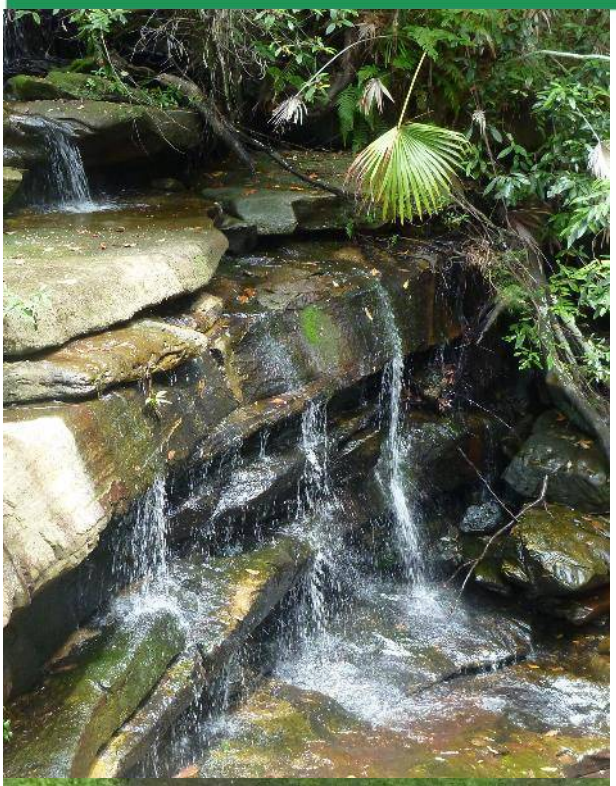
Ingleside Precinct

Riparian Corridors Assessment

Prepared for
Department of Planning and Environment

October 2016



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Abbreviations

Abbreviation	Description
BCAA	Biodiversity Certification Assessment Area
BCAM	Biodiversity Certification Assessment Methodology
BCAR	Biodiversity Certification Assessment Report
DoE	Commonwealth Department of the Environment
DP&E	NSW Department of Planning and Environment (formerly NSW Department of Planning)
DPI	Department of Primary Industries
DPI Water	Department of Primary Industries, Water (formally NSW Office of Water – NOW)
EEC	Endangered Ecological Community
ELA	Eco Logical Australia Pty Ltd
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FM Act	NSW *Fisheries Management Act 1994*
LGA	Local Government Area
NW Act	NSW *Noxious Weeds Act 1993*
OEH	NSW Office of Environment and Heritage (formerly DECCW, DECC, DEC)
PLEP	Pittwater Local Environment Plan (2010)
TS	Threatened Species
TSC Act	NSW *Threatened Species Conservation Act 1995*
VRZ	Vegetated riparian zone
WSUD	Water Sensitive Urban Design
WM Act	NSW *Water Management Act 2000*

Executive summary

Eco Logical Australia was engaged by the NSW Department of Planning and Environment to identify and assess the ecological values of riparian lands within the Ingleside Precinct. The purpose of assessment was to identify riparian constraints and opportunities within the Precinct, and to inform the preparation of the Structure Plan for the site. The Structure Plan will guide the future rezoning and development outcomes within the Precinct.

The site contains a number of recognised watercourses including Wirreanda, Crystal, and Cicada Glen Creeks. The subcatchments for these three watercourses are characterised by forested reserves outside of the Precinct, and within the Precinct approximately half of the vegetation has been cleared for a mix of uses including residential and rural-residential. There are also a number of tributaries of smaller, local creeks as well as those that serve as the headwaters of larger creeks including Mullet and Narrabeen Creeks. The site is bound by a number of sensitive environments including the Ku-ring-gai Chase National Park to the west and north, Garigal National Park to the south, and the Ingleside Chase Reserve and Narrabeen Lagoon to the east. In this regard, the water courses within the site serve as partial corridors linking these areas, while also influencing their environmental integrity with inflows of sediment, nutrients and other contaminants in the form of urban stormwater.

Within or immediately adjacent to the Precinct there are 20 watercourse reaches in varying condition. The majority of these are in a degraded condition (9), with reminder being either in moderate (5) or near intact condition (2). The condition of the remaining watercourses was not assessed given their location within the Precinct or because of access limitations. Nevertheless, all streams were evaluated in terms of their conservation and recovery potential which identified the majority (10) to have high recovery potential, 6 with moderate and 4 with low recovery potential.

In order to protect and enhance the riparian values of the Precinct, individual water courses were mapped and appropriate riparian corridor widths applied to the respective watercourse. All streams within the Precinct were identified as either a 1st or 2nd order watercourse based on the Strahler stream classification methodology. Broad recommendations have also been provided to guide the development of the Structure Plan and to afford adequate protection of the watercourses based on their position within the catchment, current condition, conservation and recovery potential, and legislative or agency requirements.

It will be important to ensure that key watercourses are protected and enhanced to prevent any increase in adverse environmental impacts on the adjoining sensitive environments as urban development intensifies within the Precinct. The layout and proposed land uses identified in the Structure Plan seek to separate water and environmental land use from neighbouring development. All creeks have been assigned the mandatory riparian buffers. In most cases the buffer areas allowed for in the Structure Plan well exceed the minimum requirements, and vary from 23m to over 400m in width.

Over 60% of the riparian corridors are protected and will be managed for environmental conservation including all those areas identified as high conservation priority in this report. A remaining 14% are in National Park or Reserves, 6% within specific water management land uses, less than 5% in rural and less than 3% in private open space. A summary of land uses applied to riparian areas is provided in **Table 1** (overleaf).

There are no additional roads crossing riparian areas identified in the Structure Plan. Existing road alignments have been intentionally retained for this purpose. Stormwater will be detained prior to entering core riparian areas.

Table 1: Summary of the length of riparian corridor land uses

Land Use	Total Length of Watercourses (km)	Percent of Watercourse Length
Environmental Conservation	11.98	62.3%
Environmental Management	0.32	1.7%
Existing Road	0.28	1.5%
Houses	0	0%
Houses on Larger Lots	0.01	0.1%
Major Road	0.46	2.4%
Outside of precinct	0.59	3.1%
National Park	1.52	7.9%
Park	1.41	7.3%
Private Open Space	0.53	2.8%
Mona Vale Road Corridor	0.08	0.4%
Rural	0.88	4.6%
Water Management	1.16	6.0%
Total	**19.22 km**	100.0%

The Structure Plan supports the assessed importance of the riparian functions of this upper catchment area by exceeding buffer distances and complying with DPI Water guidelines. As the current condition of the riparian corridors varies widely, but with many areas in the centre of the precinct in degraded condition, the proposed Structure Plan offers an opportunity to improve aquatic habitat and riparian connectivity.

1 Introduction

1.1 Project Background

The Ingleside Release Area (Ingleside Precinct) is located within the North East Subregion in the Pittwater Local Government Area (LGA). In May 2016 Pittwater Council was merged into a new body, the Northern Beaches Council. As this report was prepared prior to these changes, it makes reference to the former council. The plans and strategies of the former council continue to apply to the former local government area until the new council prepares its own plans and strategies.

The majority of the Precinct is zoned Rural Landscape (RU2) under Pittwater Local Environment Plan (LEP) 2014, which has a range of permissible uses. Ownership is a mix of public and private ownership, with approximately one third in State Government ownership.

The Minister for Planning and Council have agreed to undertake a Precinct Planning Process for the Ingleside Precinct to confirm development potential and to establish development controls to enable development consistent with that potential.

Eco Logical Australia Pty Ltd (ELA) has been engaged by Department of Planning and Environment (DP&E) to prepare a Riparian Corridors Assessment to inform and asses the development of a Structure Plan for the Precinct.

ELA has also been engaged to undertake Biodiversity and Habitat Conservation Assessment (using the Biodiversity Certification Assessment Methodology), Bio-certification Strategy and Bushfire Assessment for the Ingleside Precinct, the results of which are presented in separate documents.

1.2 Study area description

The Ingleside Precinct is approximately 700 hectares (**Figure 1**). The Precinct is bounded by major roads, conservation areas and other lands. Mona Vale Road transects the Precinct and also forms part of its south-western boundary.

Significant conservation lands are immediately adjacent to the Precinct, these include: Ku-ring-gai Chase National Park to the north and northwest, Garigal National Park to the south, Katandra Bushland Sanctuary to the east and Ingleside Chase Reserve to the east. The Katandra Bushland Sanctuary is Crown Land managed by Katandra Bushland Sanctuary Trust. The Healesville Estate, Ingleside Park and Haydon Reserve have been combined to create Ingleside Chase Reserve.

The vegetation types within the Ingleside Precinct are strongly influenced by the topography of the area. Heath vegetation is associated with shallow soils and rocky outcrops and generally occur at higher elevations within the Precinct. The topography slopes down to the north and east where at times the terrain rapidly falls away to a series of steep moist gullies. Overall, topography within the Ingleside Precinct varies from steep slopes to gently undulating terrain.

There are a number of watercourses within the Precinct, including Wirreandra Creek that forms part of the western boundary of the site, and Crystal Creek, which flows in a westerly direction along part of the northern boundary before joining Wirreandra Creek, and then flowing northwards, through Ku-ring-gai Chase National Park, into McCarrs Creek (**Figure 2**). Cicada Glen Creek drains in a northerly direction and also discharges into McCarrs Creek. In the eastern part of the Precinct, there are a number of

tributaries of Mullet and Narrabeen Creeks, which drain in an easterly direction and discharge to Narrabeen Lagoon.

Riparian corridors are generally characterised by moist sclerophyll vegetation communities that have been partially cleared to varying degrees to accommodate a range of land uses including residential, light industrial, rural residential and public open space. Typically, most watercourses have been impacted by exotic weeds and stormwater runoff, although within less disturbed subcatchments some remain in near intact condition.

1.3 Project objectives

The objectives of this report are to:

- Classify watercourses using the Strahler method and to identify riparian corridor boundaries
- Assess the ecological values and conservation and recovery potential of identified watercourses
- Identify recommendations for the protection of watercourses and riparian corridors
- Provide cross section drawings of the riparian zone

The information from this report will be considered in protecting of aquatic animals and their habitats as part of the rezoning. A separate macroinvertebrate study has also been prepared (Cardno 2016).

Riparian corridors are considered in the Biodiversity Assessment Report as part of the development of ecological corridor connections.

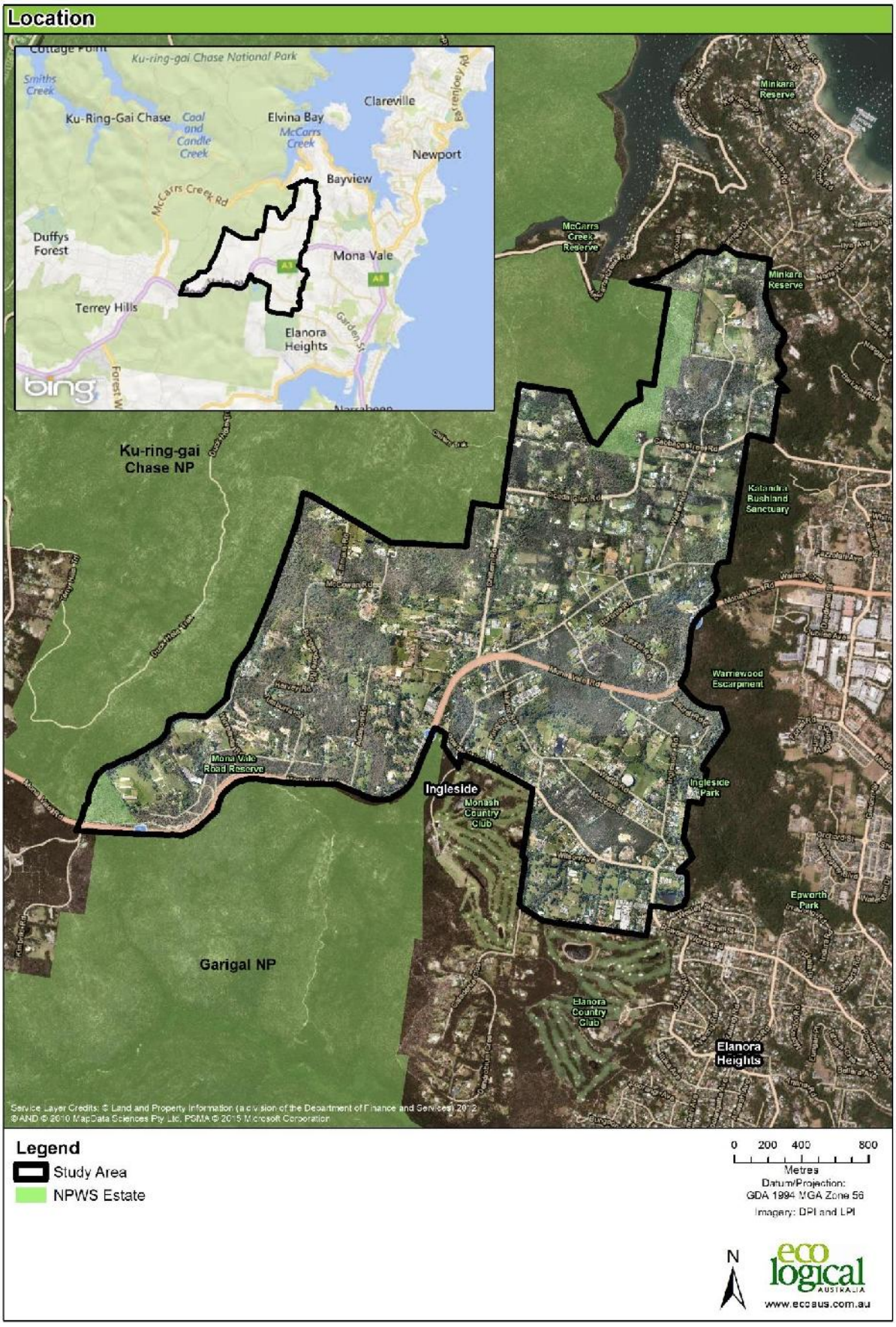

Figure 1: Ingleside Precinct locality map

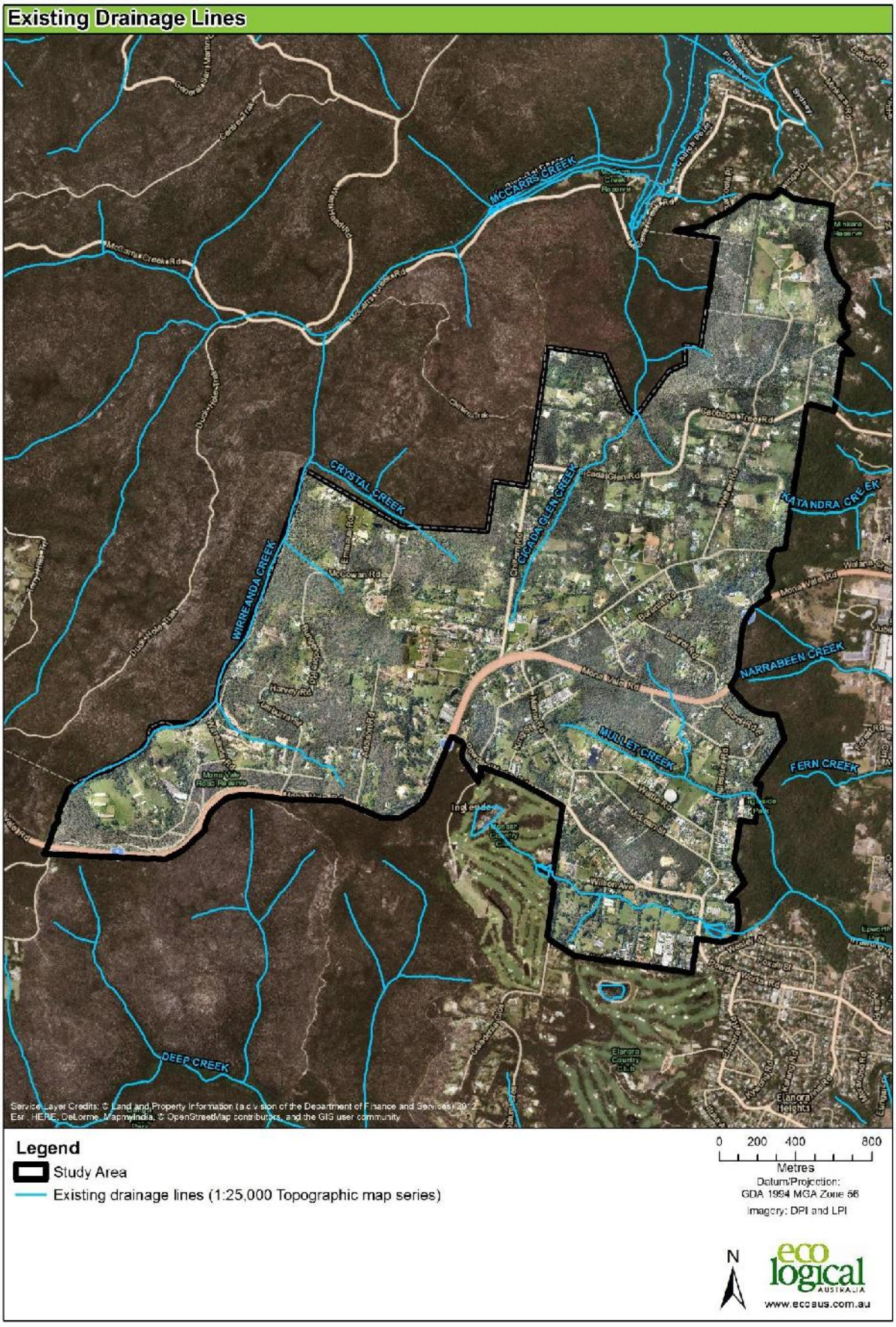

Figure 2: Ingleside Precinct drainage lines map

2 Statutory Framework

A variety of Commonwealth, State and local legislation are relevant to the Precinct and are briefly described below.

2.1 Commonwealth

Environment Protection and Biodiversity Conservation Act 1999

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a national scheme for protecting the environment and conserving biodiversity values. The EPBC Act stipulates that approval from the Commonwealth Environment Minister is required if a development is likely to have a significant impact on matters considered to be of National Environmental Significance (MNES).

For the Ingleside Precinct there are a number of threatened species that are listed under the EPBC Act and therefore considered MNES. However, relevant species will be addressed in the separate Biodiversity Assessment (refer to **Section 3.2.1**).

