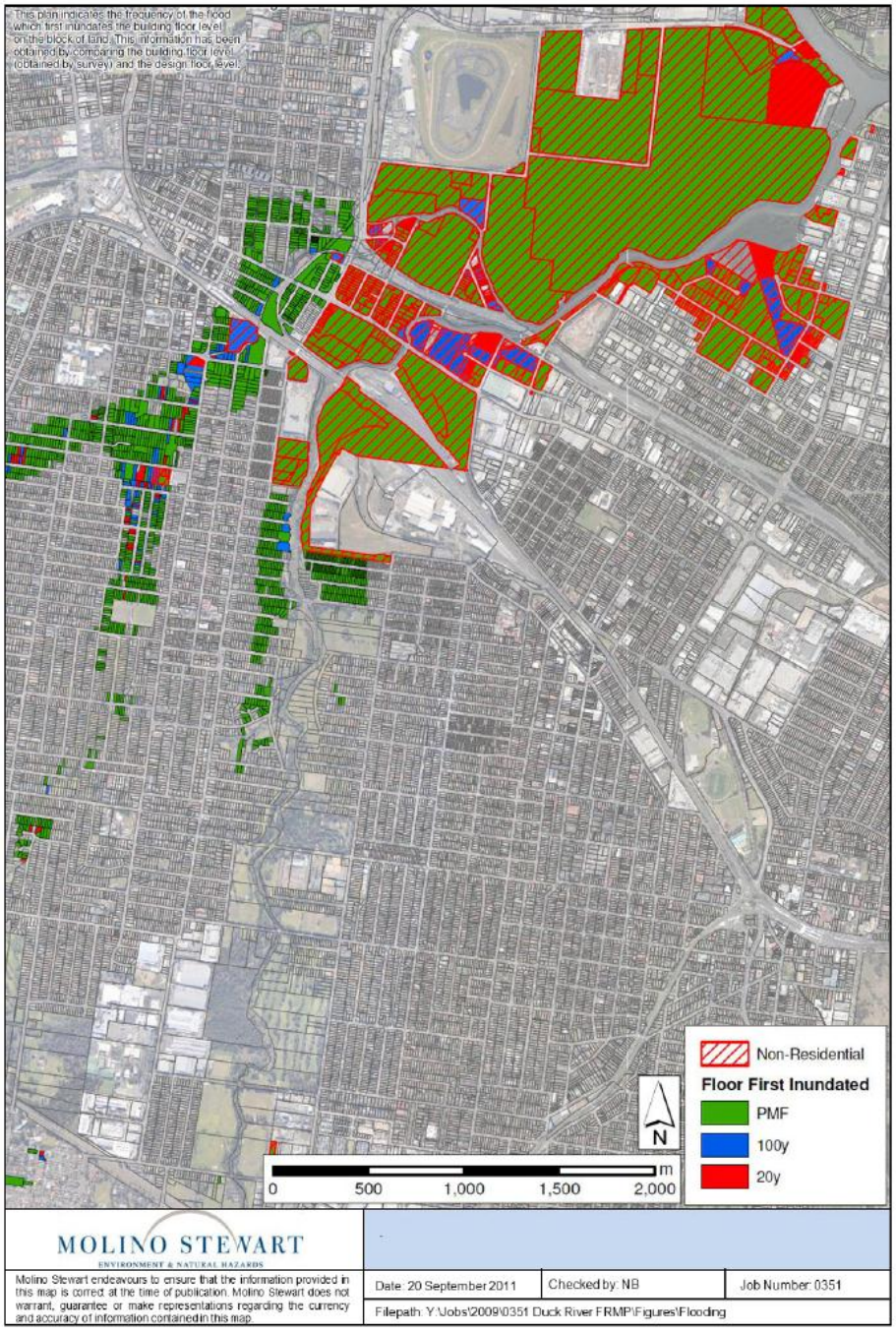


Figure 2: Overfloor flooding localities in Auburn/Parramatta

Figure 29. Overfloor flooding localities in the Duck River Catchment (Extracted from Molino Stewart 2011)

5.2.3 Additional local provisions

Part 6 of LEP 2011 includes several sub-clauses that provide additional protection for lands in the riparian corridor. Part 6.4 Biodiversity protection aims to maintain terrestrial and aquatic biodiversity, including the following:

a) protecting native fauna and flora,
b) protecting the ecological processes necessary for their continued existence,
c) encouraging the recovery of native fauna and flora and their habitats.

This clause applied to the following private lands (Figure 30):

Figure 30. Areas protected under Clause 6.4 Biodiversity protection (LEP 2011)

Part 6.5 Water protection aims to maintain the hydrological functions of riparian land, waterways and aquifers, including protecting the following:

a) water quality,
b) natural water flows,
c) the stability of the bed and banks of waterways,
d) groundwater systems.

