Government of **Western Australia**
Department of **Water**

Determining water level ranges of Pilbara riparian species

Looking after all our water needs

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Department of Water

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Australian Government
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Summary

This document describes an approach used to determine water depth ranges of dominant Pilbara riparian species. It uses the distribution of species across an ecological gradient and measured depth to groundwater or depth of inundation (flooding) across that range.

Water level ranges are determined for 16 species across 23 sites on four rivers; the Robe, Yule and De Grey Rivers and the Fortescue River at Millstream. Species include the large, deep rooted trees, *Eucalyptus camaldulensis* and *Melaleuca argentea*, smaller tree/shrubs such as *Sesbania formosa* and *Hakea subera*, and the emergent macrophytes (sedges), *Typha domingensis, Baumea juncea* and *Cyperus vaginatus.*

Water level ranges are important to determine the susceptibility of riparian species to altered water regimes. However, there are limitations to the approach and it is best regarded as a 'rule of thumb' method to be used in the absence of site specific understanding of physiological responses to changes in water.

1 Introduction

Rivers of the Pilbara region are ephemeral, flowing in response to rainfall from summer cyclones or thunderstorms. They are also often associated with shallow alluvial aquifers or subsurface storage of groundwater. Riparian flora of the region has adapted to these conditions.

Riparian vegetation is central to the ecological functioning of river ecosystems (WR&M 2008). Intact, healthy vegetation provides the following ecosystem services:

- provides complex habitat for native fauna
- stabilises sediments
- filters pollutants from surface runoff
- shades the littoral zone
- provides primary productivity.

This report describes how the water depth ranges of riparian vegetation were determined across four Pilbara alluvial aquifers (the Yule, Lower Robe and Lower De Grey rivers and the Fortescue River at Millstream). The approach is based on the physical distribution of species across an ecological gradient and the measured depth to groundwater or depth of inundation (flooding) across that range. A similar approach has been applied to wetlands and riparian systems across Western Australia – the Gnangara and Jandakot mounds (Froend & McComb 1994; Loomes 2000), the Swan and Scott Coastal Plains, the Blackwood River (Froend & Loomes 2006) and the Torbay/Elleker area on the south coast (McKay et al. 2008).

The results of this work provide an understanding of the tolerance of riparian species to changes in water availability, acting as a surrogate for detailed physiological studies.

The four study sites support vegetation that is thought to utilise groundwater to meet its water requirements between periods of soil water recharge (from surface water flows or rainfall). Three of the four sites – Yule, Lower Robe and Lower De Grey rivers – are shallow alluvial systems recharged mostly by river flow. Millstream is a complex system of wetlands sustained by groundwater discharge from the Millstream aquifer and intermittent seasonal flow from the Fortescue River (Antao & Braimbridge 2009).

2 Choice of riparian species

Riparian species in the Pilbara represent the mesic or wet end of an ecological gradient of decreasing water availability. Although vegetation higher on the ecological gradient may draw upon groundwater at times, riparian vegetation is considered the main groundwater-dependent vegetation of the Pilbara. It is also likely to be the most sensitive and least tolerant to decreased water availability.

It is possible to apply the study method to any plant species however, this study focussed on the dominant species, as they drive other ecosystem processes/services. These species are also often widespread and common to other Pilbara systems (e.g. floodplains, springs, river pools). As with all regions, riparian vegetation of the Pilbara includes species from different life form classes.

2.1 Emergent macrophytes

Emergent macrophytes, that it is sedges and rushes with vegetative parts emerging from fresh water, are associated with permanent and semi-permanent river pools. Growth of these species generally peaks in waterlogged soils, but they will tolerate drying for short periods of the year. These species can reproduce sexually or vegetatively, with underground rhizome extensions enabling them to spread rapidly in response to changing water regimes. They generally tolerate only a narrow range of water depths.

Emergent macrophytes found in the Pilbara and included in the study are:

- *Typha domingensis* – narrow-leafed, erect, native perennial, up to 4 m tall (Sainty & Jacobs 2003)
- *Baumea juncea* – perennial sedge, 0.2–1.2 m tall (Paczkowska & Chapman 2000)
- *Cyperus vaginatus* – tufted, native perennial, 0.3 – 2 m tall (Paczkowska & Chapman 2000).

2.2 Riparian trees and shrubs

Riparian trees generally occur on higher ground than emergent macrophytes or shrubs, but can tolerate inundation for extended periods of time. Due to their size and longevity, trees often have much greater water depth ranges than other life forms.

Shrubs generally tolerate lower depths of inundation for shorter time periods than trees or emergent macrophytes, and shallower depths to groundwater than trees. Their water depth ranges are therefore generally intermediate between trees and emergent macrophytes.

Riparian trees and shrubs of the Pilbara include:

- *Eucalyptus camaldulensis* – tree, 5 – 20 m tall, biomorphic root system (surface lateral roots and a tap root). Found along rivers and creeklines.

Relies on frequent floods for dispersal and germination of seeds (Pettit & Froend 2001).

- *Melaleuca argentea* – tree, 3 – 8 m tall, shallow planform (flat) root system. Found along rivers and creeklines and often associated with permanent pools.
- *E*. victrix – spreading tree 1 – 12 m tall. Thought to occur in slightly drier areas than *M. argentea* and *E. camaldulensis*.
- *Sesbania formosa* – shrub or tree, 2.5 – 13 m tall. Restricted to alluvium and creek lines or rivers (Paczkowska and Chapman 2000).
- *Atalaya hemiglauca* – shrub or tree, 1.5 – 10 m tall. Found on sandstone ridges or floodplains.