2.2 State

Environmental Planning and Assessment Act 1979

The NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) is the principal planning legislation for the state, providing a framework for the overall environmental planning and assessment of development proposals. Various legislation, such as the NSW *Threatened Species Conservation Act 1995* (TSC Act), are integrated with the EP&A Act and have been reviewed separately.

In determining a development application, the consent authority is required to take into consideration the matters listed under Section 79C of the EP&A Act that are relevant to the application. Key considerations include:

- Any environmental planning instrument, including drafts
- The likely impacts of the development
- The suitability of the site for the development
- Any submissions made in accordance with the EP&A Act or regulations
- The public interest

Threatened Species Conservation Act 1995

The *Threatened Species Conservation Act 1995* (TSC Act) aims to protect and encourage the recovery of threatened species, populations and communities listed under the Act. The TSC Act is integrated with the EP&A Act and requires consideration of whether a development under Part 4 or an activity under Part 5 of the Act is likely to significantly affect threatened species, populations and ecological communities or their habitat.

Under s.126G of the TSC Act bio-certification was introduced to confer certification on land if the Minister is satisfied that it will lead to the overall improvement or maintenance of biodiversity values – typically at a landscape scale. The effect of granting certification is that any development or activity requiring consent (Under Part 4 and 5 of the EP&A Act respectively) is automatically considered to be development that is

not likely to significantly affect threatened species. Certification removes the need to address threatened species considerations and the assessment of significance or seven part tests (s.5A of the EP&A Act), including the preparation of species impact statements (SIS).

The Biodiversity Assessment that is being undertaken for the Precinct is being conducted in accordance with Biodiversity Certification Assessment Methodology (BCAM), with the ultimate intention of applying to the Minister for the land to be bio-certified. In this regard, there are a number of aquatic species that are listed under the TSC Act, however potential impacts on these species are being assessed under the BCAM and will form part of the Biodiversity Assessment Report that is being prepared in conjunction with this study (refer to **Section 3.2.1**)

Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) aims to conserve, develop and share the fishery resources of NSW for the benefit of present and future generations. The FM Act defines 'fish' as any marine, estuarine or freshwater fish or other aquatic animal life at any stage of their life cycle. This includes insects, molluscs (eg. Oysters), crustaceans, echinoderms, and aquatic polychaetes (eg. Beachworms), but does not include whales, mammals, reptiles, birds, amphibians or species specifically excluded (eg. some dragonflies are protected under the TSC Act instead of the FM Act). Like the TSC Act, potential impacts on threatened species that are listed under the Act must also be assessed, however, unlike the TSC Act bio-certification does not switch off the requirements of the FM Act. In addition, if any activity occurs that will block fish passage, a permit under this FM Act will also be required.

For this assessment, none of the species listed under the FM Act are considered likely to occur in the Precinct (refer to **Section 3.2.1**).

Water Management Act 2000

The *Water Management Act 2000* and *Water Act 1912* control the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in New South Wales. 'Water sources' are defined very broadly and include any river, lake, estuary, place where water occurs naturally on or below the surface of the ground and coastal waters.

If a 'controlled activity' is proposed on 'waterfront land', an approval is required under the Water Management Act (s.91). 'Controlled activities' include:

- the construction of buildings or carrying out of works;
- 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 (40m) 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). It is an offence to carry out a controlled activity on waterfront land except in accordance with an approval.

DPI Water were consulted on the draft Structure Plan and on 12/5/2015 they provided advice that they were supportive of the draft Structure Plan in terms of riparian corridors.

Noxious Weed Act 1993

The objectives of the NSW *Noxious Weeds Act 1993* (NW Act) are to identify which noxious weeds require control measures, identify control measures suitable to those species, and to specify the responsibilities of both public and private landholders for noxious weed control. Some noxious aquatic weeds were identified within the study area and are discussed in **Section 3.2.3**.

2.3 Local

Pittwater Local Environmental Plan 2014

The Pittwater Local Environmental Plan 2014 (PLEP) is the principal planning instrument for the Ingleside Precinct. The LEP sets out the current planning framework and establishes the requirements for the use and development of land in the LGA, including the Ingleside Precinct.

3 Methods

As required by statutory authorities, this riparian assessment follows the methods outlined by the Department of Primary Industries, Water (DPI Water). This method assigns a Vegetated Riparian Zone (VRZ) width relative to the stream's corresponding Strahler Stream Order classification.

Specifically, this riparian assessment includes:

- Mapping of Top of Bank using a differential GPS,
- Classification of the condition of stream reaches within the study area,
- Categorisation of each stream using the Strahler stream order methodology,
- Application of VRZ widths based on stream order,
- Identification of Groundwater Dependent Ecosystems within the Precinct,
- Identification of key riparian areas recommended for protection and rehabilitation.

3.1 Riparian corridor mapping and condition assessment

The riparian categorisation was based on all 'blue lines' appearing on the 1:25,000 topographic map series **(Figure 2)**, combined with field assessment data and analysis of top of bank results. Although higher definition stream mapping has been conducted by Pittwater Council (2013), DPI Water require the 1:25,000 stream mapping to be assessed and validated under the WM Act. Therefore, additional drainage lines mapped in the Pittwater Stream Mapping Project do not contribute to the stream order numbering of this assessment. Although the Council mapping shows additional drainage lines within the study area, these are only small tributaries feeding the dominate streams used in this study (for example, see maps in Pittwater Council 2013, Volume 2, Figs. 2.08, 2.13, 2.14 and 2.15).

A survey of the Top of Bank (TOB) for all accessible watercourses in the Precinct was conducted by an experienced aquatic/riparian ecologist and ecological assistant with a differential GPS (accuracy 50 – 70 cm) on the 4th, 5th and 6th of December 2013. The TOB mapping completed in the field was verified by cross-checking with recent high resolution satellite imagery, and where necessary TOB data were manually amended. Where access was restricted (**Figure 3**), reaches were visually assessed from adjoining properties and/or from roadside verges. This approach was common to many of the reaches within the Precinct where access was not available (e.g. Reaches A, D, M). Other reaches on or slightly beyond the boundary of the Precinct were not assessed if it was determined that the required VRZ did not extend into the Precinct (e.g. Reaches Q, R and S). Only one reach (Reach I) could not be visually assessed as a result of restricted access.

The TOB mapping has been used as the basis for the initial VRZ buffer delineation. The watercourses present in many parts of the study area are highly disturbed with some reaches channelised by urban development. For this reason and due to the lack of access to all land, the location and condition of the watercourses in some parts of the area have been inferred from contour data, high resolution aerial photography data and existing topographic map data (e.g. Pittwater Council's 2013 centreline mapping). Accuracy of TOB mapping and condition assessment therefore cannot be guaranteed where access was not available.

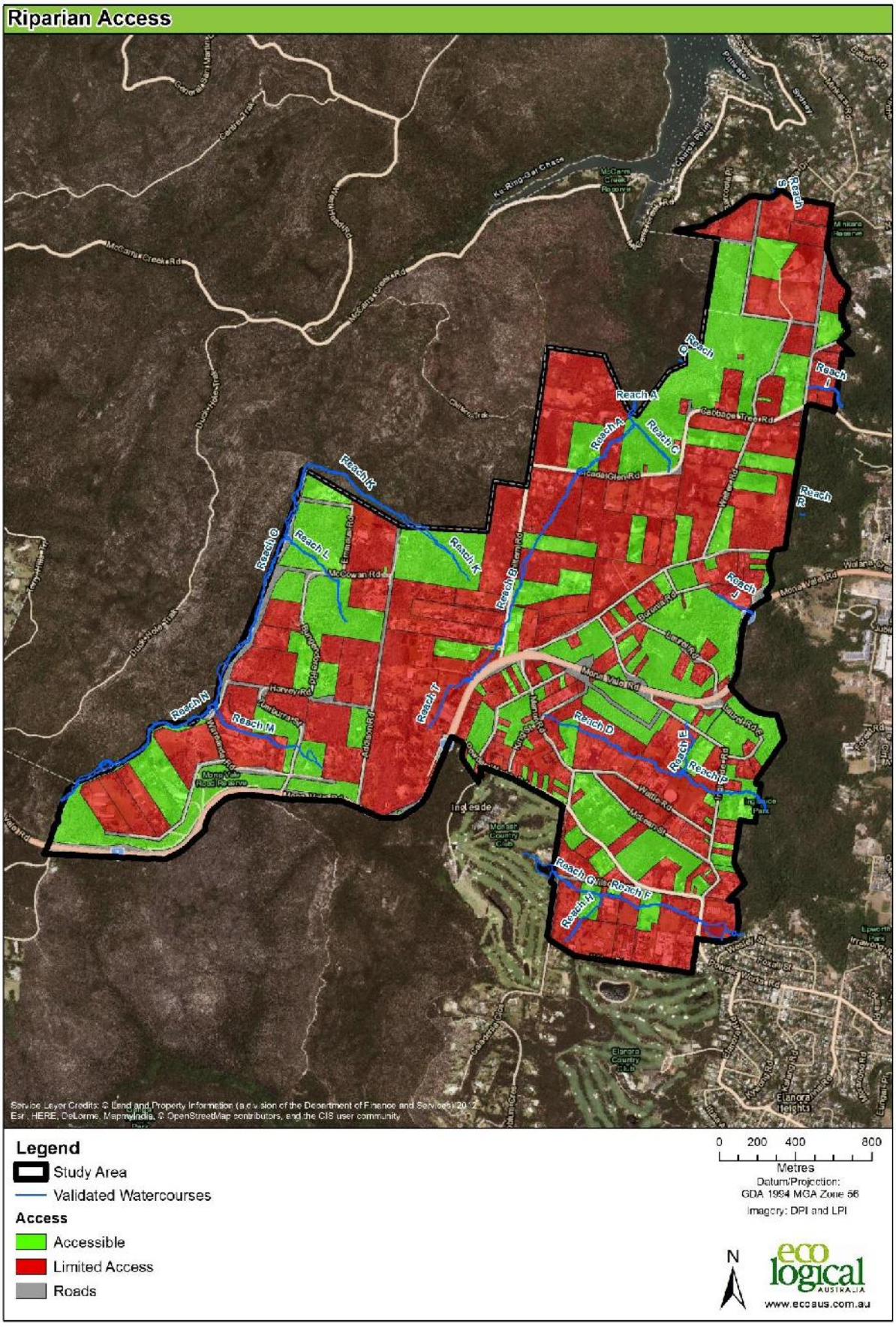

Figure 3: Access to drainage lines for field assessment

Watercourse reach numbers have been assigned to enable clear identification and descriptions of the relevant sections of each watercourse. The condition of each reach was assessed for key characteristics related to hydrology, physical form, water quality, aquatic habitat and streamside vegetation. Each reach was given an overall condition rating of:

- Near intact condition
- Good condition
- Moderate condition
- Degraded condition

Each reach was applied a stream order number using the Strahler classification. Numbering occurs from the top of the catchment with the smallest headwaters being assigned as 1st Order. Stream order number increases downstream through the catchment as same-order tributaries merge and form larger streams (**Figure 4**).

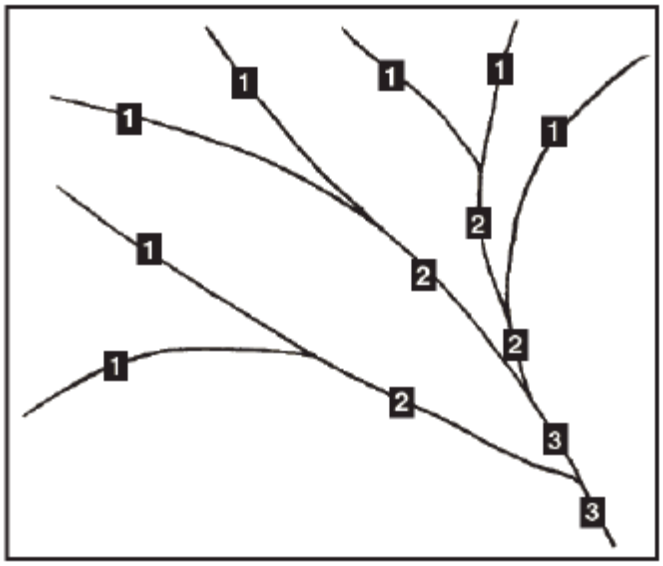

Figure 4: Strahler stream ordering system

Riparian corridor requirements in accordance with the DPI Water controlled activity *Guidelines for Riparian Corridors on Waterfront Land* are outlined in **Table 2.** The Vegetated Riparian Zone (VRZ) contains the areas formerly referred to as the core riparian zone (CRZ) and the vegetated buffer (VB).

Table 2: DPI Water riparian categories and buffer specifications

Watercourse type	VRZ width (each side of watercourse)	Total riparian corridor width
1st order	10 metres	20 m + channel width
2nd order	20 metres	40 m + channel width
3rd order	30 metres	60 m + channel width
4th order and greater (includes estuaries, wetlands and any parts of rivers influenced by tidal waters)	40 metres	80 m + channel width

3.2 Aquatic Assessment and Threatened Species

3.2.1 Threatened Species

Database searches were undertaken to identify threatened aquatic species that may occur within the Precinct. Given that the broader biodiversity assessment of the study area is being undertaken using the BCAM method, searches were restricted to aquatic species listed under the Commonwealth EPBC Act and the NSW FM Acts. Species listed under the TSC Act were not considered, as their presence, together with potential habitat and species impacts are assessed as a component of the BCAM methodology.

A review of listed threatened species dependant on in stream habitat revealed that two threatened species, Giant Burrowing Frog (*Heleioporus australiacus)* and Red-crowned Toadlet (*Pseudophrine australis),* may potentially occur, or are known to occur within the aquatic habitats present in the Precinct (**Table 3**). These species are considered under the BCAM methodology and therefore will be addressed separately in the Ecology Assessment report(s).

Table 3: Listed aquatic and amphibious species recorded in the region

Species	FM Act status	EPBC Act status	Likelihood of occurrence
Macquarie Perch (*Macquaria australica)*	E	E	Unlikely, out of natural distribution
Adam's Emerald Dragonfly (*Arhaeophya adamsi*)	E		Unlikely, but potential habitat may occur downstream of the Precinct
Sydney Hawk Dragonfly (*Austrocordulia leonardi*)	E		Unlikely, out of natural distribution
Australian Grayling (*Prototroctes maraena)*[1]	-	V	Unlikely, but potential habitat may occur downstream of the Precinct
Giant Burrowing Frog (*Heleioporus australiacus)*[1]	-	V	Likely (recorded by Pittwater Council)
Green and Golden Bell Frog (*Litoria aurea)*[1]	-	V	Unlikely
Giant Barred Frog (*Mixophyes iterates)*[1]	-	E	Unlikely
Red-crowned Toadlet (*Pseudophrine australis)*[1]	-	V	Known (Council records)

1. Species will be assessed under the BCAM Methodology

3.2.2 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are defined as ecosystems whose current species composition, structure and function are reliant on a supply of groundwater (Eamus 2009) as opposed to surface water supplies from overland flow paths. The frequency of groundwater influence may range from daily to inter-annually, however it becomes clearly apparent when either the supply of groundwater or its quality (or both) is altered for a sufficient length of time to cause changes in plant function. Groundwater use by an ecological community or individual species does not necessarily imply groundwater dependence (Dressel et al 2010).

In Australia, the majority of ecosystems have little to no dependence on groundwater, although the full understanding of the role of groundwater in maintaining ecosystems is generally poor. The exception to

this is wetland communities, for which it is thought that most have some level of dependence on groundwater resources (Hatton and Evans 1998).

GDEs are generally classified into six categories (SCCG 2006, SKM 2001):

- **Terrestrial vegetation** – forests and woodland which develop a permanent or seasonal dependence on groundwater, often by extending roots into the water table,
- **Base Flow in streams** – aquatic and riparian ecosystems that exist in or adjacent to streams that are fed by groundwater base flow,
- **Aquifer and cave systems** – aquatic ecosystems that occupy caves or aquifers,
- **Wetlands** – aquatic communities and fringing vegetation that depend on groundwater fed lakes and wetlands,
- **Estuarine and near shore marine ecosystems** – various ecosystems including mangroves, salt marsh and seagrass, whose ecological function has some dependence on groundwater discharge
- **Terrestrial fauna** – fauna species assemblages reliant on groundwater for drinking water.

A final category is also recognised – **not apparently dependent**. This category acknowledges that some ecosystems, particularly wetland and riparian vegetation, might superficially appear to be groundwater dependent while in fact they are dependent entirely on surface flows and or rainfall.

GDEs have varying degrees of dependency on groundwater. These range from total to occasional dependence and include (SCCG 2006, SKM 2001):

- **Entirely dependent** – ecosystems for which only a slight change in the groundwater regime will have catastrophic effects,
- **Highly dependent** – ecosystems for which moderate changes in the groundwater regime will result in significant changes to ecosystem distribution, health and or diversity. These ecosystems utilise both ground and surface water resources.
- **Proportionally dependent** – ecosystems for which changes in the groundwater regime result in significant changes to the ecosystem characteristics,
- **Opportunistically or minimally dependent** – ecosystems for which the reliance on groundwater is limited to seasonal or climatic variations. These ecosystems use surface water predominantly and if access to groundwater is prolonged, declines in ecosystem distribution, health, species composition or diversity may result.

GDE's within the Precinct were identified and mapped during both the riparian and terrestrial biodiversity assessment and field inspection.

3.2.3 Noxious weeds

In NSW, Noxious weeds listed under the NW Act are those class of plants that are required by law to be controlled by all landholders in the area in which it has been declared noxious (defined by LGA). In the Pittwater LGA, there are 107 declared noxious weeds; of these six are aquatic species:

- Alligator Weed (*Alternanthera philoxeriodes*)
- Longleaf Willow Primrose (*Ludwigia longifolia*)
- Ludwigia (*Ludwigia peruviana*)
- Salvinia (*Salvinia molesta*)
- Senegal Tea Plant (*Gymnocoronis spilanthoides*)
- Water Hyacinth (*Eichhornia crassipes*)

During field survey and TOB mapping, records were made of all declared noxious aquatic weeds that were observed.

4 Results

4.1 Top of bank mapping and condition assessment

The results of TOB mapping and initial delineation of riparian buffers are shown in **Figure 5**. Each stream was broken into reaches based on its general structure and clearly defined branches. The condition of each stream reach is summarised in **Table 4**. A photographic record of the accessible reaches of each stream was also made and is summarised in **Appendix A.**

The overall condition of the surveyed length of watercourses within the Precinct was generally degraded (9) or moderate (5). Two watercourses were considered to be in near intact condition, while a further four were located outside the Precinct, or could not be accessed, were therefore not assessed (**Table 4**).