And applied to the following private lands (Figure 31):

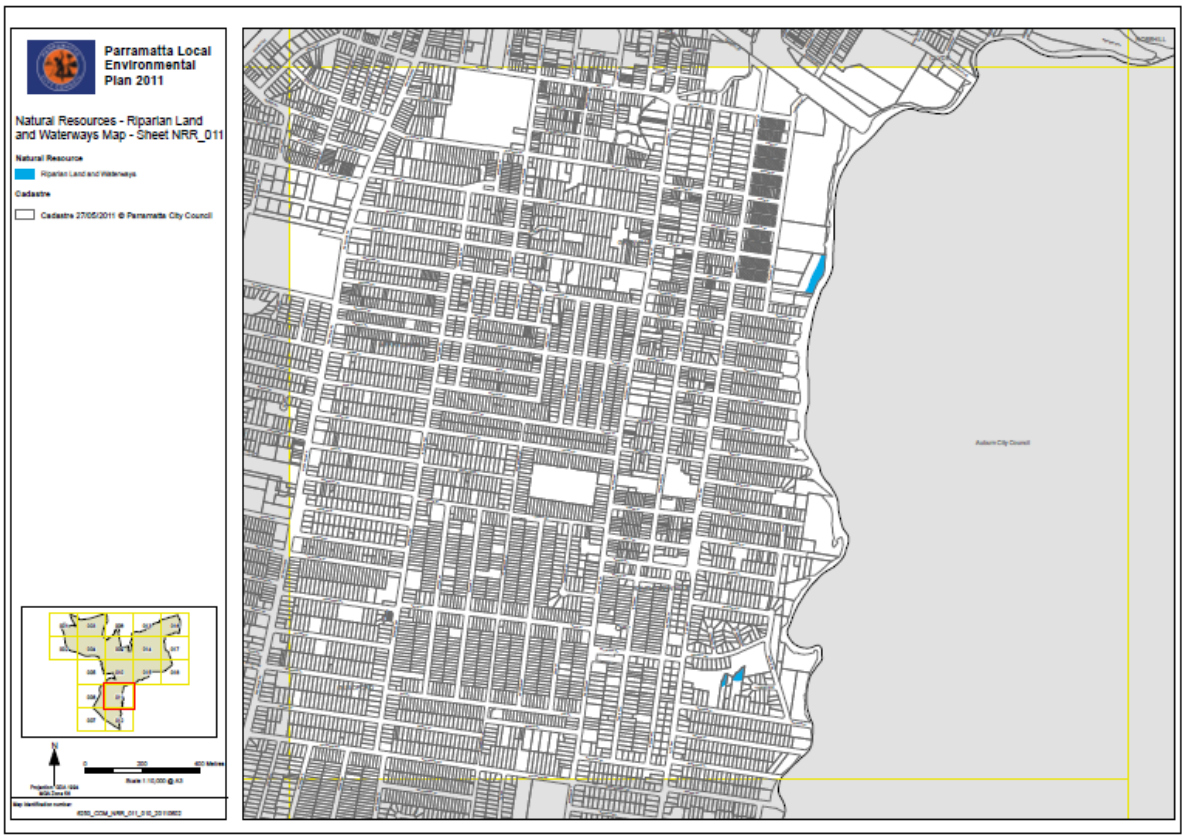


Figure 31. Areas protected under Clause 6.5 Water protection (LEP 2011)

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7 APPENDIX ONE: FEDERAL AND STATE LEGISLATION AND POLICIES

Table A 1. Overview of Legislation and its relevance for maintenance and rehabilitation in Duck River waterways corridor