Melaleuca glomerata, M. bracteata, Livistona alfredii, Lysiphyllum cunninghamii, Ficus opposita, Hakera subera and *Acacia ampliceps* were also included in the study.

3 Approach used

3.1 Measuring the distribution of species

To determine the distribution of riparian species across a site the total distance each species extended from a known point (generally the edge of an active channel or river pool) was measured. For example, in Figure 1 *Eucalyptus camaldulensis* occurred between 5 m and 15 m from the edge of the river pool.

As the elevation of a species' distribution was also required, it was most useful to measure distributions in as straight a line as possible, or at least in a pattern that was easily tracked or followed.

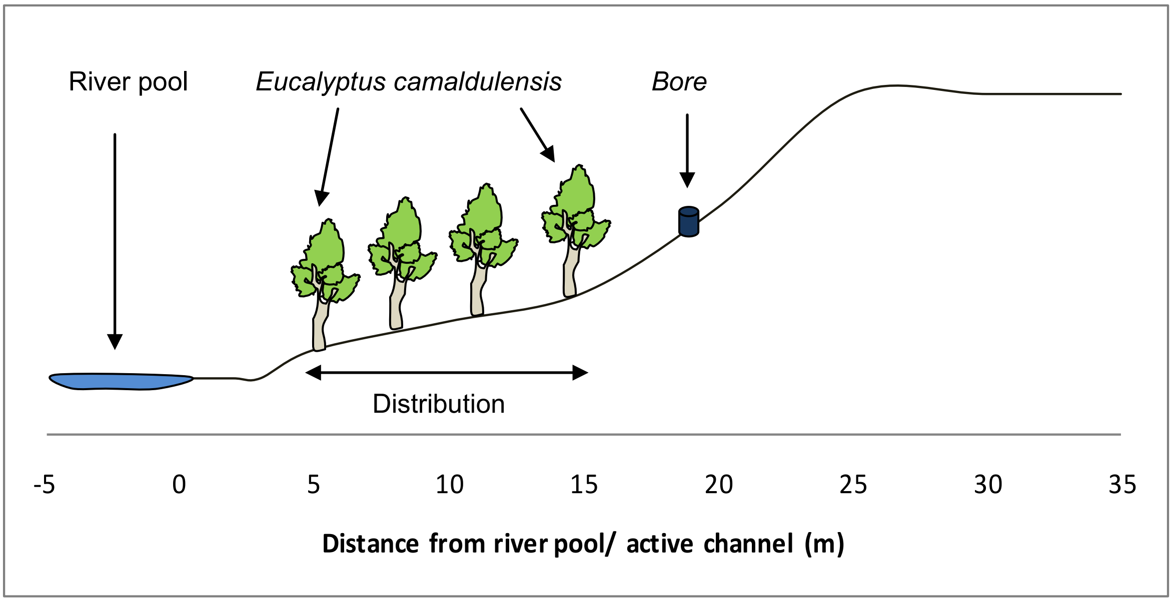


Figure 1 Example of the distribution of Eucalyptus camaldulensis

3.2 Determining the elevational range of species

Two methods were used to measure the change in elevation across the four study rivers. A dumpy level was used to measure changes at 10 sites on the De Grey River. Other surveying equipment such as a builder's auto level, levelling instruments or automatic levels, could also have been used. Once local elevations were determined, elevations relative to the AHD datum were obtained by connecting with existing surveyed points such as a bore or gauging station.

The second method was LiDAR (light detecting and ranging), a remote sensing technology that uses laser scanning to collect height or elevation data. This method was used for sites at Millstream, and at Yule and Robe rivers, where vegetation distribution had previously been measured.

Regardless of which technique was used, changes in elevation were measured at specific intervals (e.g. 10 m) across the species range. The highest and lowest elevation at which the species occurs across the site was recorded as its elevational range. In the example, *E. camaldulensis* occurred between elevations of 3.0 and 5.0 m AHD (Figure 2).

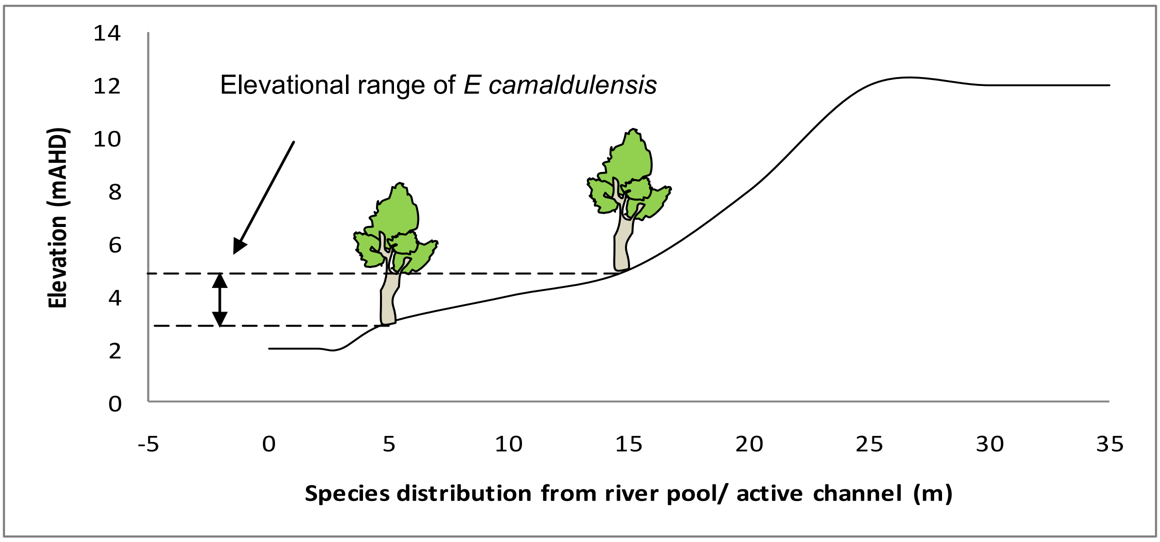


Figure 2 Example of an elevational range of E. camaldulensis

3.3 Describing the hydrological regime

The depth to the watertable is the most important component of the water regime in relation to the distribution of riparian vegetation in the Pilbara. However, the depth, duration and frequency of inundation or flooding are also important.