Other than the near intact watercourses, streamside vegetation was modified to some extent along the length of each stream reach, with the majority of vegetation subject to moderate to substantial modification. Approximately half the assessed watercourses had one or more vegetative strata dominated by exotic vegetation, with little native vegetation remaining. There were large areas of dense weed infestation of the mid-storey and understorey vegetation. Remnant vegetation was often found in isolated small patches or strips. Within the total length of the watercourses a significant proportion had been modified with the inclusion of box culverts, piped sections and/or informal weirs for the extraction of water. A dam was also present within Reach G, a tributary of Mullet Creek providing storage for irrigation water within the Monash Country Club. While some sections were subject to bank erosion, most were reasonably well stabilised by streamside vegetation, although highly modified by exotic species.

Watercourses that were assessed to be in moderate condition were generally located in areas where remnant vegetation was more extensive and the impacts of urban development less pronounced. In this regard, Reaches L, N and O (Wirreanda Creek and its tributaries) are located in areas where the sub-catchments retain relatively dense and extensive stands of native vegetation. Indeed, the western bank and beyond for Reaches N and O are located within the Ku-ring-gai Chase National Park. Similarly, Reach C a tributary in the lower reaches of Cicada Glen Creek is also located in a relatively well vegetated and undisturbed sub-catchment (**Figure 6**). In contrast, Reach P, a tributary of Mullet Creek, which is located in a more urbanised and hence disturbed sub-catchment, was also assessed to be in moderate condition. This was largely the result of the lower portion of the reach below Ingleside Road having retained more than 50% native vegetation cover.

Two watercourses were assessed to be in near intact condition Reach A (the lower reaches of Cicada Glen Creek), and Reach K (Crystal Creek). These streams showed little evidence of broad scale native vegetation removal and the remaining vegetation was not heavily impacted by exotic species. This result is largely driven by their location within the broader landscape, and in particular their immediate proximity to Ku-ring-gai Chase National Park. These streams also exhibited good to excellent frog and bird habitat.

The field surveys mapped a total of 20 stream reaches: comprised of five 2nd order and fifteen 1st order streams (**Table 4**). All reaches were considered to meet the definition of a stream, however the entirety of Reach T (Cicada Glen Creek upstream of Chiltern Road) has been heavily modified by culverts, pipes, realignment and small dams/ponds. Reach T may potentially be suitable for removal from riparian corridor requirements under the Water Management Act if approved by DPI Water.

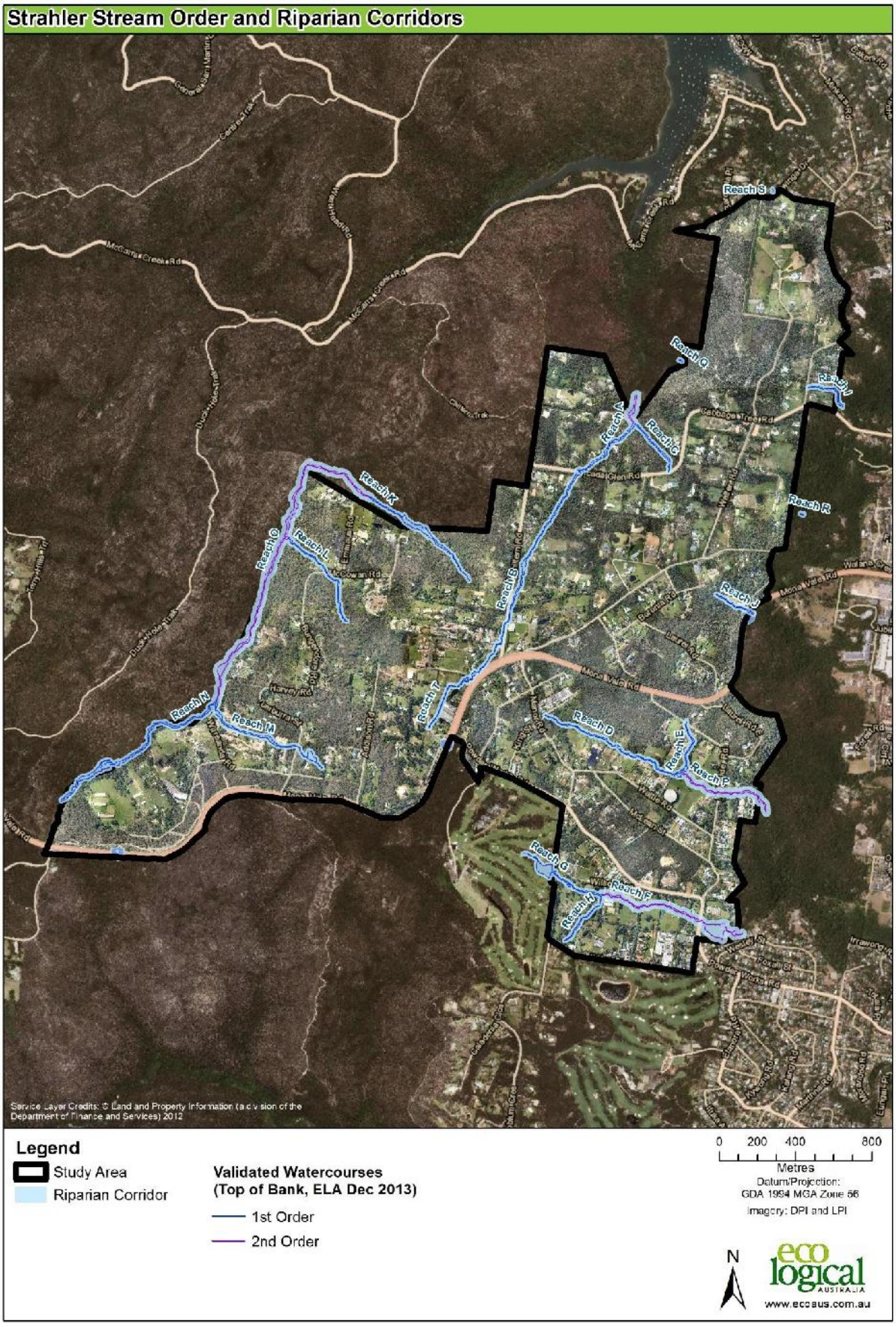

Figure 5: Strahler stream order and corresponding riparian corridors

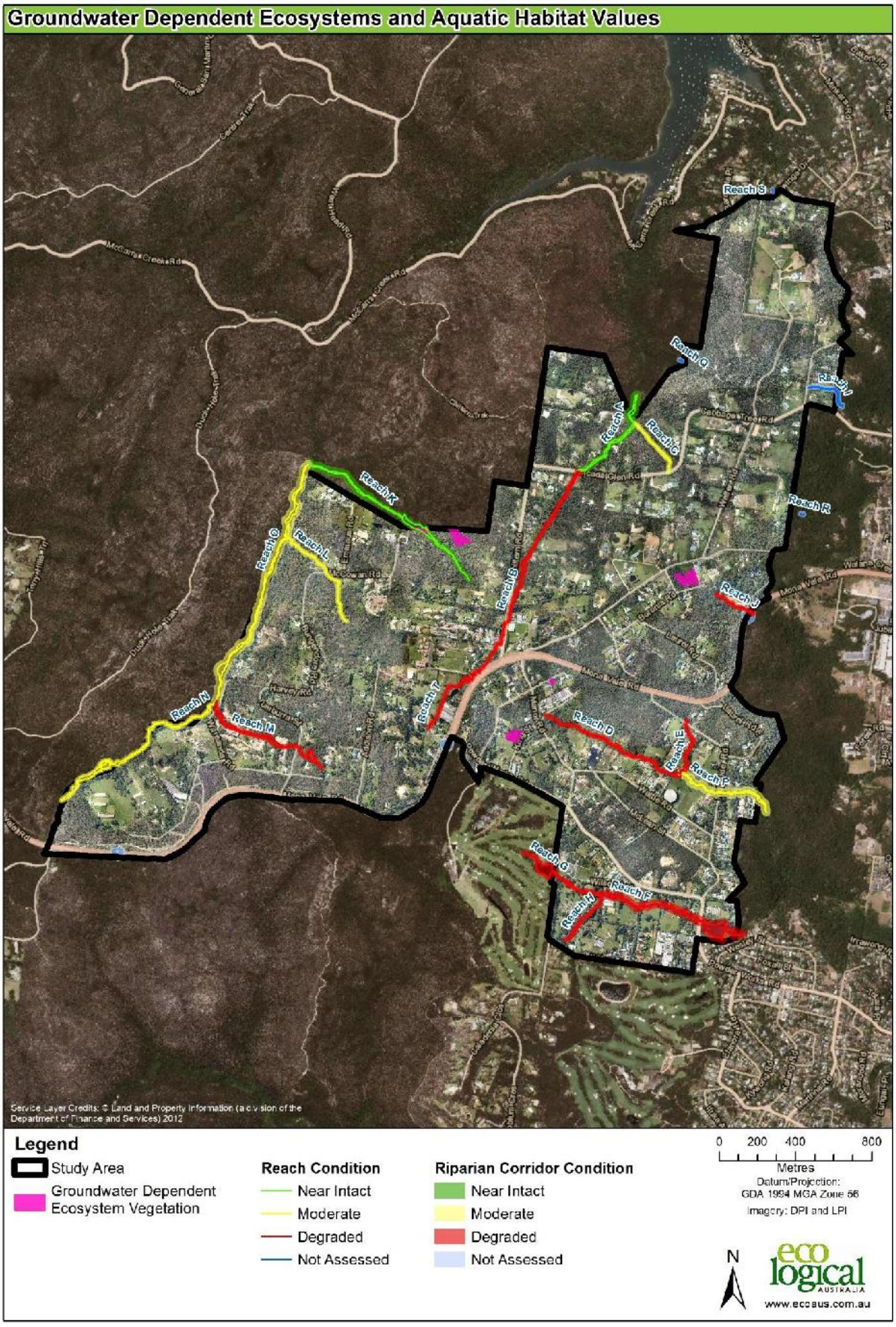

Figure 6: Groundwater Dependent Ecosystems and Aquatic Habitat values

Table 4: Water course condition assessment

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach A	Cicada Glen Creek	1st Order Stream (Strahler). Unmodified channel. Inflows modified to due to partially cleared catchment.	Bank slope = <30 degrees. Stream located primarily within sandstone landscape with little gully or sheet erosion.	Excellent aquatic habitat with in stream woody debris and aquatic vegetation. Sandstone bedrock with numerous pools and low flows through boulders and stones. Average width of channel 5m with stream depth of 10-20cm. Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Good. Frog habitat = Good.	Slightly Modified Little evidence of broad-scale loss of native vegetation with exotic species present but not dominating any strata, high impact species rare. Number of strata and cover within each similar to reference. Dominant strata with reference level of cover and at least three age classes present (juveniles, sub-adults and adults). Quantities and cover of debris similar to reference.	Near intact
Reach B	Cicada Glen Creek	1st Order Stream (Strahler). Some stream modification with partially cleared catchment affecting stream inflows.	Bank slope = 30-70 degrees. Banks well stabilised by vegetation. Some minor undercut erosion (5-25%).	Relatively poor aquatic habitat with occasional woody debris. Shallow, turbid stream flow with predominately pebble substrate. Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Good. Frog habitat = Good.	Largely modified Little evidence of broad-scale loss of native vegetation. Most strata dominated by exotic species with high impact species abundant. Cover within one stratum up to 50% lower or higher than reference. Reduced cover (<50%) of dominant strata, and only one age class present. Quantities and cover of debris similar to reference.	Degraded

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach C	Tributary of Cicada Glen Creek	1st Order Stream (Strahler). Unmodified stream with partially cleared catchment.	Bank slope = 30-70 degrees. Negligible erosion with banks well stabilised by streamside vegetation.	Excellent frog habitat, Good bird habitat with abundant in stream woody vegetation and no aquatic weeds. Relatively narrow channel (0-1m) with average depth of water 10-20 cm with very low flow at time of survey. Dominant substrate sandstone and with sand substrate Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Good. Frog habitat = Excellent.	Moderately modified Little evidence of broad-scale loss of native vegetation. One or more strata dominated by exotic species, with high impact species present. Cover within one stratum up to 50% lower or higher than reference. Reduced cover (75-50%) of dominant strata, and/or only two age classes present. Quantities and cover of debris similar to reference.	Moderate
Reach D	Tributary of Mullet Creek	1st Order Stream (Strahler). Some modification to channel with partially cleared catchment.	Bank slope = 30-70 degrees. Banks generally well stabilised by streamside vegetation. Some slump (5-25%) and undercut erosion (1-5%)	Moderate habitat with average wetted channel width of 1-3 m. Slow flowing at the time of survey. Occasional in stream woody debris with dominant sandstone substrate and sand substrate. Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Moderate. Frog habitat = Moderate.	Degraded Only small patches of well-separated native vegetation remain. Most strata dominated by exotic species, high impact species abundant. More than one stratum completely altered from reference (lost or <10% remaining). Dominant strata mostly absent. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach E	Tributary of Mullet Creek	1st Order Stream (Strahler). Partially modified channel with upper reaches and the vicinity of Mona Vale Road no longer present. Partially cleared catchment.	Clay banks with slope = <30 degrees. Negligible erosion, with banks maintained by streamside vegetation dominated by weed species.	Limited habitat. Slow flowing mostly ponded water at time of survey. Dominant substrate clay with minimal in stream woody debris. Fish habitat = Class 4 - Unlikely fish habitat. Bird habitat = Poor. Frog habitat = Moderate.	Substantially modified Only small patches of well-separated native vegetation remain. One or more strata dominated by exotic species, high impact species present. More than one stratum completely altered from reference (lost or <10% remaining). Reduced cover (<50%) of dominant strata, and only one age class present. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded
Reach F	Tributary of Mullet Creek	2nd order stream (Strahler). Some modification of channel. Culverts present. Partially cleared catchment.	Sandy banks with slope 30-70 degrees. Some gully (1-5%), slump (5-25%) and undercut (1-5%) erosion. Riparian trees and streamside vegetation dominated by weeds help maintain banks	Moderate habitat with an average wetted channel width 1-3 m with slow flowing water with an average depth 10-20 cm. Dominant substrate of bedrock with sandy subdominant substrate with common in stream vegetation. Moderate bird and frog habitat Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Moderate. Frog habitat = Moderate.	Substantially modified. Only small patches of well-separated native vegetation remain. Most strata dominated by exotic species, high impact species abundant. More than one stratum completely altered from reference (lost or <10% remaining). Reduced cover (<50%) of dominant strata, and only one age class present. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach G	Tributary of Mullet Creek	1st order stream (Strahler). Partially modified channel. Dams within golf course represent major high-flow barrier. Culverts and crossings also present. Mostly cleared catchment.	Sandy bank with slope 30-70 degrees. Sections of bank with limited riparian trees exhibiting gully (1-5%), slump (5-25%) and undercut (1-5%) erosion.	Poor to moderate habitat. Dominant substrate sand with subdominant substrate of silt. Large pools (dams) upstream of Precinct within golf course. Elsewhere minimal flow at time of survey with common in stream vegetation. *Typha* spp. Present in ponds/dams. Poor to moderate habitat. Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Poor. Frog habitat = Moderate.	Substantially modified Only small patches of well-separated native vegetation remain. Most strata dominated by exotic species, high impact species abundant. More than one stratum completely altered from reference (lost or <10% remaining). Reduced cover (<50%) of dominant strata, and only one age class present. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded
Reach H	Tributary of Mullet Creek	1st order stream (Strahler). Partially modified channel and cleared catchment.	Sandstone bedrock with bank slope 30-70 degrees. Banks generally stabilised by riparian vegetation dominated by weed species.	Moderate habitat with common in stream vegetation. Average wetted channel width 1-3 m with frequent pooling and low/stagnant flow. Occasional in stream vegetation. Fish habitat = Class 4 - Unlikely fish habitat. Bird habitat = Moderate. Frog habitat = Moderate.	Substantially modified Only small patches of well-separated native vegetation remain. Most strata dominated by exotic species, high impact species abundant. More than one stratum completely altered from reference (lost or <10% remaining). Reduced cover (<50%) of dominant strata, and only one age class present. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded
Reach I	Unnamed watercourse	1st order stream (Strahler). Partially cleared catchment.	Not assessed	Not assessed	Not assessed	Not assessed

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach J	Tributary Narrabeen Creek	1st order stream (Strahler). Some modification of channel with large culverts and bank stabilisation (boulders) works. One low-flow barrier (piped culvert). Partially cleared catchment.	Bank slope 30-70 degrees with little erosion given bedrock substrate and rock stabilisation works and culverts.	Average wetted channel width 1-3 m with relatively frequent pooling and low flow pool interflow. Dominant substrate bedrock and coble subdominant substrate. Rare in stream woody debris. Fish habitat = Class 4 - Unlikely fish habitat. Bird habitat = Moderate. Frog habitat = Moderate.	Substantially modified Only small patches of well-separated native vegetation remain. One or more strata dominated by exotic species, high impact species present. More than one stratum completely altered from reference (lost or <10% remaining). Dominant strata mostly absent. Very small quantities of debris present.	Degraded
Reach K	Crystal Creek	1st order stream (Strahler). Unmodified channel with only minor clearing in catchment.	Bank slope = >70 degrees. Bedrock and boulder dominant and subdominant substrate. Banks well vegetated with minimal erosion.	Slow flowing stream at time of survey with average wetted channel width 1-3 m. Average depth 30-100 cm. Average depth of water = 10-20 cm. Abundant in stream woody debris. Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Excellent. Frog habitat = Excellent.	Slightly modified No or little evidence of broad-scale loss of native vegetation. Vegetation predominantly native, few weeds and no high impact species. Number of strata and cover within each similar to reference. Dominant strata with reference level of cover and at least three age classes present (juveniles, sub-adults and adults). Quantities and cover of debris similar to reference.	Near intact