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
COMMONWEALTH (LEGISLATION)		
Environment Protection and Biodiversity Conservation Act 1999	The main objects of this Act are: "_ to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance" and "_ to promote ecological sustainable development through the conservation and ecologically sustainable use of natural resources".	A Commonwealth Act supporting Ecologically Sustainable Development (ESD), providing a significant overlap with NSW State Legislation such as the Environmental Planning & Assessment Act 1979 and the Threatened Species Conservation Act 1995. Future activities in waterway corridors should be undertaken within a framework of ESD. If approvals are required, NSW system can be accredited upon application being made to the Commonwealth Department.
COMMONWEALTH (POLICIES)		
National Strategy for Ecologically Sustainable Development (1992)	A National Strategy which has as its principal goal: "Development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends." A core objective of the Strategy is: "_ to protect biological diversity and maintain essential ecological processes and life support systems."	The National Strategy is implemented at the local level through the application of state and local government legislation and policies. Future activities in waterways corridors should be undertaken within a framework of ESD.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
National Strategy for the Conservation of Australia's Biological Diversity	This National Strategy provides the framework for protecting Australia's Biodiversity. The Strategy's stated aim is "to bridge the gap between current activities and those measures necessary to ensure effective identification, conservation and ecologically sustainable use of Australia's biological diversity."	The National Strategy supports programs such as native vegetation protection and management, feral weed and pest control and management of threatened species habitat, among others. These are activities which may form part of waterways maintenance and rehabilitation master plans.
Wetlands Policy of the Commonwealth Government of Australia	This policy provides strategies to ensure that the activities of the Government promote the conservation, ecologically sustainable use and enhancement, where possible, of wetlands functions. Among others, those strategies include: "Involving the Australian people in wetlands management" and "working in partnership with State/Territory and Local Governments".	The policy seeks to promote and support local government efforts in wetlands conservation and management, through encouragement of the preparation of local wetlands policies. Such local policies may form part of future waterway maintenance and rehabilitation master plans.
Local Agenda 21	In 1992, at a UN conference on environment and development, Agenda 21 was endorsed, and set out how both developed and developing countries could work towards sustainable development. Local authorities were one of the groups recognised as being fundamental in working towards sustainable development (and hence "Local" Agenda 21). At the local level in Australia, the 1997 "Newcastle Declaration" (made at an international conference focussing on the challenge of sustainability for local government) clarified and re-stated the commitment of local government in Australia to Agenda 21 and sustainable development.	The application of the principles of Local Agenda 21 during the preparation and implementation of waterway maintenance and rehabilitation master plans will ensure management within a framework of ESD. Stakeholder and Focus Group meetings were designed to involve the community through the development of specific "Vision" for Duck River catchment.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
STATE (LEGISLATION)		
Catchment Management Act 1989	This is an Act to implement the total catchment management of natural resources. The Act promotes the sustainable use of natural resources and seeks to provide for, among others, stable soil and protective vegetation cover within water catchments.	The Act and its accompanying Regulation support total catchment management practices through the establishment of Catchment Management Boards.
Environmental Planning & Assessment Act, 1979	This Act and its accompanying Regulation are the primary legislation for landuse planning in NSW. The Act encourages, among other things: • the "proper management, development and conservation of natural and artificial resources"; • the "protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats"; and • "ecological sustainable development".	The Act ensures that future activities in the waterway corridors are undertaken within a framework of ESD, and that future maintenance and rehabilitation activities are permissible within each landuse zone within which the waterway corridor lies, and that the environmental impact of any activity or work has been properly assessed.
Fisheries Management Act 1994	This Act aims to "conserve develop and share the fishery resources of the State for the benefit of present and future generations". Among other things, the Act aims to "conserve threatened species, populations and ecological communities of fish and marine vegetation" and "to promote ecologically sustainable development".	This Act will ensure that any future activities in the waterway corridors will maintain and enhance aquatic habitat. Approvals may be required under this Act depending on the nature of the proposed works.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
Local Government Act 1993	This is an Act to guide the operation of Local Government. It requires Councils among other things, "to carry out activities, appropriate to the current and future needs of local communities …..". The Act directs Councils to prepare plans of management for, among others, community land. Where community land is categorised as a "natural area", and is further categorised as a "watercourse", specific directions are made as to the core management objectives. Where land is categorised as a "natural area" the core management objectives include: • to "conserve biodiversity and maintain ecosystem function"; • to "maintain the land,..., in its natural state and setting"; • to "provide for the restoration and regeneration of the land …..". Where land is further categorised as a "watercourse" the core management objectives also include: • to "manage watercourses so as to protect the biodiversity and ecological values of the instream environment, particularly in relation to water quality and water flows"; • to "manage watercourses so as to protect the riparian environment, particularly in relation to riparian vegetation and habitats and bank stability"; • to "restore degraded watercourses"; and • • to "promote community education and community access to and use of the watercourse".	The Council's management of its waterways, and in particular the preparation of waterways Maintenance and Rehabilitation master plans, is driven through compliance with this Act.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
Noxious Weeds Act 1993	This act aims to ensure appropriate measures for the control of noxious weeds throughout NSW, and requires control of weed species listed under various schedules.	As a landowner, Council has an obligation to control noxious weeds along waterway corridors. Noxious weeds declared in Parramatta LGA and recorded in Duck River catchment include: • Alligator Weed – Class 3 • Asparagus Fern – Class 4 • Asthma Weed – Class 4 • Balloon Vine – Class 4 • Blackberry – Class 4 • Bridal Creeper – Class 4 • Castor Oil Plant – Class 4 • Lantana – Class 4 • Large-leaved Privet – Class 4 • Madeira Vine – Class 4 • Montpellier Broom – Class 3 • Morning Glory – Class 4 • Sagittaria – Class 5 • Small-leaved Privet – Class 4
Protection of the Environment Operations Act 1997	This Act has as one of its objectives, among other things, to "protect, restore and enhance the quality of the environment in New South Wales having regard to the need to maintain ecologically sustainable development". The Act provides for a range of key pollution control legislation including waters, noise and air. These Regulations enable the classification of waters in NSW and regulate the permissible discharge of pollutants to those waters.	Parts of this Act regulate the discharge of pollutants into waterways in NSW.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
Protection of the Environment Administration Act 1991	The principal objective of this Act is to constitute the Environment Protection Authority and to provide for the integrated administration of environmental protection. The Act requires that regard be had to the need for ecologically sustainable development.	This Act ensures that future activities within waterway corridors are undertaken within a framework of ESD.
Soil Conservation Act 1938	This Act makes provision for the conservation of soil resources and for the mitigation of soil erosion.	A landowner may be directed under the provisions of this Act to undertake remedial works to reduce an erosion hazard. Should the bed or banks of any waterway be identified as such a hazard, Council, as a landowner, may be directed to carry out such works. The Masterplans will identify appropriate works.
Threatened Species Conservation Act 1995	An Act to conserve threatened species, populations and ecological communities. Among other things, the objects of this Act include: • to "conserve biological diversity and promote ecologically sustainable development" and • to "protect the critical habitat of those threatened species, populations and ecological communities that are endangered".	Where any activities, proposed to be carried out in the Masterplans, are located within or adjacent to an endangered species or critical habitat, compliance with this Act may require the preparation of an eight part test to assess likely impacts and if necessary, the preparation of a Species Impact Statement, or may require the provision of alternative conservation measures.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
Water Management Act 2000	This Act replaces the Water Act 1912 and the River and Foreshores Improvement Act 1948 and provides for "the protection, conservation and ecologically sustainable development of the water sources of the state". The Act sets out water management principles which include: • "water sources, floodplains and dependant ecosystems (including groundwaters and wetlands) should be protected and restored and, where possible, land should not be degraded"; • "habitats animals and plants that benefit from water or are potentially affected by managed activities should be protected and (in the case of habitats) restored".	This Act ensures that future activities in the waterway corridors are undertaken within a framework of ESD. If a 'controlled activity' is proposed on 'waterfront land', an approval is required under the Water Management Act. (s91) 'Controlled activities' include, inter alia: • the removal of material or vegetation from land by excavation or any other means; • the deposition of material on land by landfill or otherwise; or • any activity that affects the quantity or flow of water in a water source. 'Waterfront land' is defined as the bed of any river or lake, and any land lying between the river or lake and a line drawn parallel to and forty metres inland from either the highest bank or shore (in relation to non-tidal waters) or the mean high water mark (in relation to tidal waters).