Water depth, as depth to groundwater and/or depth of inundation, was determined using surface water levels (stage heights) recorded at gauging stations and/or groundwater data from nearby monitoring bores (details of datasets used for each site are listed in Appendix 1). Two sites on the Robe River (Rob01 and Rob03) were not included in water level range analysis as there were no bores located within a suitable distance (e.g. Rob03 was about 7 km from the nearest suitable bore).

As the hydrology of Pilbara rivers is strongly influenced by large flood events and extended dry periods, both absolute (highest and lowest levels recorded) and mean depths of inundation and depth to groundwater were considered.

Longer term, temporal changes in hydrology also have an impact on vegetation composition and structure. As previously mentioned, trees tend to respond more slowly (over a period of years) to changed water regime than other species, while emergent macrophytes can respond to seasonal fluctuations. For this reason, where data were available, water level ranges were considered across different temporal scales. For example, 20-year means for tree species and 2-year means for emergent macrophytes. Therefore, mean minimum and mean maximum depths were calculated for 20-year and 2-year periods. However, as long-term hydrological data sets were not always available, 10-year and 5-year means were also calculated (Table 1, Figure 3).

Table 1 Example of hydrological data (m AHD) measured at a bore

Hydrological parameter	**1-year**	**5-year**	**10-year**	**20-year**
Mean annual min	2.05	1.80	1.54	1.25
mean annual max	4.25	3.50	3.25	2.00
Absolute min	2.05	1.35	1.05	0.50
Absolute max	10.10	6.55	7.20	6.20
mean	3.20	2.10	1.95	2.75
Time period	01/08–3/09	2004–09	1999–2009	1989–2009

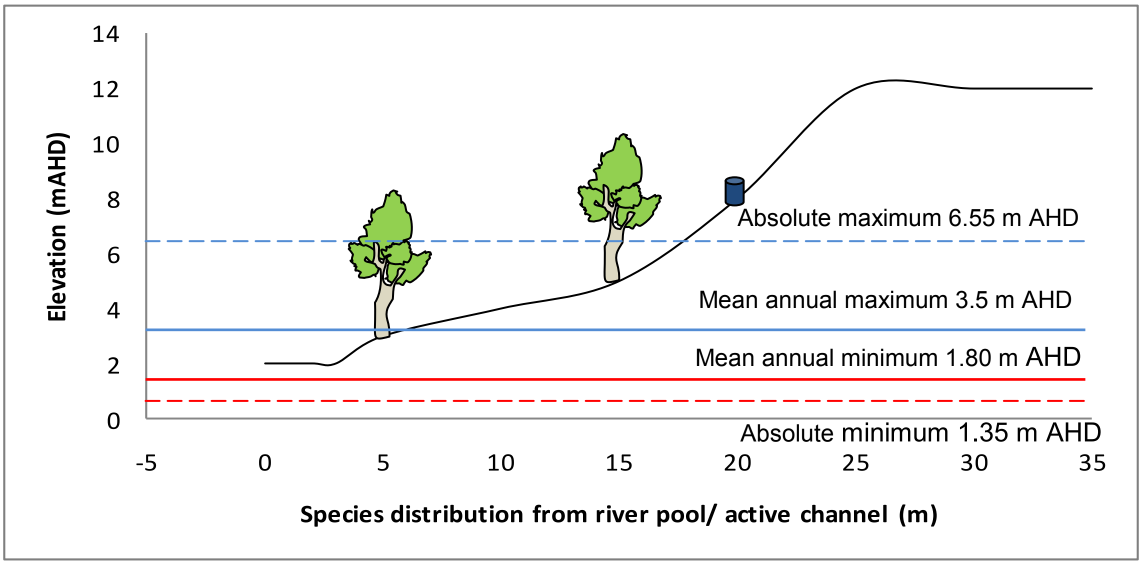


Figure 3 Example of hydrological regime experienced by E. camaldulensis *(20 year period)*

3.4 Calculating water level ranges of species

To calculate actual water depths at each site, the lowest and highest elevations at which a species was recorded across the riparian zone were subtracted from mean minimum and maximum water levels. A positive value indicates inundation, while a negative represents the depth to groundwater.

For example, if the minimum elevation of *E. camaldulensis* was 3.0 m AHD, and a 5-year mean maximum water level of 3.50 m AHD was recorded, its mean minimum depth to water over that period was +0.50 m (i.e. inundated by 0.50 m)(Figure 4). A maximum elevation of 5.0 m AHD and a mean minimum water level of 1.80 m AHD, results in a mean maximum depth to groundwater of 3.20 m, (since 1.80 minus 5.0 gives –3.20 m) (Figure 5). Therefore the mean water level range of *E. camaldulensis* over a 5-year period at the example site would be +0.50 to –3.20 m.