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach L	Tributary of Wirreanda Creek	1st order stream (Strahler). Some modification of channel with numerous low flow barriers (culverts and informal damming) Partially cleared catchment.	Bank slope = 30-70 degrees with minimal erosion.	Narrow channel with some ponding. Dominant and subdominant substrate bedrock and boulders. Common instream vegetation with exotic species present but not dominating. Fish habitat = Class 4 - Unlikely fish habitat. Bird habitat = Excellent. Frog habitat = Moderate.	Moderately modified No or little evidence of broad-scale loss of native vegetation. Exotic species present but not dominating any strata, high impact species rare. Number of strata and cover within each similar to reference. Reduced cover (75-50%) of dominant strata, and/or only two age classes present. Some evidence of unnatural loss of debris.	Moderate
Reach M	Tributary of Wirreanda Creek	1st order stream (Strahler). Mostly modified channel with numerous low-flow barriers. Mostly cleared catchment.	Bank slope 30-70 with some minor slump (1-5%) and undercut (1-5%) erosion.	Still water, primarily in ponds at time of survey with average depth of < 10 cm. Dominant substrate cobble with subdominant substrate of gravel. Rare in stream woody debris Native aquatic vegetation *Typha* spp.. Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Moderate. Frog habitat = Moderate.	Largely modified Only small patches of well-separated native vegetation remain. Exotic species present but not dominating any strata, high impact species rare. One stratum missing or extra, cover within remaining strata 50% lower or higher than reference. Reduced cover (75-50%) of dominant strata, and only one age class present. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach N	Wirreanda Creek	1st order stream (Strahler). Partially modified channel with numerous low-flow barriers including weirs for water extraction. Partially cleared catchment.	Steep bank slope >70 degrees prone to slump erosion (25-50%). Sand and gravel substrate well vegetated with in stream vegetation and riparian trees. Some impacts due to cattle grazing.	Moderate condition stream with average wetted channel width of 1-3 m. Ponding of water common with wiers present for water extraction. Abundant in stream woody debris with relatively high native species richness (4 species, *Gahnia* sp. *Alisma plantago-aquatica*, *Typha* sp., *Eleocharis sphacelata* Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Good. Frog habitat = Moderate.	Moderately modified Width reduced by up to 1/3 and/or some breaks in continuity. Exotic species present but not dominating any strata, high impact species rare. Cover within one stratum up to 50% lower or higher than reference. Dominant strata with reference level of cover and at least three age classes present (juveniles, sub-adults and adults). Quantities and cover of debris similar to reference.	Moderate
Reach O	Wirreanda Creek	2nd order stream (Strahler). Unmodified channel. Natural barriers present (small waterfalls). Partially cleared catchment.	Steep bank slope >70 degrees prone to slump erosion (25-50%) where in stream and riparian tree species lacking.	Average wetted channel width 1-3 m with average depth 10-20 cm. Velocity = Slow (<0.1 m/s). Dominant and subdominant substrate bedrock and sand respectively with dispersed pools. Abundant in stream debris Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Excellent. Frog habitat = Moderate.	Moderately modified. No or little evidence of broad-scale loss of native vegetation. Exotic species present but not dominating any strata, high impact species rare. Number of strata and cover within each similar to reference. Dominant strata with reference level of cover and at least three age classes present (juveniles, sub-adults and adults). Quantities and cover of debris similar to reference.	Moderate

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach P	Tributary of Mullet Creek	2nd order stream (Strahler). Partially modified channel. Minor barriers present (culverts, piped culverts). Section above **Ingleside Road** more modified (channelised) than below. Partially cleared catchment.	Bank slope 30-70 degrees with some slump (1-5%) and undercut (5-25%) where in stream vegetation other than riparian trees is lacking.	Dominant and subdominant substrate bedrock and sand respectively. Pooling less frequent with relatively moderate stream velocity. Occasional in stream woody debris with rare native aquatic species (*Typha* sp., *Persicaria* sp.) Fish habitat = Class 2 - Moderate fish habitat. Bird habitat = Good. Frog habitat = Good.	Moderately modified About 50% of the native vegetation remains, either in strips or patches. One or more strata dominated by exotic species, high impact species present. Cover within one stratum up to 50% lower or higher than reference. Reduced cover (75-50%) of dominant strata, and only one age class present. Some evidence of unnatural loss of debris.	Moderate
Reach Q	Tributary of Cicada Creek	1st order stream (Strahler). Partially cleared catchment.	Not assessed	Not assessed	Not assessed	Not assessed
Reach R	Unnamed watercourse	1st order stream (Strahler). Partially cleared catchment.	Not assessed	Not assessed	Not assessed	Not assessed
Reach S	Unnamed watercourse	1st order stream (Strahler). Mostly cleared catchment.	Not assessed	Not assessed	Not assessed	Not assessed

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach T	Cicada Glen Creek	1st order stream (Strahler). Heavily modified channel particularly in upper reaches. Numerous low-flow barriers (culverts, piped culverts etc.) with channelised section. Mostly cleared catchment.	Bank slope >70 degrees, stabilised by in stream vegetation dominated by exotic species. Engineered solutions prevalent in upper reaches.	Highly modified stream with rare in stream woody debris. Ponds and dams associated with residential properties dominated by native species *Typha* sp., *Eleocharis sphacelata* and weed species made up of garden escapes. Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Moderate. Frog habitat = Moderate.	Degraded Only small patches of well-separated native vegetation remain. One or more strata dominated by exotic species, high impact species present. More than one stratum completely altered from reference (lost or <10% remaining). Reduced cover (<50%) of dominant strata, and only one age class present. Very small quantities of debris present.	Degraded

4.2 Aquatic Habitat and Threatened Species

While many of the watercourses within the Precinct are disturbed and in a degraded condition, they still provide some degree of habitat for aquatic species. Typical of urban and semi urban streams, most of the watercourses demonstrate the effects of urban stormwater flows including sedimentation and nutrient accumulation, the later most evident in the prevalence of exotic weed species within the various creek lines.

Road and drainage works have also impacted on aquatic habitat in the form of culverts and other modifications, particularly in the vicinity of Mona Vale Road and Reach E. In this instance the watercourse has been modified to the extent that it no longer extends to or beyond Mona Vale Road. Similarly, within Reach T (the upper reaches of Cicada Glen Creek above Lane Cove Road), the watercourse is highly modified as a series of box culverts, pipes, and formalised channels interspersed with short sections of highly impacted open watercourse and small ponds/dams.

Nevertheless, the majority of water courses within the study area are relatively stable and well vegetated and have value as part of a series of vegetated riparian corridors which provide habitat for local flora and fauna. The water courses, with the exception of Reach S, flow into reserved areas with conservation values. These corridors also create partial links between the Ku-ring-gai Chase National Park which forms portions of the western and northern boundary of the Precinct, Garigal National Park to the south, and the reserves (Ingleside Chase, Katandra and Minkara) to the east.

Habitat for frogs and birds within the majority of the watercourses ranged between 'moderate' and 'good' with some parts exhibiting 'excellent' habitat (**Table 4**). In contrast, fish habitat was generally considered to be 'minimal' or 'unlikely' for all streams other than Reach P, which was assessed as having 'moderate' fish habitat. These results reflect the various barriers to fish passage within the area (culverts, dams, informal weirs etc.) and its position at the top of the catchment.

Regardless, there are a host of common aquatic species including eels, yabbies and macroinvertebrates that rely on the health of aquatic habitat for their ongoing survival. Aquatic habitat is an important component of overall ecosystem health and contributes to the diversity and viability of terrestrial habitat. It is recommended that future urban development considers the provision of good quality instream habitat, longitudinal connectivity and fringing riparian vegetation. In addition, erosion and sediment control should be a key requirement during construction, and Water Sensitive Urban Design (WSUD) principles applied to help protect important downstream, high quality bushland environments (National Parks, Ingleside Chase Reserve, Katandra Bushland Sanctuary, Minkara Reserve and Narrabeen Lagoon).

4.2.1 Threatened Species

Relevant database searches identified two aquatic threatened species that are considered as 'likely' to occur within the Precinct, Red-crowned Toadlet (*Pseudophrine australis*) and Giant Burrowing Frog (*Heleioporus australiacus*) (**Table 3**). Pittwater Council has listed a record of Red-crowned Toadlet in the Precinct. These species are being considered under a separate Biodiversity Assessment. As a result, no further assessment of potential impacts on aquatic threatened species is required as part of this assessment.

4.2.2 GDE

GDEs mapped in the study area (**Figure 6**) are confined to the Coastal Upland Wet Heath Swamp and Coastal Upland Damp Heath Swamp vegetation types (SMCMA 2009). These vegetation types correlate to the Biometric Vegetation Type Needlebush Banksia Wet Heath on the Sandstone Plateaux of the Sydney Basin and were validated during field survey undertaken as part of the biodiversity assessment

for the Precinct. These vegetation types may utilise groundwater fed base flows associated with shallower aquifer's linked to Reaches D, J and K.

The dependence on groundwater varies greatly with each community and its position in the landscape. There is little available information on the level of groundwater dependency of theses patches of Heath Swamp vegetation within the Precinct. However, as a safeguard for future planning, freshwater GDEs such as streams, riparian zones and wetlands should be grouped as highly dependent, particularly during base flows.

4.2.3 Noxious weeds

Six species of aquatic noxious weeds were identified as having the potential to occur within the Precinct (**Section 3.2.3**). While none were detected during field investigations as part of this assessment, *Ludwigia* spp have been previously identified in Cicada Glen Greek (Pittwater Council 2013). Moreover, given that not all watercourses or sections of watercourse could be accessed, it is possible that these species may in fact occur more broadly within the Precinct. In this context, a precautionary approach should be taken during future riparian corridor works and or maintenance activities, and should any of the noxious species be identified their location should be accurately mapped and appropriate control techniques employed.

4.3 Conservation potential

A summary of conservation priority is provided in **Table 5**, and depicted graphically in **Figure 7**. The conservation and recovery potential for most streams is considered moderate to high, particularly those that are located within or adjacent to areas of remnant, relatively high quality vegetation (**Figure 7**). This includes Wirreanda Creek and its tributaries (Reaches N, O and L), Crystal Creek (Reach K) and the lower reaches of Cicada Glen Creek (Reaches A, B and C). Recovery potential of these watercourses is also enhanced by their proximity to, and relationship with, the important downstream environments of the Ku-ring-gai Chase National Park.

Other high conservation potential streams include those that serve as a tributary for larger or less degraded watercourses beyond the study area. This includes the tributaries of Mullet and Narrabeen Creeks (Reaches F, P and J), which form the headwaters of these watercourses and flow though the adjacent Ingleside Chase Reserve and discharge to the Narrabeen Lagoon. In this context the conservation and recovery potential of these watercourses is further enhanced given their important role in maintaining and improving the environmental values of these downstream environments.

A small number of watercourses (Reaches D, G, H and M) have been assessed as having moderate conservation and recovery potential. These streams are generally more degraded streams that serve as tributaries of higher value streams. The remaining streams (Reaches E, I, T and R) have lower conservation priority where the natural geomorphic condition has been completely altered as a result of being partially channelled, piped or realigned (e.g. Reaches T and E), or the downstream environment has been substantially modified by urban development (e.g. Reach R becomes part of a stormwater pipe system; and Reach I is a small headwater section of a creek flowing to a series of golf course dams). Other lower impact modifications such culverts are also common throughout the study area.

In the context of the broader Precinct rezoning, where possible high value riparian corridors should be retained in public ownership, zoned and managed as conservation lands, and recognised as such within the Biodiversity Certification Assessment Area considered under the BCAM methodology.

Table 5: Riparian corridor conservation priority

Reach	Conservation Priority	Reach	Conservation Priority
A	High	K	High
B	High	L	High
C	High	M	Moderate
D	Moderate	N	High
E	Low	O	High
F	High	P	High
G	Moderate	Q	Moderate
H	Moderate	R	Low
I	Low	S	Moderate
J	High	T	Low

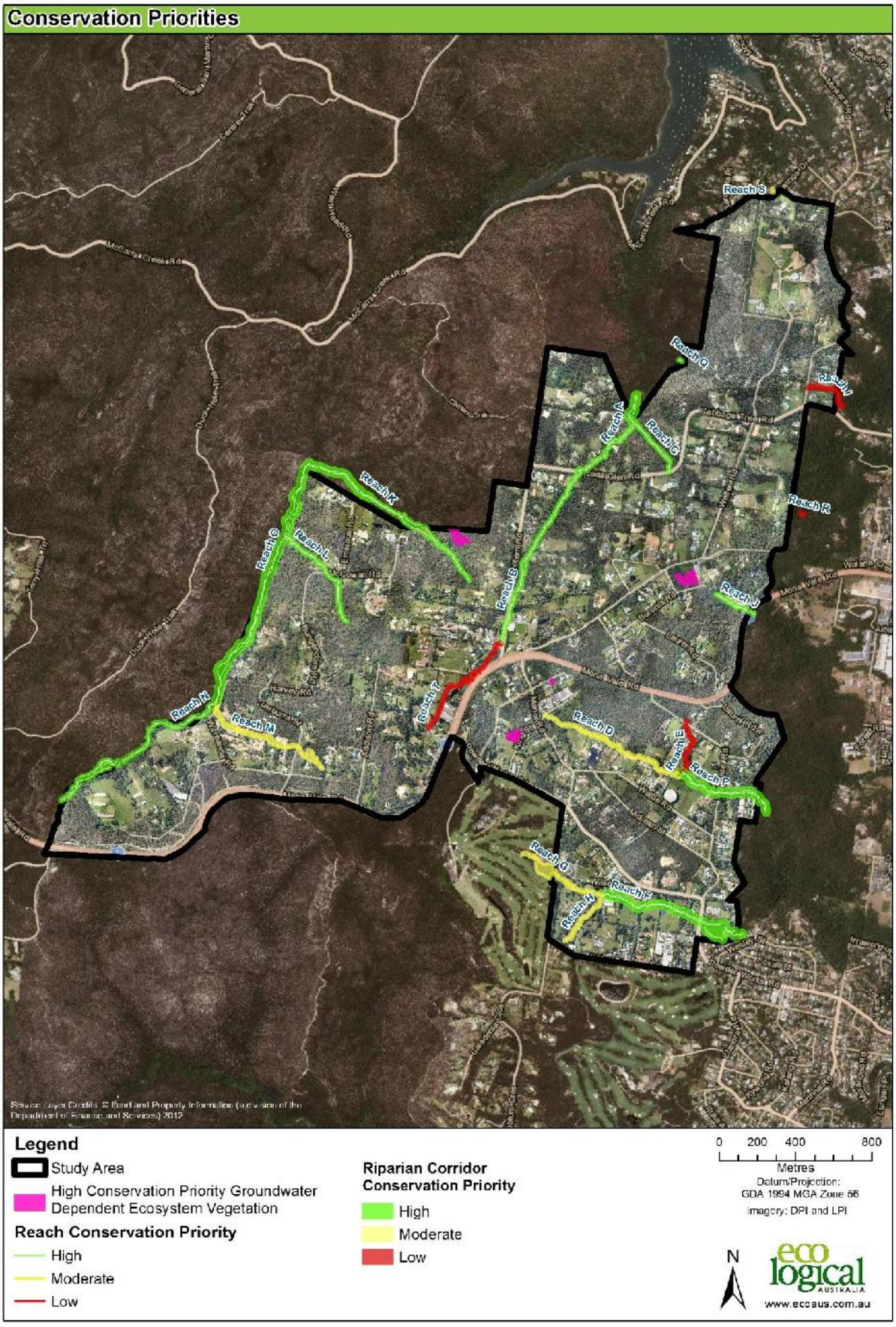

Figure 7: Watercourse conservation priority

5 Riparian Vegetation Management Study

This section of the report draws on the outcomes of the field assessment, identified conservation priorities, and recovery potential of the watercourses within the Precinct. This section does not provide detailed procedures for the ongoing rehabilitation and management of watercourses and riparian vegetation, but instead provides broad guidance with regard to future urban development within the Precinct. The guidance that is provided has been prepared recognising that many of the watercourses within the study area are located immediately adjacent to, or within, existing residential properties where the opportunities to establish recognised riparian corridors are more limited. The priorities for riparian corridor conservation are identified in **Section 4.3** and depicted in **Table 5** and **Figure 7**.

With the implementation of DPI Water requirements for riparian corridor restoration, the aquatic and riparian habitat of the existing watercourses within the study area will improve over time as development works progress and more natural vegetation and flow regimes are re-established, particularly with the more disturbed watercourses of the Precinct. How this may be achieved with the inclusion of bioretention and other devices or management approaches is discussed below. Given the current state of some watercourses that have been highly modified and or channelised there may be opportunity for these reaches to be removed and replaced with suitable engineered water management solutions (**Figure 7**).

It is likely that future development will require stormwater detention areas and other WSUD features to maintain natural flow regimes and water quality outcomes within the study area. Such features will serve an important role in re-establishing or enhancing habitat within the study area, particularly for those watercourses that have been more heavily modified by channelling or realignment in areas adjacent to existing urban development. Opportunities for such works will need to be considered in terms of the availability of suitable land and modelled flow regimes as the future development footprint is refined. Land ownership will be an important consideration in this regard, especially for those watercourses that are located immediately adjacent to existing residential development and where the opportunities to install WSUD features will be more limited.

Two dams exist within the study area, along reaches F and G. While the dam within reach G is located in the Monash Country Club, both dams should be considered with regard to their impact on natural flow regimes as well as the provision of aquatic habitat. Future stormwater/hydrology modelling within the Precinct should consider the role of these dams within the intended urban landscape (as defined by the Structure Plan) to ensure both that natural flow and habitat regimes are maintained at current levels as a minimum, or enhanced. In this regard, given the location of the dam on reach G, which is located at the headwaters of Mullet Creek, there are likely to be opportunities to restore more natural flow regimes within this watercourse as urban development proceeds and the volume of surface runoff increases. Similarly, should the dam on reach F be removed, dewatering should take place in accordance with detailed dewatering plans to manage and minimise impacts on the existing aquatic flora and fauna. Should this occur, it is recommended that any dewatering of the dam be staged so that any aquatic fauna utilising it have the opportunity to seek other habitat. Examples of compensatory habitat could include appropriately designed wet basins containing similar habitat features to the dams which are removed.

The patches of potential GDEs within the study area are generally isolated from existing watercourses, other than that which is located adjacent to Crystal Creek (Reach K, **Figure 7**). In this regard the role and function of these important ecosystems is somewhat less apparent within the study area. Nevertheless, the proposed rezoning presents an opportunity to recognise and enhance these important environmental features as a component of the broader riparian network of the Precinct. It is therefore recommended that where possible these areas of vegetation be retained and appropriately integrated

with the Structure Plan and future urban development. If groundwater extraction is proposed as any part of future development proposals, impacts on these GDE's would need to be further assessed.

5.1.1 Riparian Ownership and Management Options

Land ownership within the study area is fragmented and in some cases proposed riparian corridors would impact on existing residential properties and other forms of urban land use. Where it can be achieved riparian corridors should be in public ownership, which would increase the likelihood of achieving consistent environmental outcomes, and provide integrated uses and access for the community.

Where possible, drainage and detention structures should be owned and managed by Council. These areas can then be revegetated and managed as a naturalised feature. It is assumed that in accordance with the WM Act a vegetation management plan will be required and prepared to the satisfaction of DPI Water and Council for future development applications which impact on these areas.