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
STATE (POLICY)		
Flood Prone Land Policy	The primary objective of the policy is "to reduce the impact of flooding and flood liability on individual owners and occupiers of floodprone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible". The policy provides for among other things: "… the need to consider ways of maintaining and enhancing the riverine and floodplain ecology in the development of floodplain risk management plans".	Any future activity to be implemented through the master plans will be considered from a floodplain risk management perspective. Impacts of works or activities will be assessed against predicted impacts on flood behaviour. The policy sets out the process leading to the preparation of Floodplain Risk Management Plans, for the waterways and associated floodplains.
Rivers and Estuaries Policy	A Policy which has as its objectives the management of the State's Rivers and Estuaries in ways which: • "slow, halt or reverse the overall degradation in their systems"; • "ensure the long term sustainability of their essential biophysical functions"; and • "maintain the beneficial use of these resources."	One of the principles of this Policy is: "Environmentally degraded areas should be rehabilitated and their biophysical functions restored". This principle will guide the planned activities to be implemented through the Duck River master plans.
NSW Biodiversity Strategy	A strategy launched by the NSW Government in 1999. The strategy commits all government agencies to biodiversity conservation across all landscapes of the State. Goals of the strategy include, among others: "_ Protecting native species and ecosystems"; "_ Managing natural resources better"; and "_ Involving landowners and communities in biodiversity conservation".	This strategy ensures that State Government authorities involved throughout the preparation and implementation of master plans will focus broadly on biodiversity conservation.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
NSW Weirs Policy	The aim of this policy is to reduce and remediate the environmental impact of weirs. Main components of the policy require: _ the limiting of approvals for new and expanded weirs; _ the review of all existing weirs in NSW; and _ the consideration of the need for fishways ateach structure.	Elements of this policy will ensure the consideration of fish migration where in-stream structures (eg. a rock riffle) are proposed for implementation in the master plans.
NSW Fisheries – Policy and Guidelines for Aquatic Habitat Management and Fish Conservation	These Policies and Guidelines support one of the principal functions of NSW Fisheries, that is, the protection and management of fish resources, marine vegetation and aquatic habitat. General policies include, among others: “Fish and their aquatic habitats are important natural resources, and impacts on these resources must be assessed, in all development and planning procedures, using a precautionary approach”; and, “Terrestrial areas adjoining freshwater, estuarine and coastal habitats should be carefully managed in order to minimise landuse impacts on these aquatic habitats. As a precautionary approach, foreshore buffer zones at least 50 metres wide should be established and maintained, with their natural features and vegetation prescribed….”.	Elements of these policies and guidelines will provide direction as to the protection of aquatic habitat during the preparation and implementation of the waterway master plans.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
State Environmental Planning Policy (SEPP) 19 – Bushland in Urban Areas	SEPP 19 offers protection to natural bushland on areas zoned or reserved for public open space purposes	Where any works or activities to be implemented through the Masterplan impacts on areas of urban bushland, the provisions of SEPP 19 will apply. Those provisions relate to the extent that the Council must consider the conservation of any bushland proposed to be disturbed.
LOCAL GOVERNMENT PLANS		
Draft Parramatta Local Environmental Plan (LEP) 2008	Draft Parramatta LEP 2008 describes the planning controls which apply to landuse zones throughout the Parramatta local government area. Most of the land within the riparian corridor is zoned: • E2 - Environmental conservation • RE1 – Public recreation	Any action or work required through implementation of the Masterplan will be prepared in accordance with the objectives and requirements of the relevant land use zone.
Draft Parramatta Development Control Plan (DCP) 2008	The Draft DCP 2008 provides controls to support the standards set down in the Draft PLEP 2008. This document will consolidate all of Council's existing DCPs into a single document. The controls will include requirements for such issues as setbacks.	Future actions or works proposed to be implemented through the Masterplans will be assessed against the appropriate performance standards set down in Parramatta's Draft DCP 2008.
Parramatta City Council Tree Preservation Order	The purpose of Council's Tree Preservation Order is to: "establish procedures for the proper management of trees in order to minimise the unnecessary loss of significant tree resources".	Any activity or work required through implementation of the Masterplans, where trees or bushland may be impacted, will require consent under Council's Tree Preservation Order.

LEGISLATION OR POLICY TITLE	DESCRIPTION SUMMARY	EFFECTS ON MAINTENANCE AND REHABILITATION ACTIVITIES IN WATERWAY CORRIDORS
Stormwater Management Plans (various catchments)	During 1997, the NSW Environment Protection Authority (EPA) issued Notices to Councils in NSW requiring the preparation of Stormwater Management Plans (SMPs) for catchments under each Council's management. In metropolitan Sydney, most of the SMPs were completed and submitted to the EPA during 1999 and 2000. Each plan described existing catchment conditions, and established catchment values through a process of consultation. Management options and implementation strategies were developed to achieve aims and objectives set out in the SMPs.	Development of a "Vision" for each of Council's waterway corridors will be assisted by the range of catchment values developed during preparation of SMPs. It is expected that waterway Masterplans will be consistent with the aims and objectives of each relevant SMP.
Upper Parramatta River Catchment Trust: Green Corridors Vegetation Management Strategy	The Green Corridor Vegetation Management Strategy identifies a network of green corridors in the Upper Parramatta River catchment, which are to be protected and managed for biodiversity conservation. The strategy also provides an overview of the catchment's indigenous vegetation and habitat and identifies opportunities for achieving their conservation and enhancement.	Having regard to the rehabilitation of riparian vegetation along waterway corridors and the conservation of biodiversity, actions and implementation strategies proposed in waterway Masterplans should be consistent with those identified in the Green Corridors Vegetation Management Strategy.