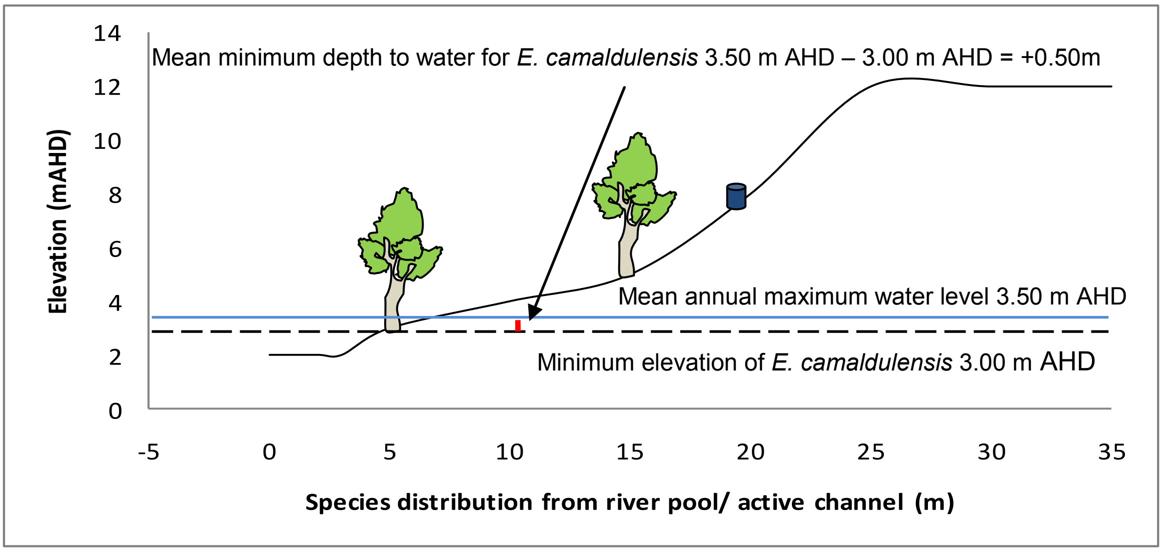


Figure 4 Example of 5-year mean minimum depth to groundwater for E. camaldulensis

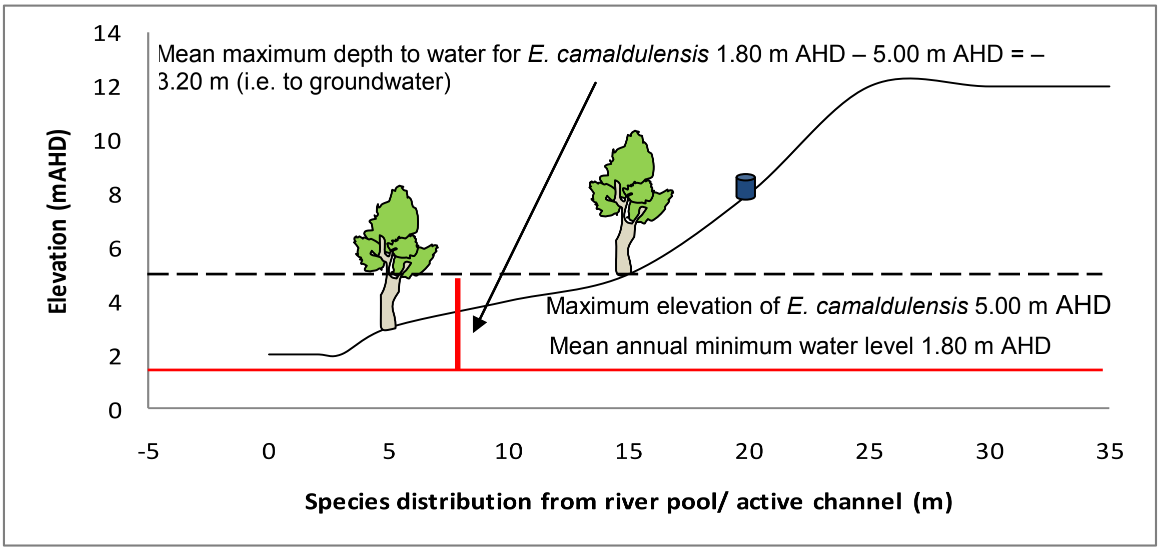


Figure 5 Example of 5-year mean maximum depth to groundwater for E. camaldulensis

The worked examples above are based on bore water level data, but stage heights (surface water levels) were also used to determine the depth of inundation. For example, using a 5-year absolute maximum surface water of 10.00 m AHD and a minimum elevation for *E. camaldulensis* of 3.00 m AHD, results in an inundation depth of 7.00 m.

To establish the mean and absolute water level range of a number species across all four study rivers, data from all sites across which each species was recorded were combined. A summary of the water level ranges of the selected Pilbara riparian species is presented in Appendix B. Graphs showing ranges of species found at four or more sites are presented in Appendix C.

4 Water level ranges of dominant tree species

4.1 *Eucalyptus camaldulensis*

The water level range of *E. camaldulensis* (Figure 6) was determined across nine sites on the De Grey River, five sites at Millstream, seven on the Yule River and two sites on the Robe River. The 'driest' site was Yul02a on the Yule River, the 'wettest' was H at Millstream. There was little difference in ranges across the four time periods (current, 5-, 10- and 20-year periods). In Figure 6 mean ranges are represented by the box plots and absolute ranges by the whiskers.

The 5-year (2004–09) mean and absolute Pilbara ranges (-1.68 to -4.86 and 1.56 to -9.21 m, respectively) determined here are consistent with those described in previous studies. Dames and Moore (1984) described a water level range of -1.00 to -3.00 m at Millstream, Strategen (2006) a range of -3.16 to -5.43 m on the De Grey River and Maunsell (2003) a range of -4.8 to -8.1 m on the Yule River.