Where public ownership cannot be achieved, consideration of suitable zoning and planning controls should be made in order to facilitate appropriate riparian land management outcomes.

5.1.2 Water Management Act

Further review of appropriate planning mechanisms (zoning and development controls) will need to be carried out by DPI Water, Council and NSW DP&E in order to determine a set of controls which will be appropriate for the Ingleside Precinct.

It is recommended that a Riparian Lands Map be included within the amended LEP and linked to the WM Act in a way that defines waterfront land within the Precinct as being limited to the extent of the Riparian Lands identified. It is noted that confirmation of stream locations and TOB may be a condition for areas of identified Riparian Lands where access was not possible for this project.

5.2 Management of Riparian Protected Areas

The DPI Water has developed controlled activity guidelines that enable applicants to determine relevant approval requirement's for controlled activities under the WM Act. The guidelines include a series of urban design principles and recommendations in relation to certain activities on waterfront land. The key elements of these guidelines in relation to the study area are presented below.

5.2.1 Urban Development Principles

The controlled activity guidelines do not encompass specific planning controls however they do contain objectives and a guide to works and activities generally allowable on waterfront land. The overarching objective of controlled activity provisions of the WM Act is to establish and preserve the integrity of riparian corridors. Ideally, the environmental functionality of riparian corridors should be restored and maintained by applying the following principles:

- Seek to maintain or recreate a riparian corridor / vegetated riparian zone with fully structured native vegetation in accordance with the riparian corridor requirements (refer to **Table 2**),
- Seek to minimise disturbance and harm to the recommended riparian corridor / vegetated riparian zone,
- Minimise the number of creek crossings and provide a perimeter road separating development from the riparian corridor / vegetated riparian zone,
- Locate infrastructure and services outside the riparian corridor / vegetated riparian zone,
- Where services or infrastructure are located within riparian corridors, co-locate facilities in one concentrated area to minimise overall disturbance and breaks in corridor continuity,
- Treat stormwater runoff before discharging it into the riparian corridor.

DPI Water does allow for a range of works and land uses within the outer (landward) edge of riparian corridors so long as they have minimal environmental harm. Activities which may be permissible are presented in **Table 6** below. The following principles are contained within the DPI Water guidelines and are to be considered in conjunction with the matrix presented in **Table 6**.

- Riparian Corridor offsetting for non-riparian corridor uses: Non-riparian uses, such as Asset Protection Zones are allowed in the outer 50% of the vegetated riparian zone, so long as offsets are provided in accordance with the averaging rule (see **Figure 8**)
- Cycleways and Paths: Cycleways or pedestrian paths no wider than 4m (total disturbance footprint) can be built in the outer 50% of the vegetated riparian zone
- Detention Basins: detention basins can be built in the outer 50% of the vegetated riparian zones or online (where indicated in the DPI Water Controlled Activity Guidelines for a) Outlet structures and b) Instream work. Online basins must:
    - Be dry and vegetated,
    - Be for temporary flood detention only with no permanent water holding,
    - Have an equivalent vegetated riparian zone for the corresponding watercourse order, and
    - Not be used for water quality treatment purposes.
- Stormwater outlet structures and essential services: Stormwater outlets or essential services are allowed in the riparian corridor. Works for essential services on a 4th order or greater stream are to be undertaken by directional drilling or tied to existing crossings (refer to DPI Water Controlled Activity Guidelines for a) Laying pipes and cables in watercourses and b) Outlet Structures).
- Stream alignment: Indicates that a watercourse may be re-aligned (refer to DPI Water Controlled Activity Guidelines for Instream Works)
- Road Crossings: Indicates permitted road crossing methods (refer to DPI Water Controlled Activity Guidelines for Watercourse Crossings and DPI (Fisheries) Policy and Guidelines for Fish Friendly Waterway Crossings for Class 1 and 2 Waterways).

Works not associated with the establishment and maintenance of riparian corridors can be authorised within the outer riparian corridor provided that the average width of the vegetated riparian zone can be achieved over the length of the watercourse within the development site. That is, where appropriate, 50% of the outer vegetated riparian zone width may be used for non-riparian uses provided that an equivalent area is offset on site and is adequately connected to the riparian corridor vegetation. The inner 50% of the vegetated riparian zone is required to be fully protected and vegetated with native endemic riparian species, and satisfy the minimum area requirements to maintain bed and bank stability. The averaging rule (**Figure 8**) should generally be applied to cleared waterfront land. Development proposals involving waterfront lands that contain existing native vegetation should seek to preserve the existing vegetation in accordance with the riparian corridor widths outlined in **Table 6**.

Table 6: DPI Water riparian corridor matrix

Requirements & allowable uses	Stream order			
	1st	2nd	3rd	4th +
Vegetated Riparian Zone (VRZ) Width	10 m each bank	20 m each bank	30 m each bank	40 m each bank
Riparian Corridor Offsetting for Non-Riparian Corridor uses	✓	✓	✓	✓
Cycleways and Pathways	✓	✓	✓	✓
Detention Basins				
- Only within outer 50% VRZ	✓	✓	✓	✓
- Online	✓	✓		
Stormwater Outlet Structures & Essential Services	✓	✓	✓	✓
Stream Re-alignment	✓			
Road Crossings				
- Any	✓	✓		
- Culvert			✓	✓
- Bridge			✓	✓

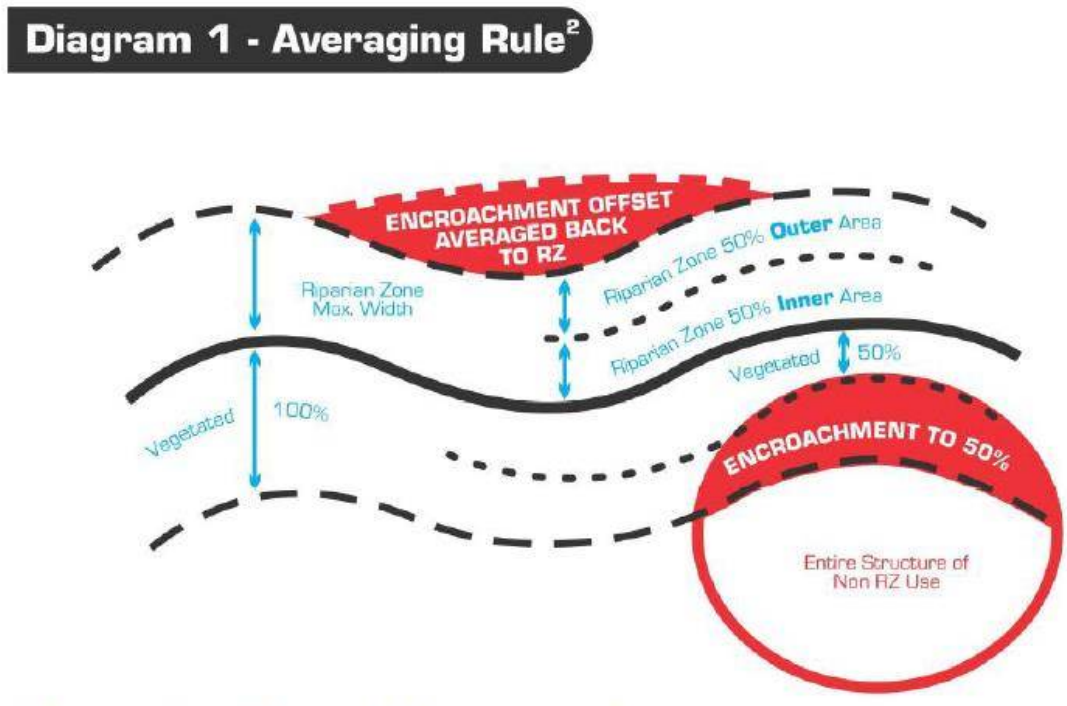

Figure 8: Averaging Rule (Source DPI Water Controlled Activity Riparian Corridor Guidelines)

5.2.2 Riparian Corridor Cross Sections

In determining the appropriate application of the riparian corridor management options described above, basic physical properties of individual watercourses such as channel width and invert are important factors for consideration, in that they help identify the suitability and potential scale of any works that may be required or under consideration.

Basic cross sections for selected watercourses within the Pittwater Estuary, including Wirreanda and Cicada Glen Creeks, have been previously prepared by Pittwater Council (Pittwater Council 2013). For the remainder of the watercourses, including Mullet and Narrabeen Creeks, sections have been prepared based on the information collected during the December 2013 field survey and provide a general interpretation of the dimensions of the respective stream reach. Within the Precinct, watercourses have a channel width and invert that range from between 1 and 10, and 0.2 and 2.3 m respectively. The location of the cross sections for these watercourses are presented in **Figure 9** and provided in **Appendix B.**

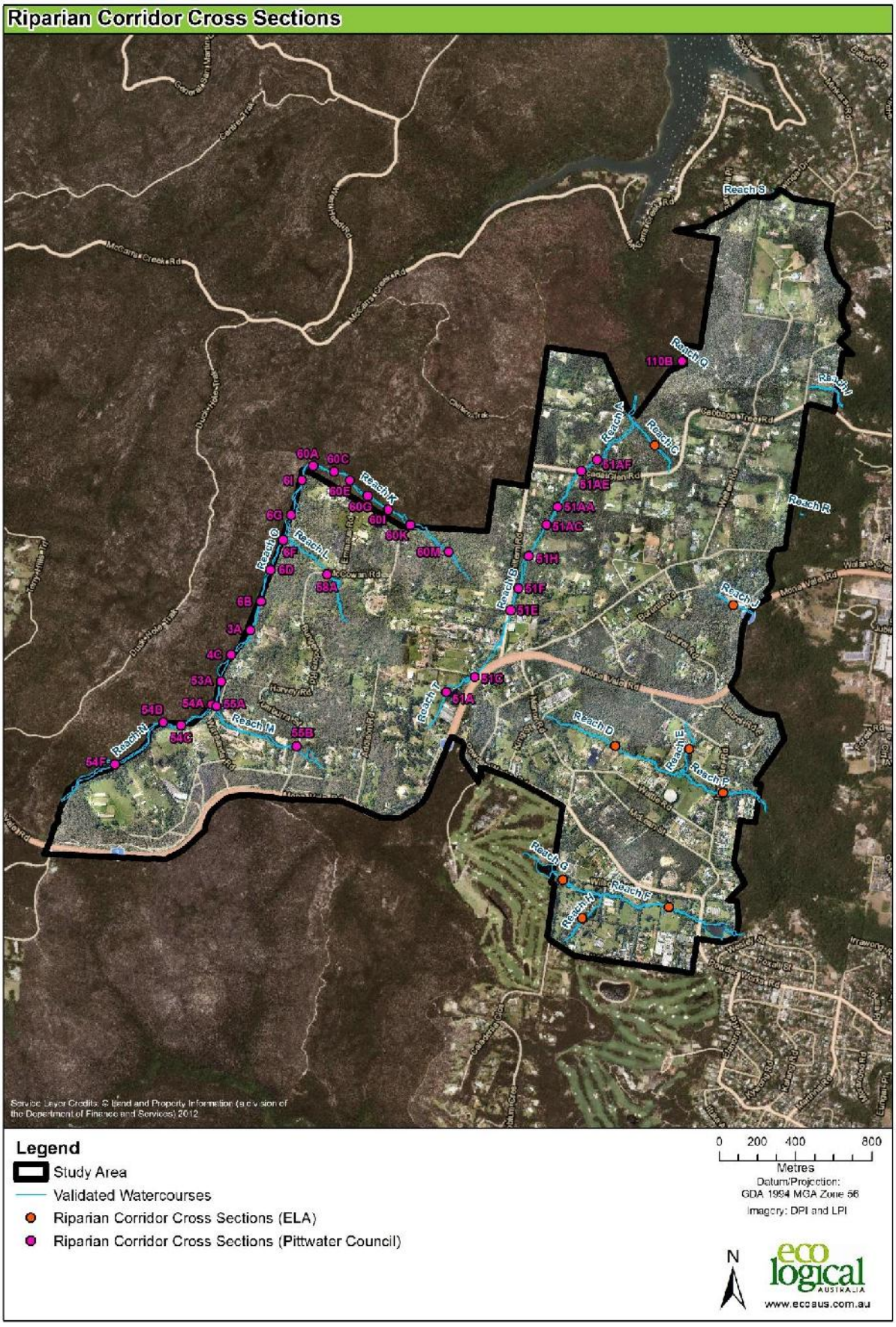

Figure 9: Location of riparian corridor cross sections

6 Conservation and Management Recommendations

The riparian corridors within the Precinct range from degraded to near intact condition, with the majority assessed to be in a degraded condition. However, of the 20 watercourses identified 16 have been assessed as having high or moderate recovery potential either because of their existing condition, function as part of a larger catchment, or potential to impact on sensitive environments. The remaining 4 watercourses have been assessed as having a low recovery potential having already been substantially modified or located within urbanised or highly disturbed sub-catchments.

In this context, the majority of the watercourses within the Precinct should be afforded suitable protection, and the application of appropriate riparian buffers. Integration of the riparian corridors as part of recognised biodiversity corridors within the Precinct should also be considered.

The placement and management of detention/bioretention basins and public open space will be important in helping to maintain and improve the ecological condition of riparian areas. Proposed detention basins should be placed in sections of land which are preferably adjacent to riparian corridors, vegetated with local provenance species, and retained in public ownership. Where possible, open space areas, and water quality and flood detention devices should be located in degraded stream reaches to minimise the loss of existing or better quality habitat across the Precinct.

Where the public ownership of riparian corridors cannot be achieved, opportunities to maximise aquatic ecological values across the site should be considered through the rehabilitation of remnant vegetation in areas zoned for public or private open space, drainage and education infrastructure, and possibly environmental conservation and environmental living.

Specific riparian and aquatic design considerations include;

- Adequate Riparian Protection Areas along Wirreandra, Cicada Glen, Mullet and Narrabeen Creeks (or their tributaries with moderate conservation and recovery potential), with co-location of water treatment/detention facilities to maintain or increase the effective riparian corridor width,
- Integration of GDE's as part of the broader riparian and/or biodiversity corridor network within the Precinct.
- Embellishment of existing native riparian and aquatic vegetation and restoration of the aquatic habitat of the watercourses as part of a riparian corridor management plan
- Where possible, incorporation of new wetlands and the rejuvenation of aquatic habitat within areas of open space and or conservation lands to replace areas lost for infrastructure,
- Use of local provenance wetland species for detention basin design, with specific consideration given to establishing or enhancing suitable wetland/aquatic habitat,
- Appropriate use of large woody debris to re-introduce in stream habitat,
- Control of peak flows to reduce erosion impacts and improve water quality through the implementation of WSUD.
- Design and placement of sewer infrastructure to reduce the potential impact of overflows within riparian environments.
- Perimeter roads to separate development areas from the riparian corridor VRZ.

7 Assessment of Structure Plan

This section provides a brief analysis of the Structure Plan (**Figure 10**). The Office of Water controlled activity guidelines, whilst not directly applicable to a rezoning, have been considered during the development of the Structure Plan. The structure plan achieves the objectives of NSW policy settings in the following manner:

1. All waterways contain riparian buffers that comply with DPI Water guidelines. These areas are displayed as 'hatched' and labelled 'creek corridors' in the Structure Plan (**Figure 10**).
2. The Structure Plan protects via **all** riparian corridor VRZ reaches identified as 'high riparian corridor conservation priority' (**Figure 7**) on site by assigning appropriate environmental land uses areas. This appropriate application of land use areas is broken down in **Table 7** below.
3. The land use controls provided by environmental conservation and water management will minimise disturbance and harm to the recommended larger riparian corridor VRZ areas.
4. The widths allowed for riparian buffers in the Structure Plan often exceeds DPI Water guidelines minimum widths. **Figure 10** shows a series of measured riparian and ecological corridors widths, within the portion of the Ingleside Precinct proposed for development. These widths are based only on proposed Environmental Conservation land use, and do not include stormwater basins, parks, or other landuses). These are:
    a. For Cicada Glen Creek to the east of Cicada Glen Drive the widths are 23m - 70m. The portion to the west of Cicada Glen Drive is proposed for a park landuse. This is considered appropriate given that this is in the upper reach of this creek, and this section is already cleared of native vegetation, or has exotic vegetation.
    b. A proposed ecological corridor connecting Narrabeen Creek (at the eastern edge of the precinct just north of Mona Vale Road) connecting to the eastern tributary of Cicada Glen Creek (north of Cicada Glen Road / Cabbage Tree Road). The measured widths for this corridor are 50m - 427m. It is noted that this includes both riparian and non-riparian sections, with the width of the non-riparian section limited by current development.
    c. On the northern branch of Mullet Creek widths are 25m - 290m.
    d. For the proposed ecological corridor located between the northern and southern branches of Mullet Creek (and not associated with a riparian corridor), widths are 26m - 296m.
    e. On the southern branch of Mullet Creek widths are 27m - 61m.

5. Creek crossings have been restricted to existing crossings only. Those being:
    a. On Wirreanda Creek via Tumburra St and Wirreanda Rd (Reach M) on the northern tributary, and McCowan Road (Reach L) in the southern tributary
    b. On Mullet Creek via Powder Creek Rd (Reach F) & Ingleside Rd (Reach P) and
    c. On Cicada Glen Creek via Cicada Glen Drive (Reach A) and Chiltern Rd (Reach B).

6. Stormwater basins are generally located "off-line" (Cardno 2016)
7. Where stormwater detention is required outside the riparian corridor but within the VRZ a water management land use has been assigned.
8. All stormwater run-off will be detained prior to discharging into the riparian corridor VRZ.
9. Native vegetation within the environmental conservation landuse areas will be retained and there are significant corridors established as a result.
10. DPI Water were consulted on the draft Structure Plan and on 12/5/2015 they provided advice that they were supportive of the draft Structure Plan in terms of riparian corridors.

Vegetation Management Plan(s) and DCPs for the environmental conservation land use areas have not yet been prepared, but there is the opportunity for areas mapped as cleared and exotic vegetation, to be revegetated, and for disturbed areas to be rehabilitated and/or used for passive recreational opportunities appropriate for the setting. Specific riparian and aquatic design considerations are outlined in the previous chapter.