8 APPENDIX TWO: AVIAN SPECIES RECORDED IN THE CATCHMENT

Table A 2. Avian species recorded in Duck River catchment and their location

COMMON NAME	SPECIES NAME	DUCK RIVER NORTH	DUCK RIVER SOUTH	CAMPBELL HILL-WADDANGALLI	UPPER DUCK CREEK	LOWER DUCK CREEK	LITTLE DUCK CREEK
Number of species by locality		43	28	31	12	6	10
Australasian Darter	*Anhinga melanogaster*	y				y	
Australian Magpie	*Gymnorhina tibicen*	y	y	y	y	y	y
Australian Raven	*Corvus coronoides*	y	y	y			
Australian White Ibis	*Threskiornis molucca*	y	y	y	y		y
Australian Wood Duck	*Chenonetta jabata*	y	y	y			
Azure Kingfisher	*Alcedo azurea*	y					
Barn Swallow	*Hirundo rustica*	y		y			
Bell Miner	*Manorina melanophrys*			y			
Black Bird	*Turdus merula*		y				
Black-faced Cuckoo Shrike	*Coracina novaehollandiae*			y			
Brown Thornbill	*Acanthiza pusilla*		y	y			
Bulbul*	*Pycnonotus jocosus*	y	y	y	y		y
Chestnut Teal	*Anas castanea*	y					
Common Starling*	*Sturnus vulgaris*			y			
Australian Coot	*Fulica atra*	y	y				
Crested Pigeon	*Ocyphaps lophotes*	y	y	y	y		y
Diamond Dove	*Geopelia cuneata*	y					
Domestic pigeon*	*Columba livia* f. *domestica*	y	y	y			
Dusky Moorhen	*Gallinula tenebrosa*	y	y				
Eastern Spinebill	*Acanthorhynchus tenuirostris*	y					
Galah	*Eolophus roseicapillus*					y	
Grey Butcherbird	*Cracticus torquatus*			y			
House Sparrow	*Passer domesticus*	y	y	y	y		
Indian (or common) Myna*	*Acridotheres tristis*	y	y	y	y		y
Jacky Winter	*Microeca fascinans*	y					
Koel (Common)	*Eudynamys scolopacea*		y				
Laughing Kookaburra	*Dacelo novaeguineae*	y	y	y			
Lewins Honeyeater	*Meliphaga lewinii*	y				y	
Little wattlebird	*Anthochaera chrysoptera*	y		y			
Magpie-lark (Pee wee)	*Grallina cyanoleuca*	y	y	y	y		y
Mallard	*Anas platyrhynchos*		y				
Masked Lapwing	*Vanellus miles*			y	y		
Noisy Miner	*Manorina melanocephala*	y	y	y	y	y	y
Olive-backed Oriole	*Oriolus sagittatus*	y					
Pacific Black duck	*Anas superciliosa*	y	y	y	y		

Pekin Duck (domestic duck breed)*	*Anas platyrhynchos domestica*	y					
COMMON NAME	SPECIES NAME	DUCK RIVER NORTH	DUCK RIVER SOUTH	CAMPBELL HILL-WADDANGALLI	UPPER DUCK CREEK	LOWER DUCK CREEK	LITTLE DUCK CREEK
Pied Currawong	*Strepera graculina*	y	y	y	y		
Purple Swamp Hen	*Porphyrio porphyrio*	y					
Rainbow Lorikeet	*Trichoglossus haematodus*	y		y			y
Red-browed Finch	*Neochmia temporalis*	y	y	y			
Red-rumped Parrot	*Psephotus haematonotus*		y				
Reed warbler	*Acrocephalus australis*	y					
Restless Flycatcher	*Myiagra inquieta*	y	y	y			y
Rock Dove*	*Columba livia*		y				
Scarlet Robin**	*Petroica boodang*			y			
Silvereye**	*Zosterops lateralis*			y			
Spotted Turle-Dove*	*Streptopelia chinensis*	y	y	y			y
Striated Pardalote	*Pardalotus striatus*	y	y				
Sulphur-crested Cockatoo	*Cacatua galerita*	y			y		
Superb Fairy-wren	*Malurus cyaneus*	y	y	y		y	
Tawny Frogmouth	*Podargus strigoides*	y	y				
Welcome Swallow	*Hirundo neoxena*	y					
White-plumed Honeyeater	*Lichenostomus penicillatus*	y					
Willie Wagtail	*Rhipidura leucophrys*	y		y			
Yellow Thornbill	*Acanthiza nana*	y					
Yellow-faced Honeyeater	*Lichenostomus chrysops*	y		y			
Yellow-tailed Black Cockatoo	*Calyptorhynchus funereus*	y					

9 APPENDIX THREE: OTHER FAUNA SPECIES RECORDED IN DUCK RIVER CATCHMENT

Table A 3. Other species recorded in Duck River catchment and their location

COMMON NAME	SPECIES NAME	DUCK RIVER NORTH	DUCK RIVER SOUTH	CAMPBELL HILL-WADDANGALLI	UPPER DUCK CREEK	LOWER DUCK CREEK	LITTLE DUCK CREEK
FROGS							
Bleating Tree Frog	*Litoria dentata*		y				
Common Froglet	*Crinia signifera*		y				y
Eastern Banjo Frog	*Limnodynastes dumerilii*	y	y	y			y
Peron's Tree Frog	*Litoria peronii*			y			
Green Tree Frog	*Litoria caeralea*	y	y				y
REPTILES							