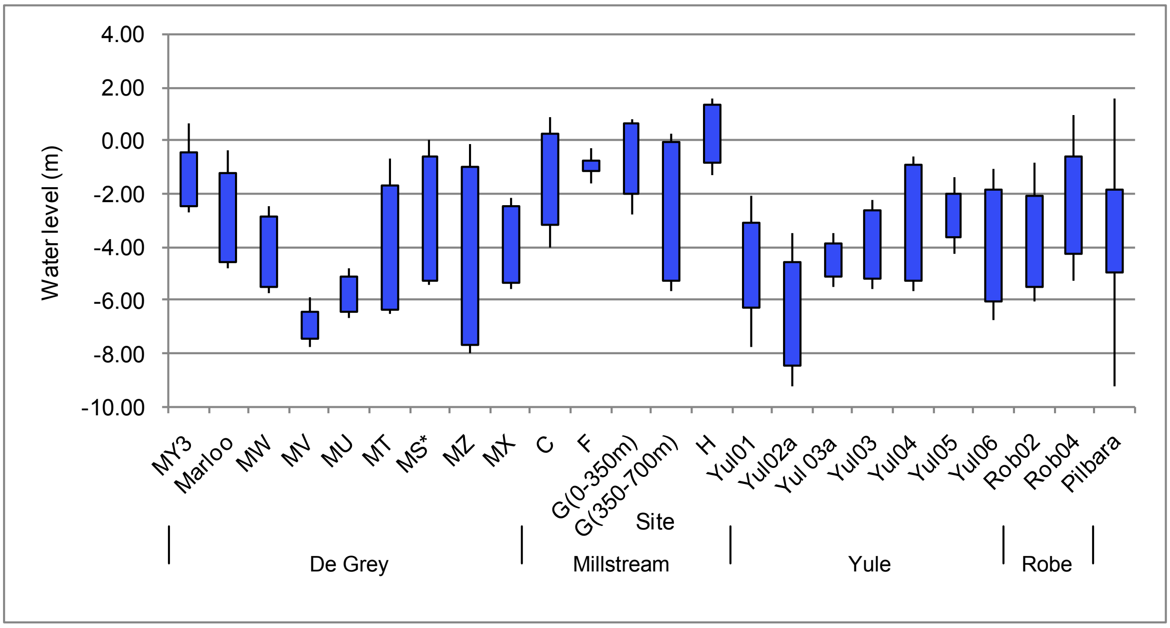


Figure 6 Water level ranges of E. camaldulensis across four Pilbara rivers (2004–2009) and the Pilbara regional mean

4.2 *Eucalyptus victrix*

Eucalyptus victrix was only identified at one site on the De Grey River (MY3) and one at Millstream (H) (Figure 7). Although its mean maximum depth to groundwater (-4.03 m) was less than that of *E. camaldulensis*, its mean minimum depth was greater (-2.18 m). This provides some support for the view that this species is found in slightly drier areas than *E. camaldulensis* and may be not as responsive to watertable fluctuations (HGM 2002). However, the low number of sites precludes the formation of any solid conclusions.

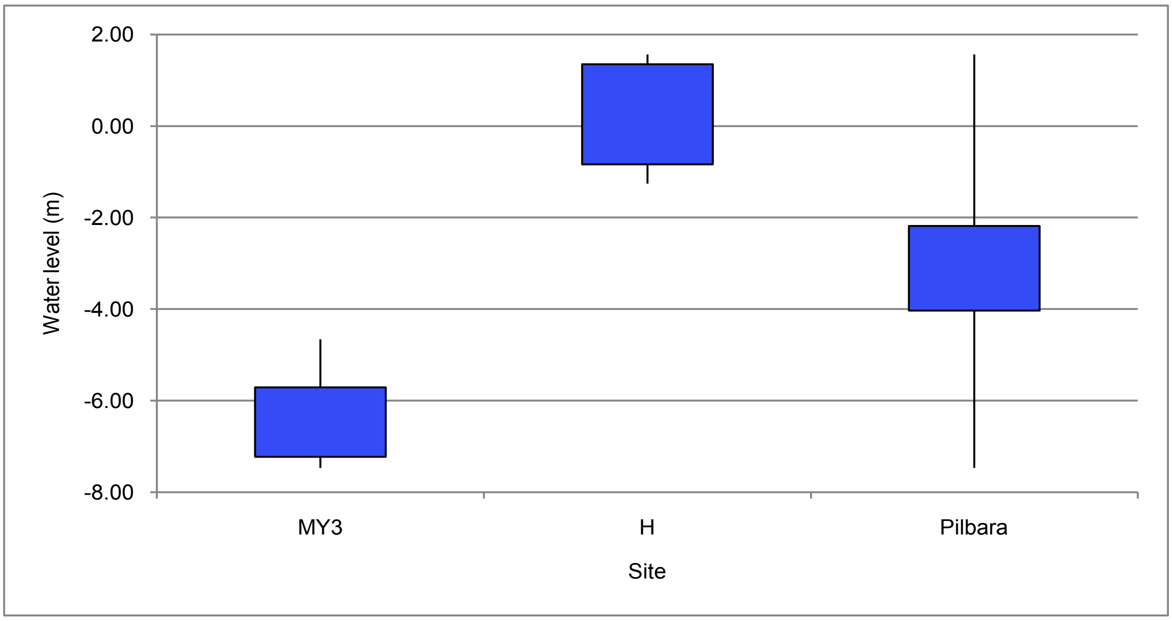


Figure 7 Water level ranges of E. victrix across two Pilbara rivers and the Pilbara regional mean (2004–2009)

4.3 *Melaleuca argentea*

The water level range of *M. argentea* (Figure 8) was determined across nine sites on the De Grey River, four sites at Millstream, four on the Yule River and one site on the Robe River. The 'driest' site was MV on the De Grey River, the 'wettest' was MX also on the De Grey River. As with *E. camaldulensis,* there was little difference in ranges across the four time periods (current, 5-, 10- and 20-year periods).