Table 7: Land uses applied to riparian corridors

Reach	Environmental Conservation	Environmental Management	Existing Road	Houses	Houses on Larger Lots	Major Road	Outside of Precinct	National Park	Park	Private Open Space	Proposed Mona Vale Road Corridor	Rural	Water Management	Total (KMs)
Reach A	0.9					0.02	0	0.06						**0.98**
Reach B	1.14					0.29			0.12				0.54	**2.09**
Reach C	0.49					0.01							0.16	**0.66**
Reach D	1.61		0.02										0.12	**1.75**
Reach E	0.5		0.05		0.01								0.11	**0.67**
Reach F	1.14					0.04	0.01			0.53				**1.72**
Reach G	0.67						0.38							**1.05**
Reach H	0.64													**0.64**
Reach I		0.32				0.02	0							**0.34**
Reach J	0.35										0.07			**0.42**
Reach K	0.84													**0.84**
Reach L	1.16		0.06											**1.22**
Reach M	0.51		0.11					0.05				0.88		**1.55**
Reach N	0.56						0.2	0.33						**1.09**
Reach O	0.71							1.08						**1.79**
Reach P	0.76		0.04				0						0.17	**0.97**
Reach T				0		0.08			1.29		0.01		0.06	**1.44**
Total (KMs)	**11.98**	**0.32**	**0.28**	**0**	**0.01**	**0.46**	**0.59**	**1.52**	**1.41**	**0.53**	**0.08**	**0.88**	**1.16**	**19.22**

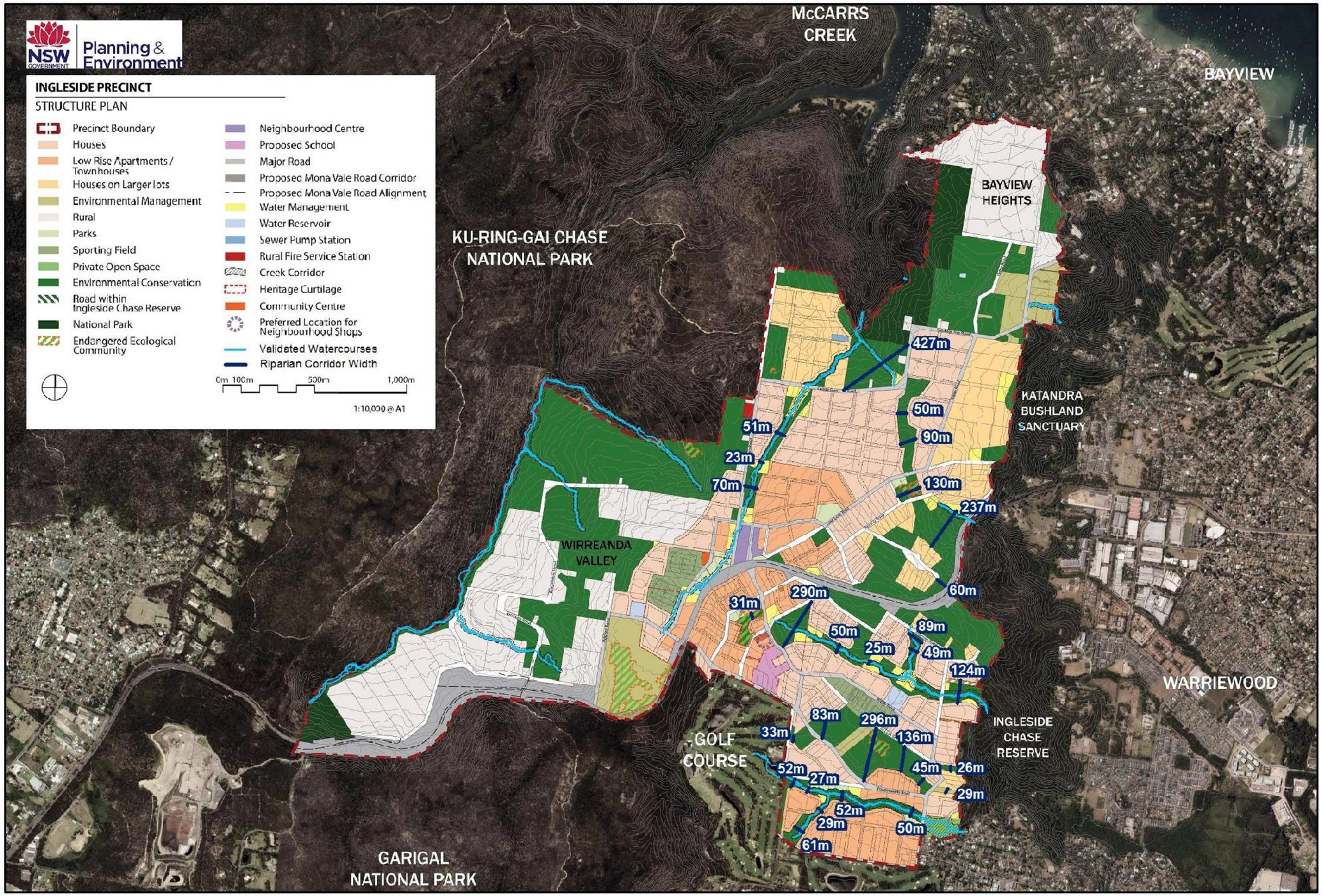

Figure 10: Structure Plan and riparian corridor widths

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Appendix A: Watercourse images recorded in the field

Watercourse		
Cicada Glen Creek		
Reach A		

Reach B		
Reach C		

Reach T		

Wirreanda Creek		
Reach L		

Reach M		
Reach N		

Reach O		

Crystal Creek		
Reach K		

Mullet Creek		
Reach D		

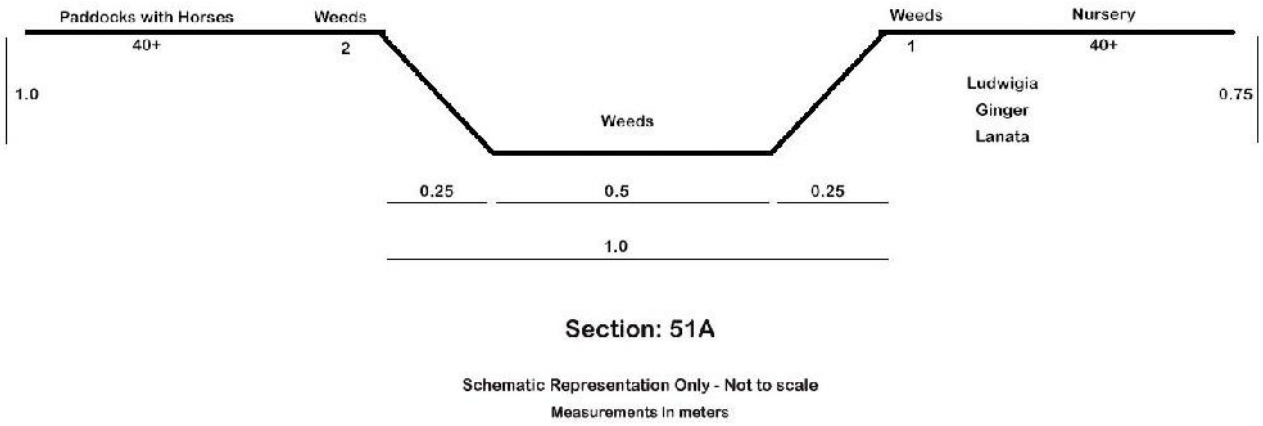
Reach E		
Reach F		

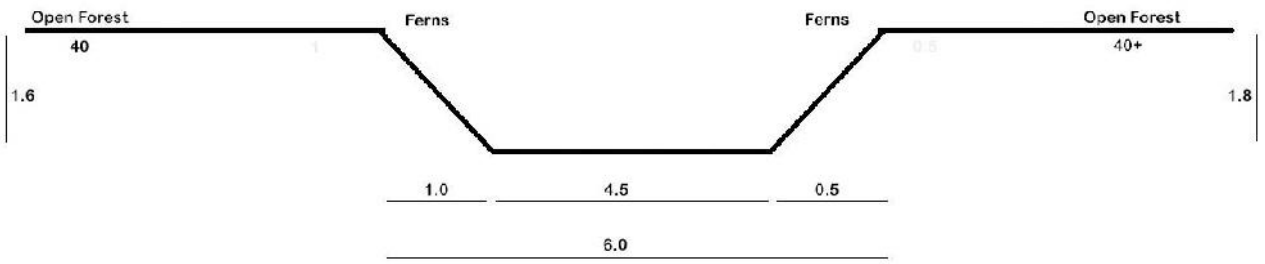
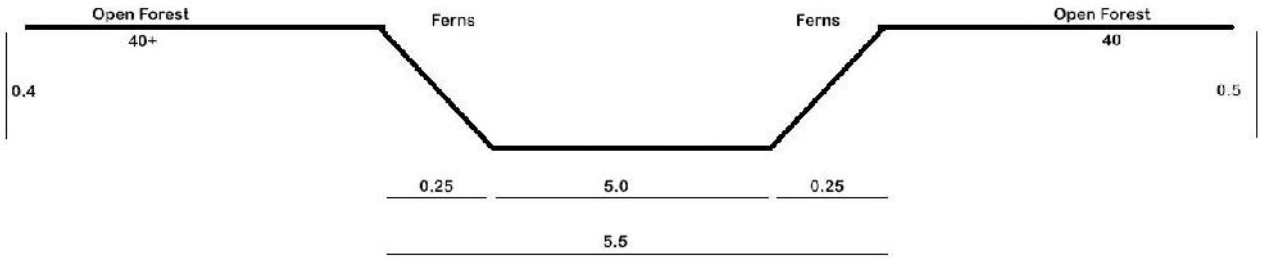
Reach G		
Reach H		

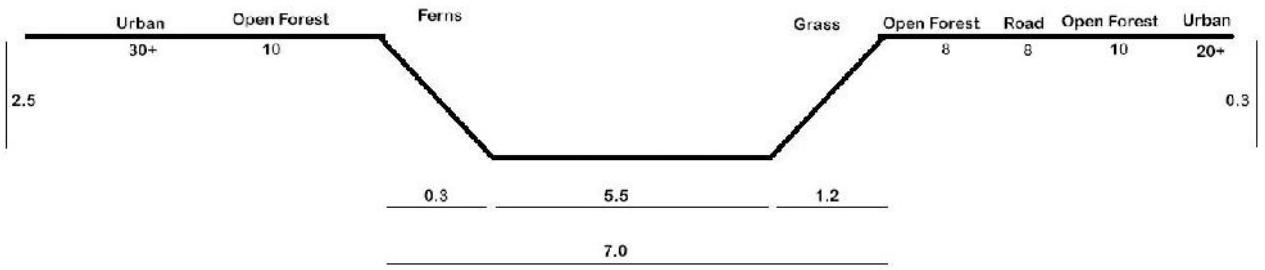
Reach P		

Narrabeen Creek		
Reach J		

Appendix B: Riparian Corridor Cross Sections

Water Course	Riparian Cross Section	
Cicada Glen Creek	51A	

	51AA	 **Section: 51AA** Schematic Representation Only - Not to scale Measurements in meters
	51AC	 **Section: 51AC** Schematic Representation Only - Not to scale Measurements in meters

	51AE	 **Section: 51AE** Schematic Representation Only - Not to scale Measurements in meters	
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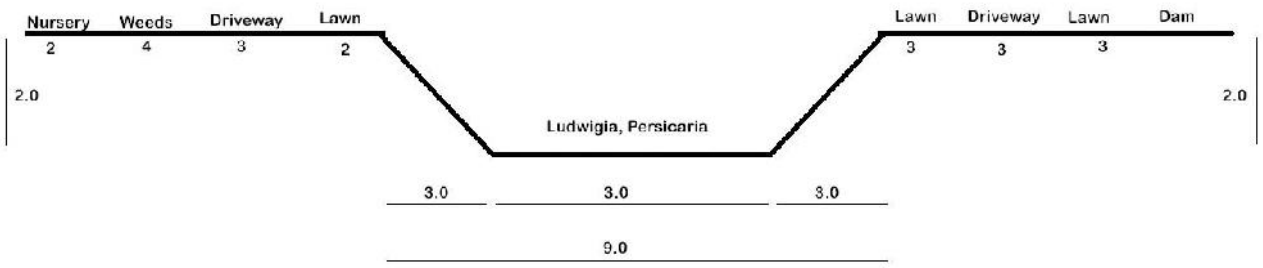
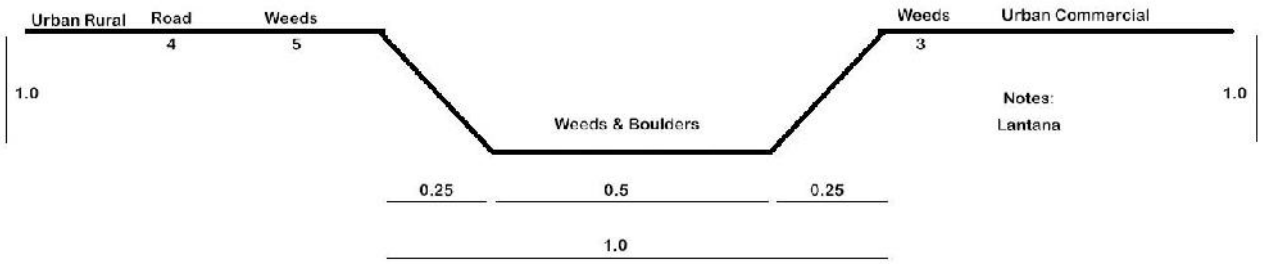
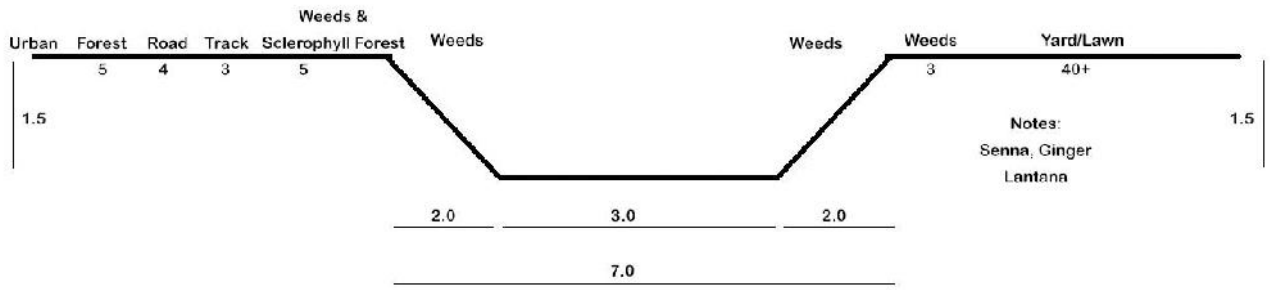
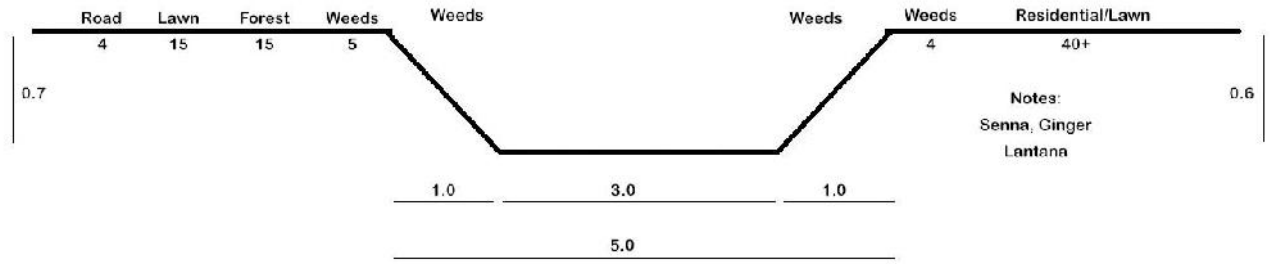
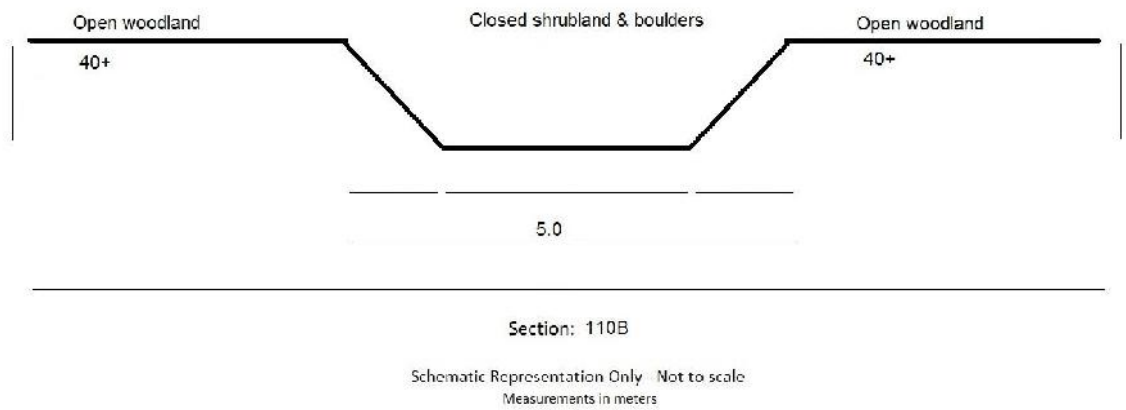
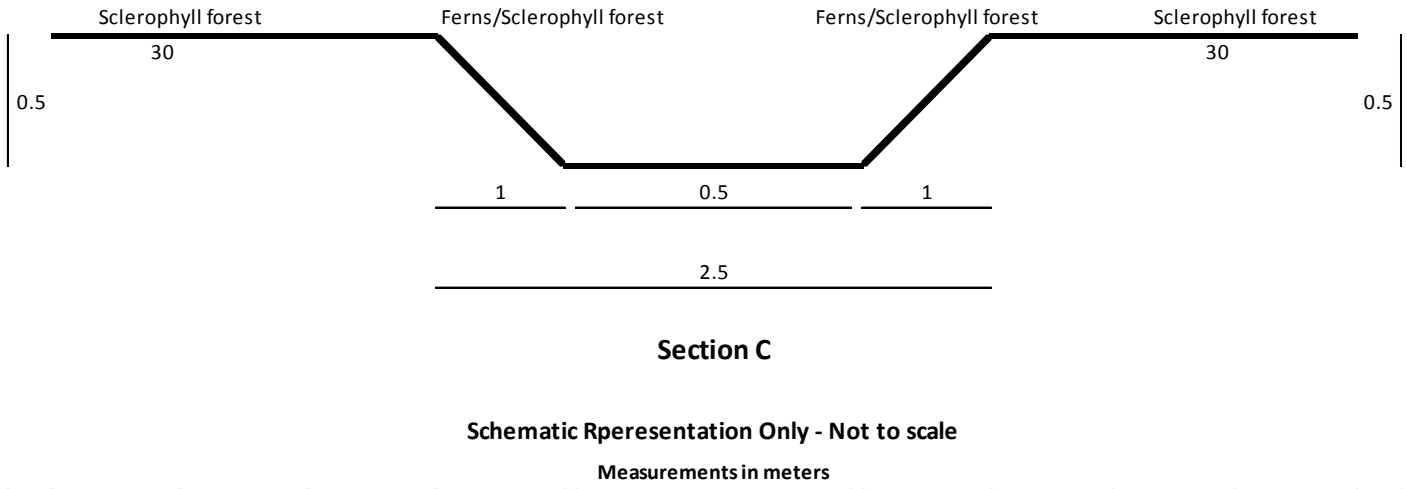
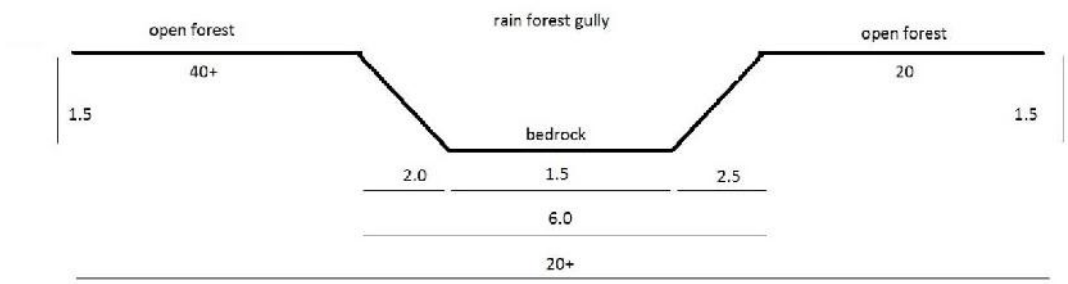
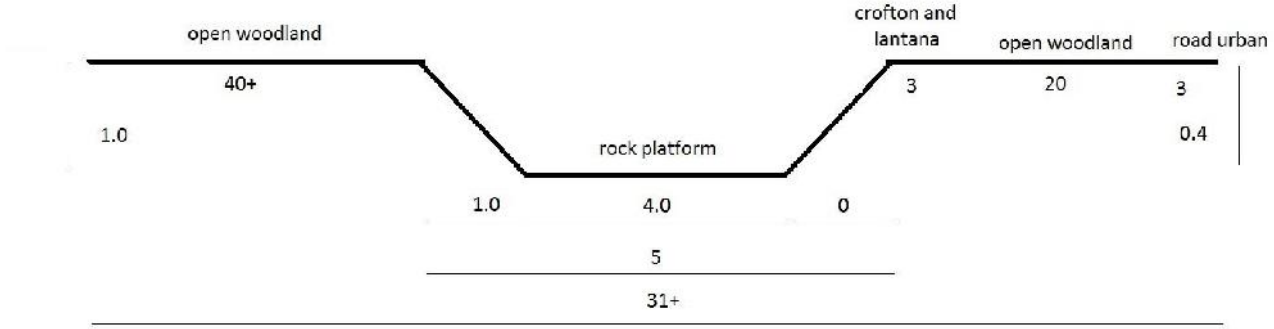
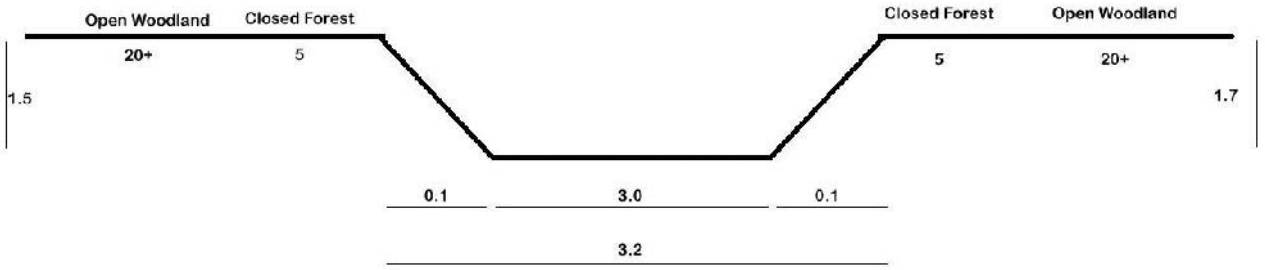
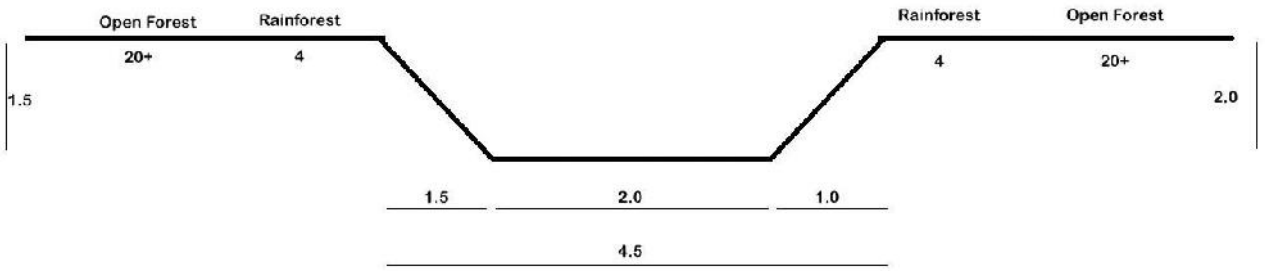
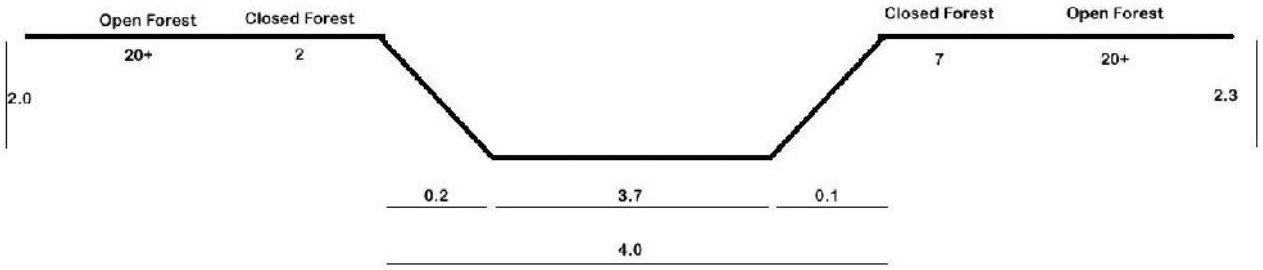
	51C	 **Section: 51C** Schematic Representation Only - Not to scale Measurements in meters
	51E	 **Section: 51E** Schematic Representation Only - Not to scale Measurements in meters