COMMON NAME	SPECIES NAME	DUCK RIVER NORTH	DUCK RIVER SOUTH	CAMPBELL HILL-WADDANGALLI	UPPER DUCK CREEK	LOWER DUCK CREEK	LITTLE DUCK CREEK
Delicate or Garden Skink	*Lampropholis delicata*		y			y	
Eastern Blue-tongue Lizard	*Tiliqua scincoides scincoides*	y		y			
Eastern Blue-tongue Lizard	*Tiliqua scincoides*	y					
Eastern Water Dragon	*Physignathus lesueurii*	y	y				
Eastern Water Skink	*Eulamprus quoyii*	y	y	y			
Grass Sun-skink	*Lampropholis guichenoti*	y	y			y	
Jacky Lizard	*Amphibolurus muricatus*		y				
Red-bellied Black Snake	*Pseudechis porphyriacus*	y					
MAMMALS							
Grey-headed Flying-fox**	*Pteropus poliocephalus*	y	y				y
Eastern Bent-wing Bat**	*Miniopterus schreibersii oceanensis*		y	y			
Gould's Wattle Bat	*Chalinolobus gouldii*		y	y			
Long-eared Bat	*Nyctophilus* sp			y			
Southern Freetail Bat (short penis)	*Mormopterus* sp. 2		y				
White-striped Free-tailed Bat	*Tadarida australis*			y			
Yellow-bellied Sheathtail Bat**	*Saccolaimus flaviventris*		y				
Domestic Cat*	*Felis catus*	y	y		y	y	y
Domestic Dog*	*Canis lupus*	y	y	y			y
Rabbit*	*Oryctolagus cuniculus*			y			
Red Fox	*Vulpus vulpus*		y	y			
FISH							
Common Carp*	*Cyprinus carpio*	y	y				
Mosquito Fish*	*Gambusia holbrookii*		y	y			
OTHER HERPS							
Long necked turtle	*Chelodina longicollis*	y					
THREATENED INVERTEBRATES							
Cumberland Land Snail	*Meridolum corneovirens*		y				

10 APPENDIX FOUR: NATIVE FLORA SPECIES RECORDED IN DUCK RIVER CATCHMENT

Table A 4. Native flora species recorded in Duck River catchment and their location