The five year (2004–09) mean and absolute Pilbara ranges (1.15 to 3.87 m and –1.22 to 7.71 m depth to groundwater respectively) determined here are consistent with those described in previous studies. Massini (1988), BHP (1997), Lamontagne et al (2005) and Muir Environmental (1995) described *M. argentea* as occurring where the watertable was less than 5.0 m below the surface. Strategen (2006) determined a mean water level of 2.02 to 3.87 m depth to groundwater and an absolute range of 0.17 to 7.31 m depth to groundwater on the De Grey River, and Maunsell (2003) a range of 1.8 to 5.1 m depth to groundwater on the Yule River.

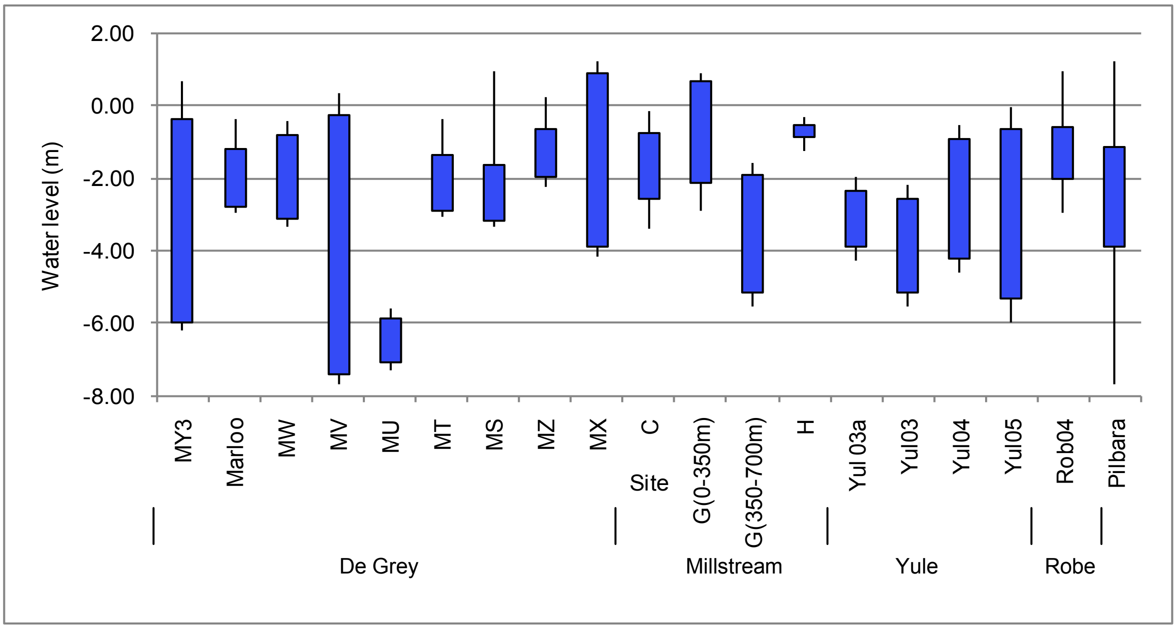


Figure 8 Water level ranges of M. argentea *across four Pilbara rivers and the Pilbara regional mean (2004–2009)*

5 Using water level ranges to determine susceptibility

5.1 Example of use

Water level ranges can be used to determine the susceptibility of riparian species to altered water regimes. Comparison of a specie's regional (e.g. Pilbara) mean range with the range of that species at a 'study site' will show whether it occurs towards the 'wet' or 'dry' end of its mean water level range.

For example, in Figure 9 below, the mean water level range of species X at Site D is similar to its Pilbara mean range but it occurs in 'wetter' conditions at Site B and A and 'drier' conditions at Site C. As its water level range is lower than the mean at Site C, this species is likely to be more susceptible to groundwater decline than at other sites.

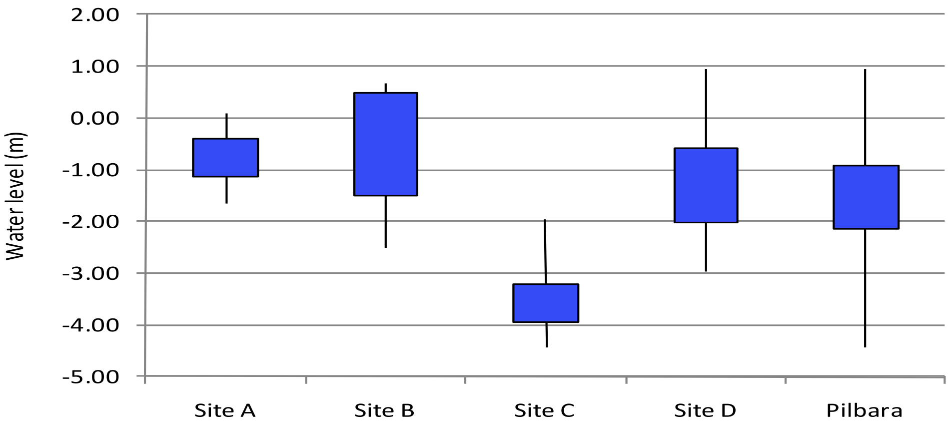


Figure 9 Example of comparing water level ranges of species X across sites

5.2 Limitations

Although this approach is a useful tool in predicting susceptibility, it is best regarded as a 'rule of thumb' method to be used in the absence of a better understanding of the physiological tolerances of riparian vegetation to altered water regimes, and/ or stronger rules or guidelines. It should be applied in the method described here with consideration of the following limitations.