	51F	 **Section: 51F** Schematic Representation Only - Not to scale Measurements in meters
	51H	 **Section: 51H** Schematic Representation Only - Not to scale Measurements in meters

	110B	
	Reach C	

Wirreanda Creek	3A	 Section: 3A Schematic Representation Only - Not to scale Measurements in meters
	4C	 Section: 4C Schematic Representation Only - Not to scale Measurements in meters

	6B	 **Section: 6B** Schematic Representation Only - Not to scale Measurements in meters
	6D	 **Section: 6D** Schematic Representation Only - Not to scale Measurements in meters

	6F	 **Section: 6F** Schematic Representation Only - Not to scale Measurements in meters
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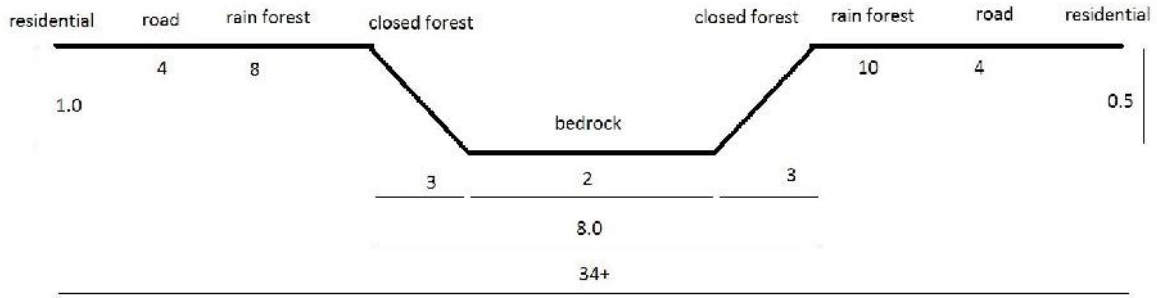
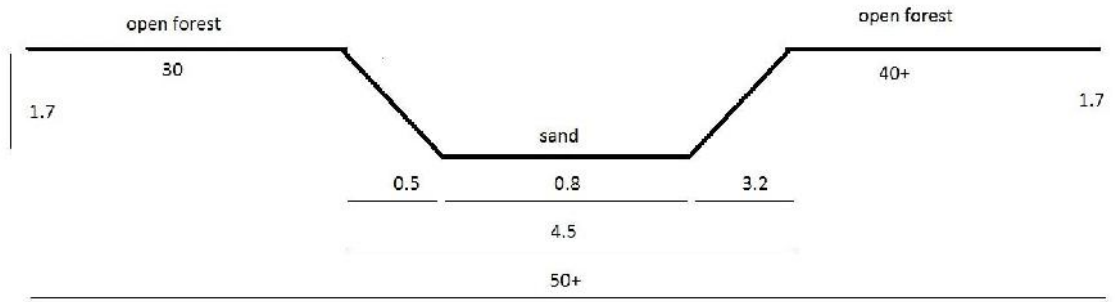
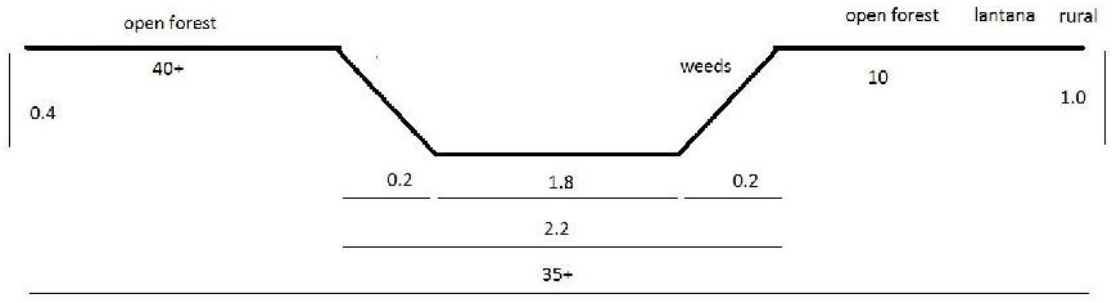
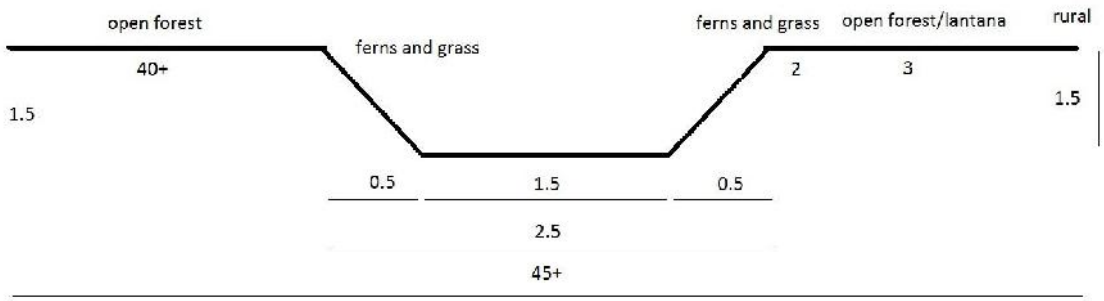
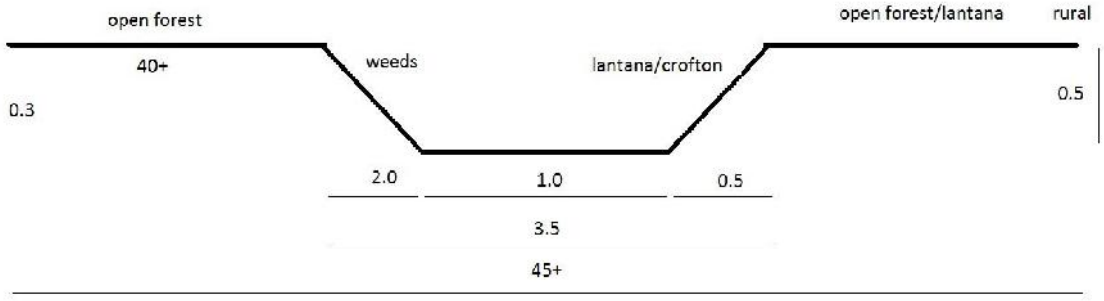
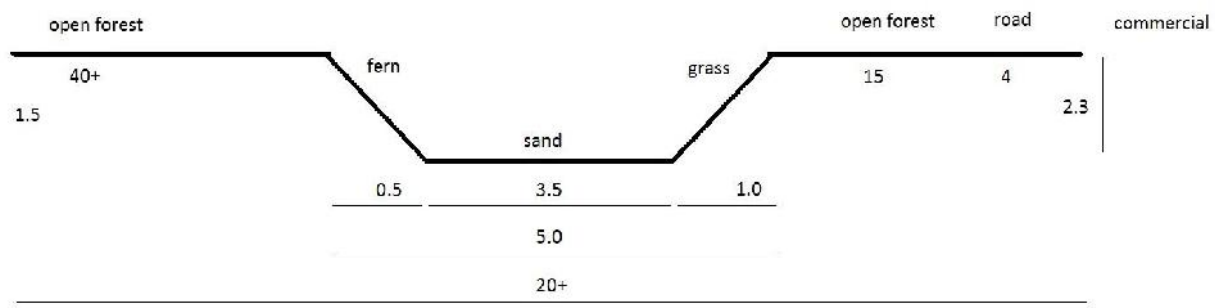
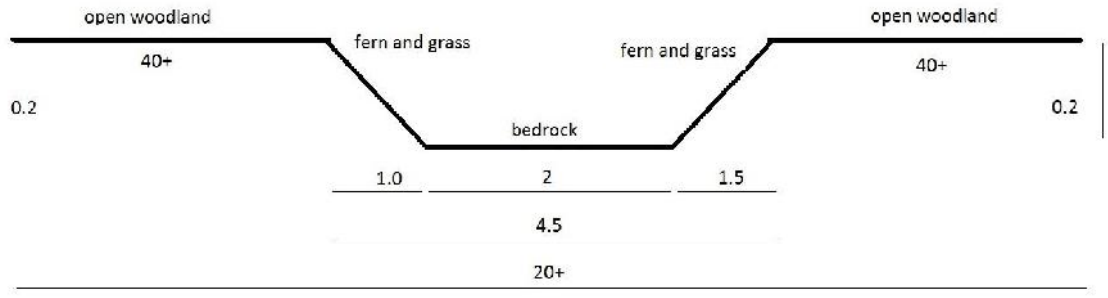
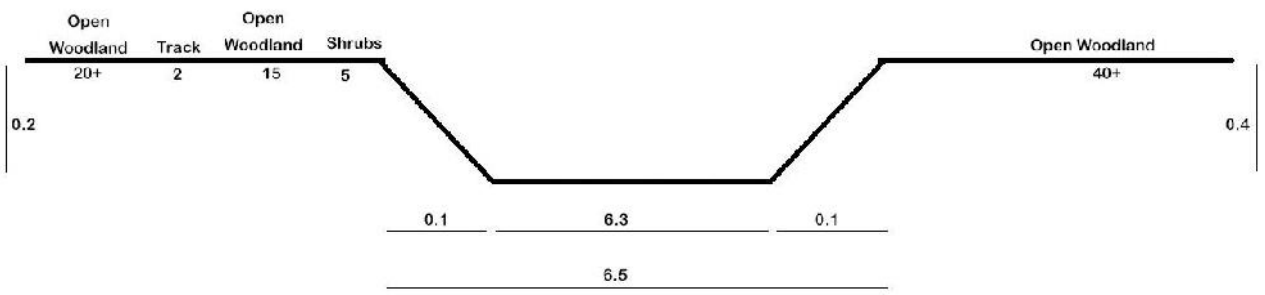
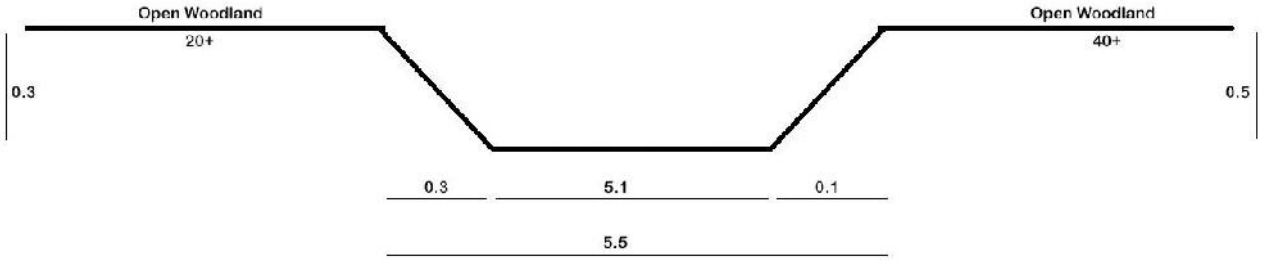
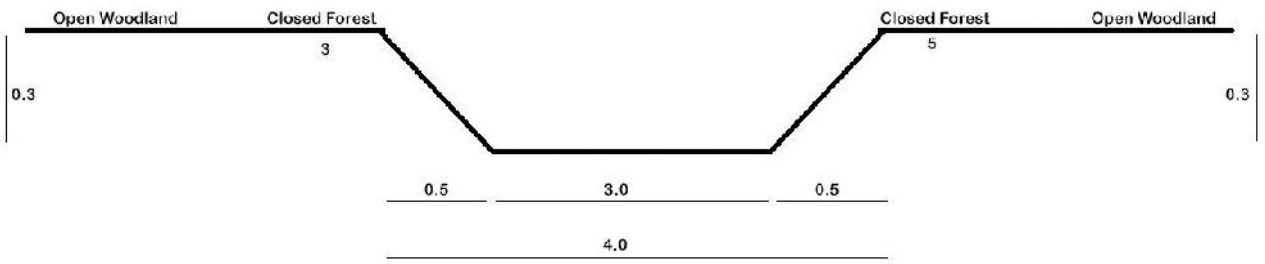
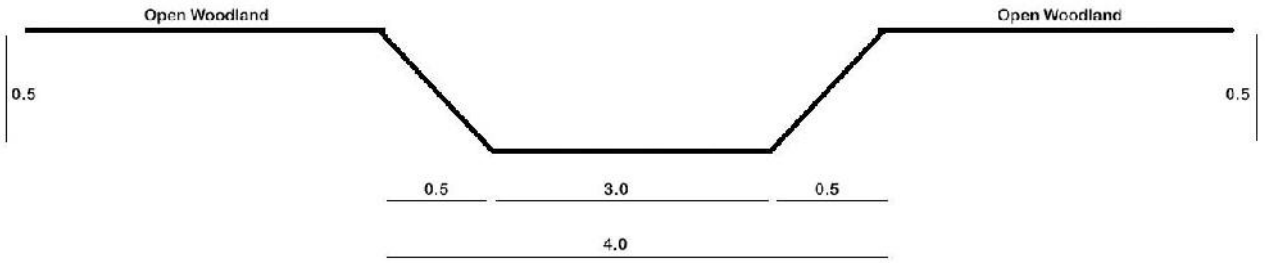
	53A	 Section: 53A Schematic Representation Only - Not to scale Measurements in meters