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Acacia binervia	Coastal Myall		y
Acacia brownei			y
Acacia decurrens	Sydney Green Wattle	y	y
Acacia falcata		y	y
Acacia longifolia var. longifolia	Sydney Golden Wattle	y	y
Acacia parramattensis	Parramatta Green Wattle	y	y
Acacia pubescens	Downy Wattle	y	y
Acacia stricta	Straight Wattle		y
Acacia ulicifolia	Prickley Moses	y	y
Adiantum aethiopicum	Common Maidenhair Fern	y	y
Agrostis aemula	Blown Grass		y
Agrostis avenacea	Blown Grass		y
Allocasuarina torulosa	Forest Oak		y
Alternathera denticulata	Lesser Joyweed		y
Amyema gaudichaudii			y
Angophora floribunda	Rough Barked Apple	y	y
Aristida ramosa	Three-awn Speargrass	y	y
Aristida vagans	Three-awn Speargrass	y	y
Arthrodium minus	Small Vanilla Lily		y
Arthropoduum milleflorum	Pale Vanilla Lily		y
Asperula conferta	Common Woodruff		y
Asterolasia correifolia			y
Astoloma humifusum			y
Billardiera scandens	Apple Berry	y	y
Boronia polygalifolia	Milkwort Boronia		y
Bossiaea buxifolia			y
Bossiaea prostrata			y
Bothriochloa decipiens			y
Bothrochloa macra			y
Brachiara foliosa			y
Brachychiton populneus	Kurrajong		y
Brachycome angustifolia var. angustifolia			y
Breynia oblongifolia	Coffee Bush	y	y
Brunoniella australis	Blue Trumpet	y	y
Brunoniella pumilio	Dwarf Trumpet		y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Bursaria spinosa	Blackthorn	y	y
Caesia parviflora	Pale Grass Lily		y
Caesia vittata	Blue Grass lily		y
Callistemon linearifolius	Bottlebrush		y
Callistemon linearis	Narrow-leaved Bottlebrush		y
Callistemon pinifolius	Bottlebrush		y
Callistemon rigidus	Stiff Bottlebrush	y	y
Callistemon salignus	Willow Bottlebrush		y
Calotis cuneifolia	Blue Burr-daisy	y	y
Calotis lappulacea	Wooly-headed Burr-daisy		y
Carex inversa			y
Cassinia aculeata	Dogwood		y
Cassytha glabella	Slender Devil's Twine		y
Cassytha pubescens	Common Devils Twine	y	y
Casuarina glauca	Swamp She-Oak	y	y
Cayratia clematidea		y	
Centella asiatica	Centella	y	y
Centipeda minima	Spreading Sneezeweed		y
Cheilanthes sieberi ssp sieberi	Mulga Fern	y	y
Chorizema parviflorum			y
Clematis aristata	Old Man's Beard		y
Clematis glycinoides var. glycinoides	Forest Clematis, Old Man's Beard	y	y
Commelina cyanea	Scurvy Weed	y	y
Correa reflexa		y	y
Cotula australis			y
Cotula coronopifolia	Water Buttons, Marsh Daisy		y
Crassula sieberana	Austral Stonecrop		y
Cymbopogon refractus	Barbed-wire Grass	y	y
Cynodon dactylon	Common Couch		y
Cyperus gracilis	Slender Sedge	y	
Cyperus mirus	Sedge		y
Cyperus polystachyos	Sedge		y
Austrodanthonia linkii var. fulva	Wallaby Grass	y	y
Austrodanthonia linkii var. linkii	Wallaby Grass		y
Austrodanthonia longifolia	Wallaby Grass		y
Austrodanthonia racemosa	Wallaby Grass	y	y
Austrodanthonia setacea	Wallaby Grass		y
Austrodanthonia tenuior	Wallaby Grass	y	y
Daviesia ulicifolia		y	y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Dendrophthoe vitellina			y
Desmodium rhytidophyllum			y
Desmodium varians			y
Deyeuxia appressa	Bent Grass		y
Deyeuxia quadriseta	Reed Bent Grass		y
Dianella caerulea	Blue Flax Lily		y
Dianella laevis	Flax Lily		y
Dianella longifolia	Flax Lily	y	
Dianella revoluta	Mauve Flax Lily	y	y
Dichelacne micrantha	Shorthair Plume Grass	y	y
Dichelacne rara	Plume Grass		y
Dichondra repens	Kidney Weed	y	y
Dichopogon strictus	Grass Lily		y
Digitaria parviflora	Small-flower Fingergrass		y
Digitaria ramularis	Fingergrass		y
Dillwynia juniperina	Parrot Pea		y
Dillwynia sieberi		y	
Diuris brevifolia	Double Tail		y
Diuris maculata	Spotted Double Tail		y
Diuris sulphurea	Tiger Orchid		y
Dodonaea triquetra	Hop Bush	y	y
Drosera peltata	Sundew		y
Dysphania littoralis			y
Echinochloa telmatophila			y
Echinopogon caespitosus var. caespitosus	Tufted Hedgehog Grass	y	y
Echinopogon ovatus	Hedgehog Grass	y	y
Einadia hastata	Einadia	y	y
Einadia nutans ssp. nutans	Einadia		y
Einadia polygonoides	Einadia		y
Einadia trigonos	Einadia		y
Entolasia marginata	Right-angle Grass	y	y
Entolasia stricta	Right-angle Grass	y	y
Epilobium billardierianum ssp. billardierianum	Willow Herb		y
Epilobium billardierianum ssp. cinereum	Willow Herb		y
Eragrostis philippica	Love Grass		y
Eragrostis brownii	Browne's Love Grass	y	y
Eragrostis parviflora	Love Grass		y
Eremophila debilis		y	y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Eriochloa pseudoacrotricha	Early Spring Grass		y
Eucalyptus amplifolia	Cabbage Gum	y	y
Eucalyptus crebra		y	
Eucalyptus fibrosa ssp. fibrosa	Broad-leaved Ironbark	y	y
Eucalyptus globoidea	White Stringybark	y	y
Eucalyptus longifolia	Woolybutt		y
Eucalyptus moluccana	Grey Box	y	y
Eucalyptus moluccana X Eucalyptus fibrosa ssp. fibrosa			y
Eucalyptus punctata ssp. punctata	Grey Gum	y	y
Eucalyptus resinifera	Red Mahogany		y
Eucalyptus tereticornis	Forest Red Gum		y
Euchiton sphaericus		y	
Eustrephus latifolius	Wombat Berry	y	y
Exocarpos cupressiformis	Cherry Ballart	y	y
Exocarpos strictus	Dwarf Currant		y
Gahnia aspera	Saw Sedge	y	y
Gahnia melanocarpa	Saw Sedge		y
Geranium solanderi	Cutleaf Cranesbill		y
Glochidion ferdinandi	Cheese Tree		y
Glossogyne tenuifolia	Cobblers Tack		y
Glycine clandestina	Love Creeper	y	y
Glycine microphylla	Lesser Love Creeper	y	
Glycine tabacina	Love Creeper		y
Gompholobium glabratum	Golden Glory Pea		y
Gonocarpus tetragynus	Poverty Raspwort		y
Goodenia bellidifolia ssp. bellidifolia	Daisy-leaved Goodenia		y
Goodenia hederacea subsp. hederacea	Violet-leaved Goodenia	y	y
Goodenia ovata	Hop Goodenia		y
Goodenia paniculata	Swamp Goodenia		y
Hakea sericea	Bushy Needlebush		y
Hardenbergia violacea	Hardenbergia	y	y
Helichrysum apiculatum	Paper Daisy		y
Helichrysum diosmifolium	Paper Daisy		y
Helichrysum scopioides	Paper Daisy		y
Hibbertia aspera	Guinea Flower		y
Hibbertia diffusa	Guinea Flower		y
Hibbertia pedunculata	Guinea Flower		y
Hovea longifolia var. longifolia			y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Hydrocotyle peduncularis	Native Pennywort		y
Hypericum gramineum	Native St Johns Wort		y
Hypoxis hygrometrica	Yellow Stars		y
Imperata cylindrica var. major	Blady Grass	y	y
Indigofera australis	Indigofera	y	y
Isotoma fluviatalis ssp. fluviatalis			y
Jacksonia scoparia	Dogwood		y
Juncus bufonius	Juncus		y
Juncus homalocaulis	Juncus		y
Juncus planifolius	Broad-leaf Rush		y
Juncus sarophorus	Juncus		y
Juncus usitatus	Common Rush		y
Kennedia rubicunda	Dusky Coral Pea		y
Kunzea ambigua	Tick Bush		y
Lachnagrostis filiformis		y	
Lagenifera sp.			y
Lagenifera stipatata			y
Lasiopetalum ferrugineum		y	
Lasiopetalum parviflorum	Rusty Petals		y
Laxmannia gracilis		y	
Lepidosperma laterale		y	
Lepidosperma lineare	Sword Sedge		y
Leptospermum attenuatum	Tea Tree		y
Leptospermum flavescens	Tea Tree		y
Leucopogon juniperinus	Bearded Heath	y	y
Leucopogon lanceolatus var. lanceolatus	Lance Beard Heath		y
Linum marginale	Native Flax		y
Lissanthe strigosa	Native Cranberry	y	y
Lomandra filiformis ssp. coriacea	Mat Rush	y	y
Lomandra longifolia	Mat Rush	y	y
Lomandra multiflora ssp. multiflora	Mat Rush	y	y
Macrozamia spiralis	Burrawang	y	y
Maytenus silvestris		y	y
Melaleuca decora	White Feather Honeymyrtle	y	y
Melaleuca erubescens	Pink Honeymyrtle		y
Melaleuca linariifolia	Snow-in-Summer		y
Melaleuca nodosa	Ball Honeymyrtle	y	y
Melaleuca quinquenervia		y	
Melaleuca sieberi		y	