The approach assumed that surface or groundwater levels across a site were the same as indicated by the bore levels or stage heights that were available. This ignores changes in depth resulting from changes in topography or geomorphology, although this is less of a problem if the bore or gauging station used is close to the transect. Additionally, incomplete or patchy hydrological data reduces the accuracy of the water level ranges determined.

A number of other factors also need to be considered. The local groundwater conditions under which vegetation establishes is a strong determinant of tolerance to water level change. For example, riparian tree species established over shallow groundwater are likely to have shallower roots than those established over greater depths to water. This means they have less root area in the unsaturated soil profile and less access to soil water once groundwater is depleted. Other factors that should be considered when assessing tolerance are:

- cumulative changes (historic and predicted) in water regimes
- duration and frequency of altered water availability
- vegetation condition – healthy vegetation may tolerate a greater change in water regime before being affected
- other disturbance impacts such as grazing and fire.

Appendices

Appendix A — Hydrological datasets

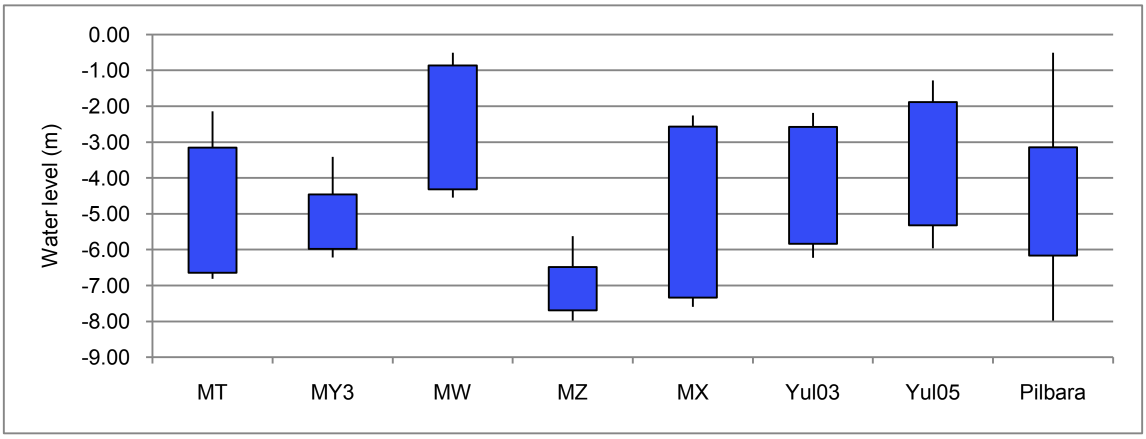
Site	Transect	Bore or gauge	WIN (water information database)	Data available
Yule	Yul01	9/04	70912275	03/05–01/10
	Yul02a	21	70918057	07/67–01/10
	Yul03	17/04	70912273	03/05–01/10
	Yul03a	17/04	70912273	03/05–01/10
	Yul04	17/04	70912273	03/05–01/10
	Yul05	13/04	70912279	03/05–01/10
	Yul06	1/73	70918089	03/75–01/10
Robe[1]	Rob02	13A[2]	70730114	10/83–02/91
	Rob04	1A	70730101	10/83–06/09
De Grey	Marloo Pool	Marloo Pool SW	7101039	01/98–01/10
	MS	1/04	71012142	04/05–01/10
		X1	71018092	06/00–01/09
	MT	9/04	71012150	04/05–01/10
		T2	71018089	06/00–01/10
	MU	2/04	71012143	04/05–01/10
	MV	8/04	71012149	04/05–01/10
		4/76	71018032	06/77–12/09
	MW	3/04	71012144	04/05–01/10
		U1	71018036	08/78–01/10
	MX	4/04	71012145	04/05–01/10
	MY3	7/04	71012148	04/05–01/10
		E1	71018007	08/74–12/09
	MZ	6/04	71012147	04/05–01/10
Millstream	A	P1/78	70818123	6/79–11/01
		P10/75	70818111	3/76–4/92
	B	P1/77	70818112	11/77–7/98
	C	P2/77	70818113	7/77–7/09
	E	P7/77	70818118	7/92–7/99
	F	P8/77	70818119	1/79–7/09
	G	P4/78	70818126	7/77–7/09
	H	P9/78	70818131	1/79–7/09