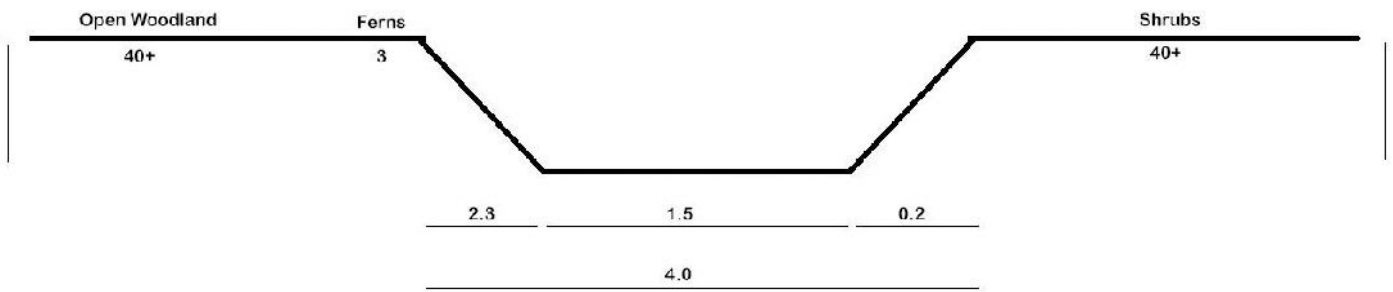
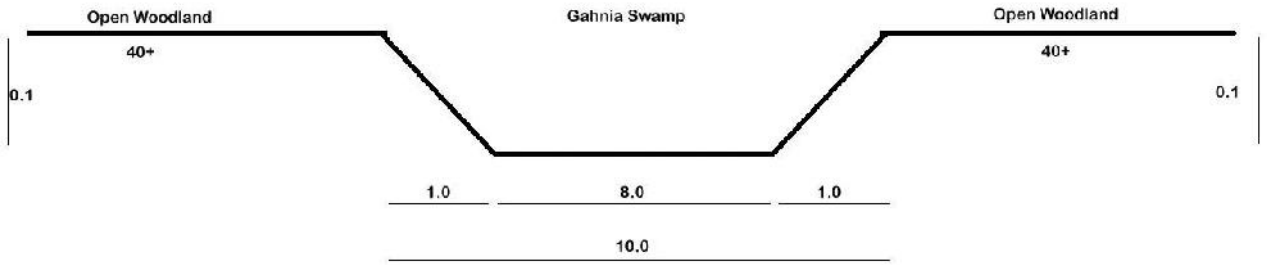
	54A	 Section: 54A Schematic Representation Only - Not to scale Measurements in meters
	54C	 Section: 54C Schematic Representation Only - Not to scale Measurements in meters

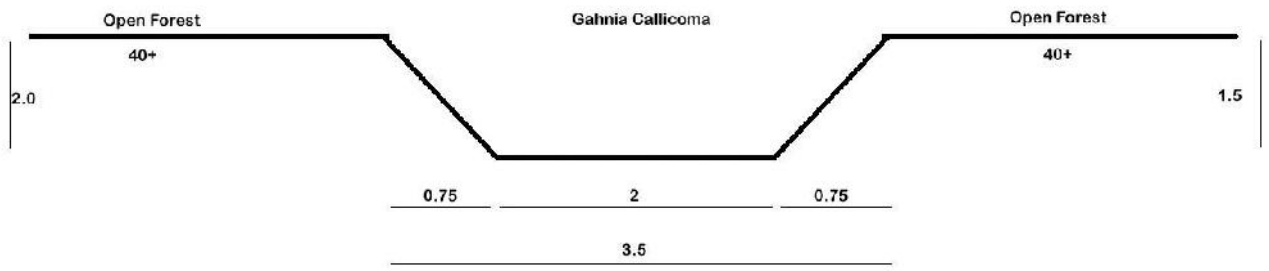
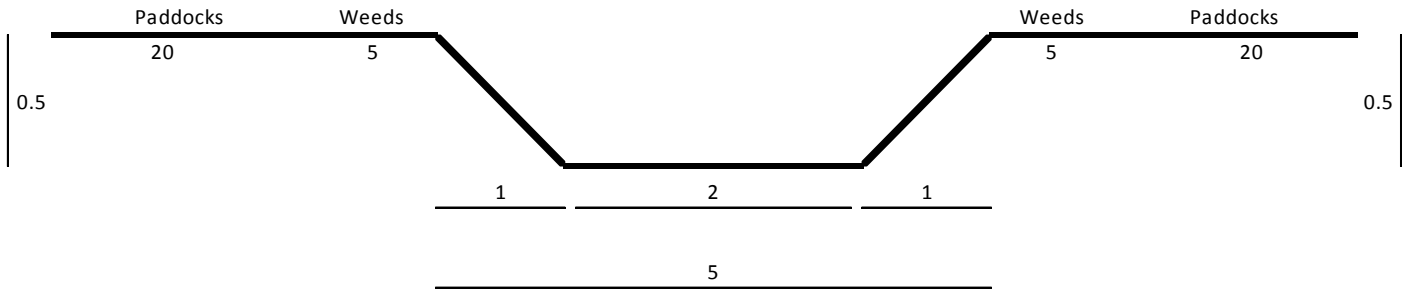
	54D	 Section: 54D Schematic Representation Only Not to scale Measurements in meters
	54F	 Section: 54F Schematic Representation Only Not to scale Measurements in meters

	55A	 Section: 55A Schematic Representation Only Not to scale Measurements in meters	
	55B	 Section: 55B Schematic Representation Only Not to scale Measurements in meters	

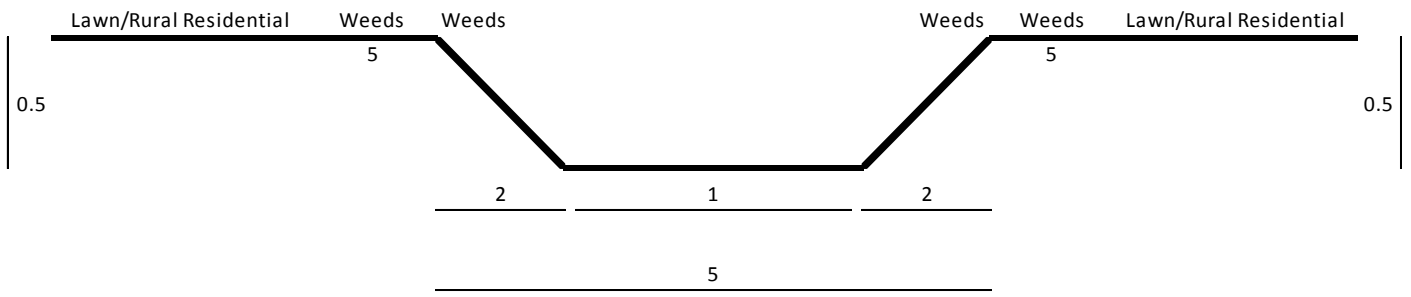
Crystal Creek	60A	 **Section: 60A** Schematic Representation Only - Not to scale Measurements in meters
	60C	 **Section: 60C** Schematic Representation Only - Not to scale Measurements in meters

	60E	 **Section: 60E** Schematic Representation Only - Not to scale Measurements in meters
	60G	 **Section: 60G** Schematic Representation Only - Not to scale Measurements in meters

	60I	 **Section: 60I** Schematic Representation Only - Not to scale Measurements in meters
	60K	 **Section: 60K** Schematic Representation Only - Not to scale Measurements in meters

	60M	 **Section: 60M** Schematic Representation Only - Not to scale Measurements in meters
Mullet Creek	Reach G	 **Reach G** **Schematic Rperesentation Only - Not to scale** **Measurements in meters**

Reach H

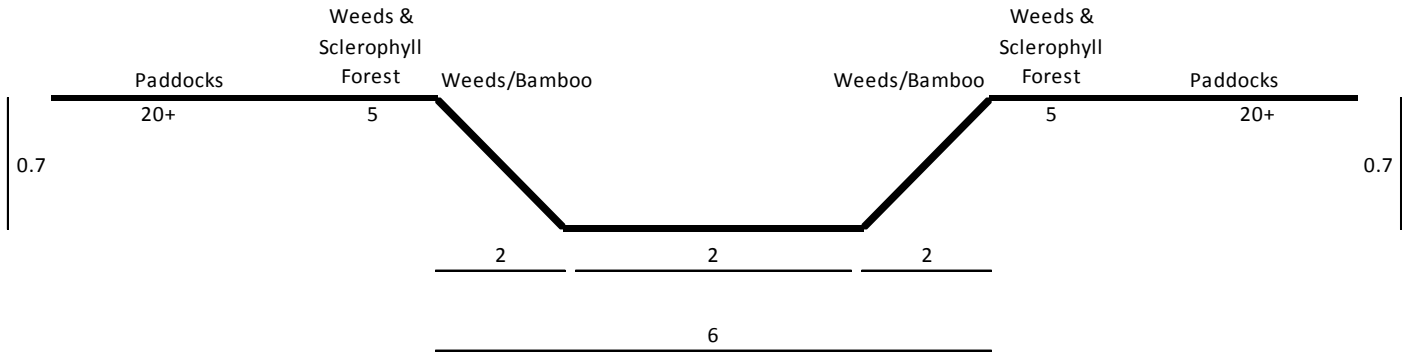


Section H

Schematic Rperesentation Only - Not to scale

Measurements in meters

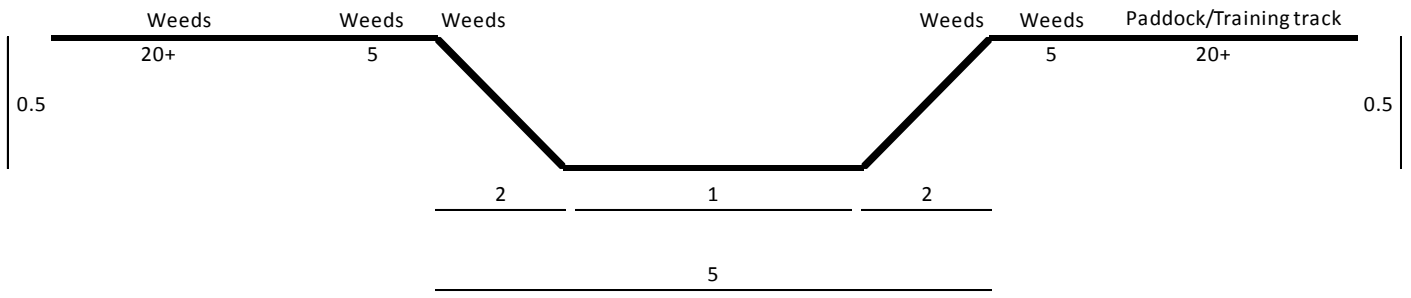
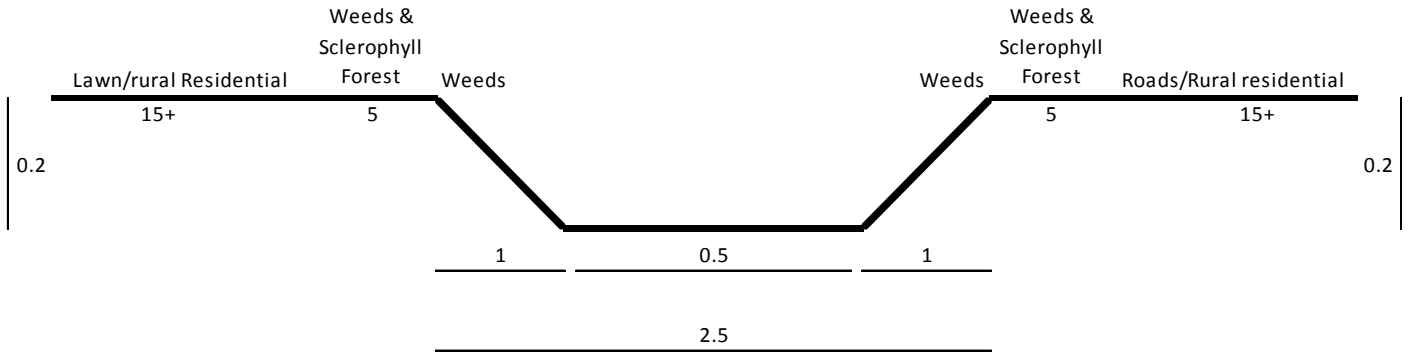
Reach F

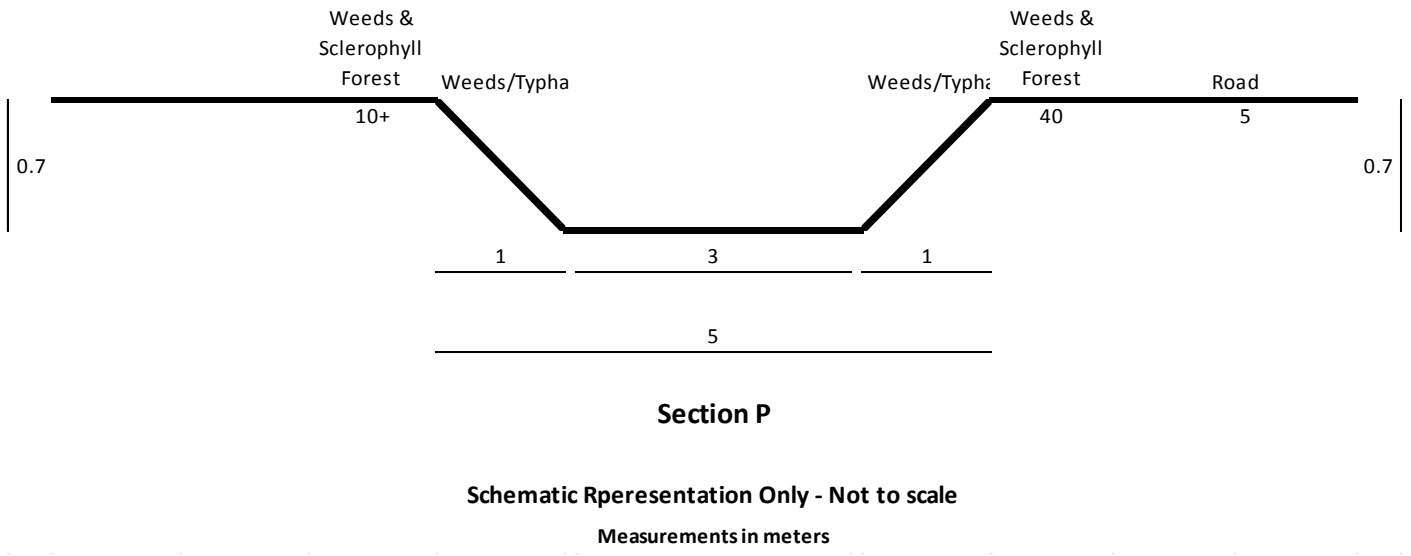
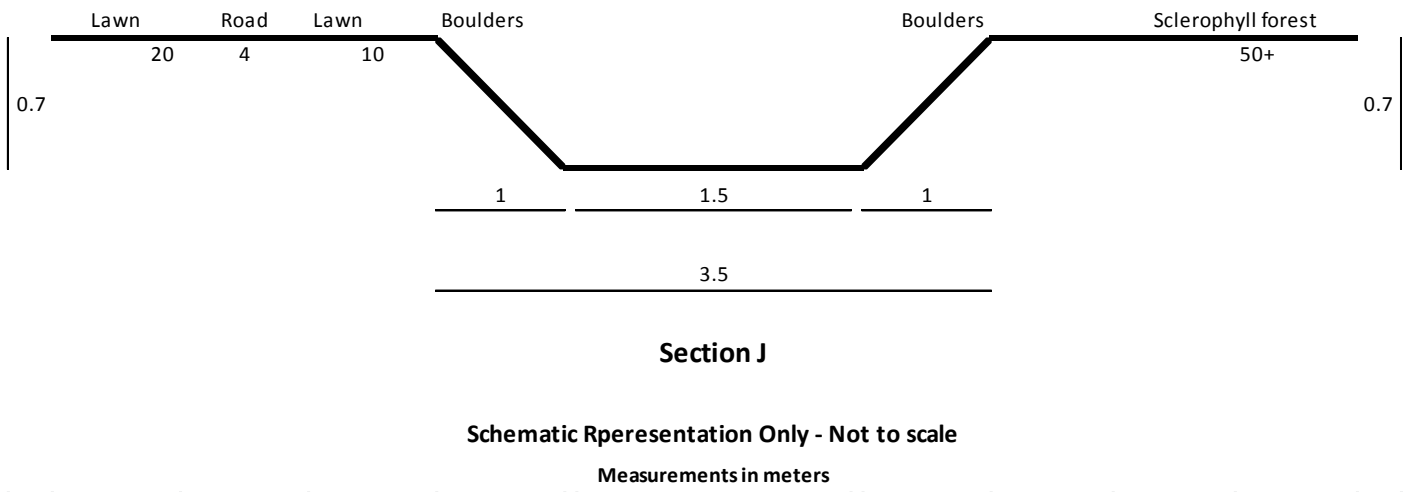


Section F

Schematic Rperesentation Only - Not to scale

Measurements in meters

	Reach D	 **Section D** **Schematic Rperesentation Only - Not to scale** **Measurements in meters**
	Reach E	 **Section E** **Schematic Rperesentation Only - Not to scale** **Measurements in meters**

	Reach P	
Narrabeen Creek	Reach J	

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