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Melaleuca styphelioides	Prickly-leaved Paperbark	y	y
Mentha saturejoides	Creeping Mint		y
Microlaena stipoides var. stipoides	Weeping Meadow Grass	y	y
Mitrasacme polymorpha	Mitreworts		y
Muellerina eucalyptioides		y	y
Myoporum insulare	Boobialla		y
Notelaea longifolia f. longifolia	Mock Olive	y	y
Notelaea ovata	Mock Olive		y
Olearia microphylla	Bridal Daisy Bush		y
Olearia visciudula	Daisy Bush		y
Homalanthus populifolius	Bleeding Heart Tree	y	y
Omphacomeria acerba			y
Opercularia aspera	Coarse Stinkweed		y
Opercularia diphylla	Stinkweed	y	y
Opercularia varia	Variable Stinkweed		y
Oplismenus imbecillis	Basket Grass		y
Oxalis corniculata			y
Oxalis perennans		y	
Pandorea pandorana ssp. pandorana	Wonga Vine	y	y
Panicum effusum	Hairy Panic		y
Panicum simile	Two-colour Panic		y
Paspalidium aversum			y
Paspalidium criniforme			y
Paspalidium radiatum			y
Paspalum vaginatum	Saltwater Couch		y
Pelargoium inodorum	Wild Geranium		y
Pellaea falcata	Sickle Fern		y
Persicaria lapathifolium	Knotweed		y
Persicaria sp. A, once *Polygonum decipiens*	Knotweed		y
Persoonia linearis	Narrow-leaved Geebung	y	y
Phragmites australis	Giant Reed		y
Phyllanthus gasstroemii	Spurge		y
Pimelea linifolia	Rice Flower	y	y
Pittosporum revolutum	Pittosporum		y
Pittosporum undulatum	Sweet Pittosporum	y	y
Plectranthus parviflorus	Cockspur		y
Poa labillardierei	Snow Grass	y	
Polymeria calycina	Swamp Bindweed	y	y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Polyscias sambucifolia	Elderberry Panax		y
Pomaderris ferruginea	Rusty Pomaderris		y
Pomaderris lanigera	Wooly Pomaderris		y
Poranthera microphylla			y
Pratia purpurascens	Whiteroot	y	y
Pseuderanthemum variabile	Pastel Flower	y	
Pseudognaphalium luteoalbum	Jersey Cudweed		y
Pterostylis nutans	Parrot's Beak Orchid		y
Pultenaea retusa	Notched Bush Pea		y
Pultenaea villosa	Hairy Bush Pea	y	y
Ranunculus lappaceus	Common Buttercup		y
Rapanea variabilis	Muttonwood		y
Rubus parvifolius	Native Raspberry		y
Rulingia pannosa			y
Rumex brownii	Swamp Dock		y
Sarcopetalum harveyanum	Pearl Vine		y
Scaevola albida	Pale Fan Flower		y
Senecio hispidulum var. hispidulus	Rough Groundsel		y
Senecio hispidulus var. dissectus	Rough Groundsel		y
Senecio linearifolius	Groundsel		y
Senecio quadridentatus	Groundsel		y
Sporobolus creber		y	
Sporobolus elongatus	Couch		y
Stackhousia viminea			y
Austrostipa pubescens	Tall Speargrass		y
Austrostipa rudis ssp. nervosa	Speargrass	y	y
Austrostipa scabra	Speargrass		y
Syncarpia glomulifera	Turpentine		y
Thelymitra pauciflora	Slender Sun Orchid		y
Themeda australis	Kangaroo Grass	y	y
Thysanotus tuberosus	Fringe Lily		y
Tricoryne elatior	Yellow Rush-Lily		y
Tricoryne simplex	Yellow Rush-Lily		y
Triplodiscus pygmaeus			y
Tylophoroa barbata		y	y
Typha domingensis	Bullrush		y
Typha orientalis	Bullrush		y
Vernonia cinerea var. cinerea			y
Veronica calycina	Speedwell		y

SPECIES NAME	COMMON NAME	DUCK RIVER BUSHLAND	UPPER DUCK RIVER (OTHER)
Veronica plebeia	Speedwell		y
Viola betonicifolia	Purple Violet		y
Vittadinia cuneata	Fuzzweed		y
Vittadinia. muelleri	Fuzzweed		y
Wahlenbergia communis	Tufted Bluebell		y
Wahlenbergia gracilis	Native Bluebell		y
Wahlenbergia stricta	Tall Bluebell		y
Xanthorrhoea resinosa ssp. concava	Grass Tree		y
Zieria smithii	Sandfly Zieria	y	y
Zornia dyctiocarpa			y

11 APPENDIX FIVE: RESULTS OF AHIMS BASIC SEARCHES

FOR INTERNAL USE ONLY