Appendix B — Water level ranges of riparian species at four Pilbara study sites

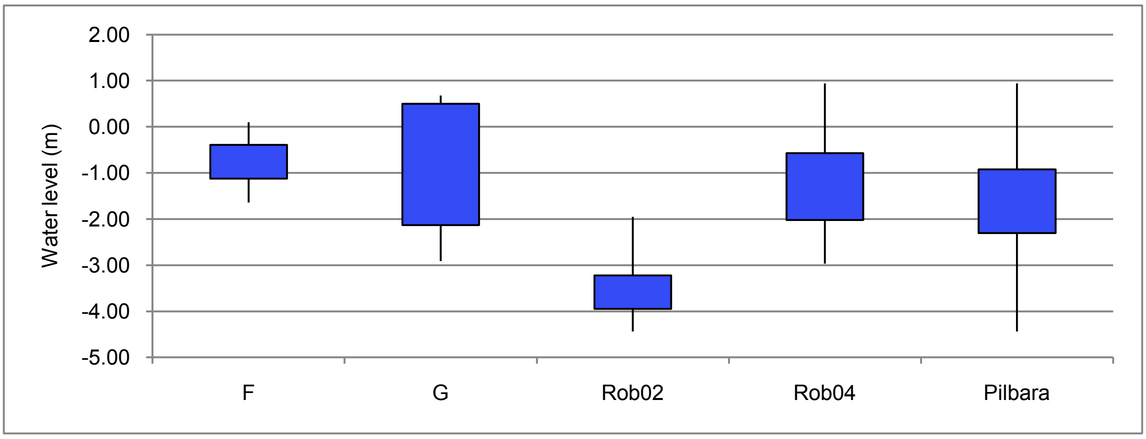
Species	Time series	Mean minimum m	Mean maximum m	Absolute minimum m	Absolute maximum m
E. camaldulensis	20 years	-1.16	-3.86	1.99	-8.88
	10 years	-1.14	-4.12	1.99	-9.21
	5 years	-1.68	-4.86	1.56	-9.21
	current	-1.87	-4.88	1.56	-8.54
M. argentea	20 years	-1.14	-3.74	3.19	-8.81
	10 years	-0.96	-3.31	3.19	-6.80
	5 years	-1.15	-3.87	1.22	-7.71
	current	-1.34	-3.92	1.22	-7.71
E. victrix	20 years	-2.93	-4.26	1.99	-8.55
	10 years	-2.80	-4.15	1.99	-8.05
	5 years	-2.18	-4.03	1.56	-7.47
	current	-2.54	-4.13	1.56	-7.47
M. bracteata	20 years	-0.92	-3.41	0.88	-8.81
	10 years	-0.29	-2.72	0.88	-6.26
	5 years	0.04	-2.72	0.88	-5.54
	current	0.04	-2.68	0.88	-5.13
M. glomerata	20 years	-1.48	-3.12	0.94	-6.53
	10 years	-0.99	-2.55	0.94	-5.44
	5 years	-0.92	-2.31	0.94	-4.44
	current	0.04	-1.62	0.68	-2.91
E. xerothermica	20 years	0.32	-1.71	1.65	-3.34
	10 years	0.53	-1.58	1.65	-3.21
	5 years	0.61	-1.47	1.65	-3.21
	current	0.45	-1.64	1.65	-2.71
Livistona alfredii	20 years	-0.15	-2.07	2.00	-4.36
	10 years	0.32	-1.99	2.00	-3.57
	5 years	1.36	-0.66	1.57	-1.08
	current	1.02	-1.09	1.57	-1.26
Lysiphyllum cunninghamii	10 years	-4.80	-5.69	-3.36	-6.17
	5 years	-4.41	-5.93	-3.36	-6.17
	current	-5.62	-6.05	-4.19	-6.75
Sesbania formosa	10 years	-2.41	-3.06	-0.09	-5.06
	5 years	-1.46	-3.46	0.74	-4.97
	current	-1.62	-3.44	0.74	-4.87
Atalaya hemiglauca	10 years	-3.31	-5.53	0.36	-7.66
	5 years	-3.14	-6.16	-0.51	-7.98
	current	-3.29	-5.93	-0.51	-7.98

Species	**Time series**	**Mean minimum m**	**Mean maximum m**	**Absolute minimum m**	**Absolute maximum m**
Ficus opposita	10 years	-3.38	-4.92	-1.69	-7.46
	5 years	-2.53	-4.93	-0.86	-6.61
	current	-2.84	-4.68	-0.86	6.61
Hakea subera	10 years	-0.85	-2.34	-0.25	-2.75
	5 years	-0.74	-2.24	-0.25	-2.75
	current	-0.71	-2.15	-0.25	-2.25
Acacia ampliceps	5 years	0.08	-2.81	0.88	-5.54
	current	0.08	-2.77	0.88	-5.13
Cyperus vaginatus	5 years	-0.98	-3.66	0.94	-6.22
	current	-0.72	-3.95	0.88	-6.12
Typha domingensis	5 years	-1.28	-2.49	0.94	-4.89
	current	-1.31	-2.59	0.15	-4.48
Baumea juncea	5 years	-0.39	-1.13	0.10	-1.64
	current	-0.36	-1.04	0.10	-1.14

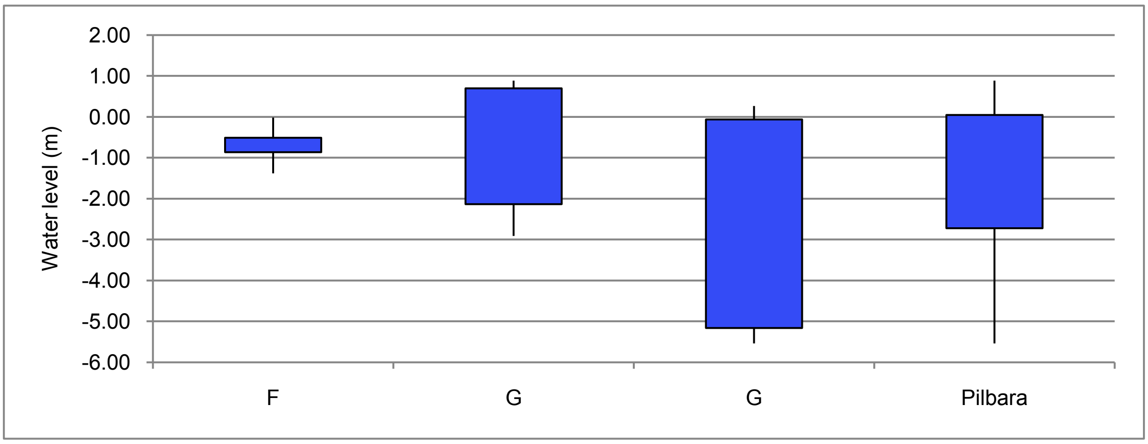
Appendix C — Water depth range graphs (2004–2009)



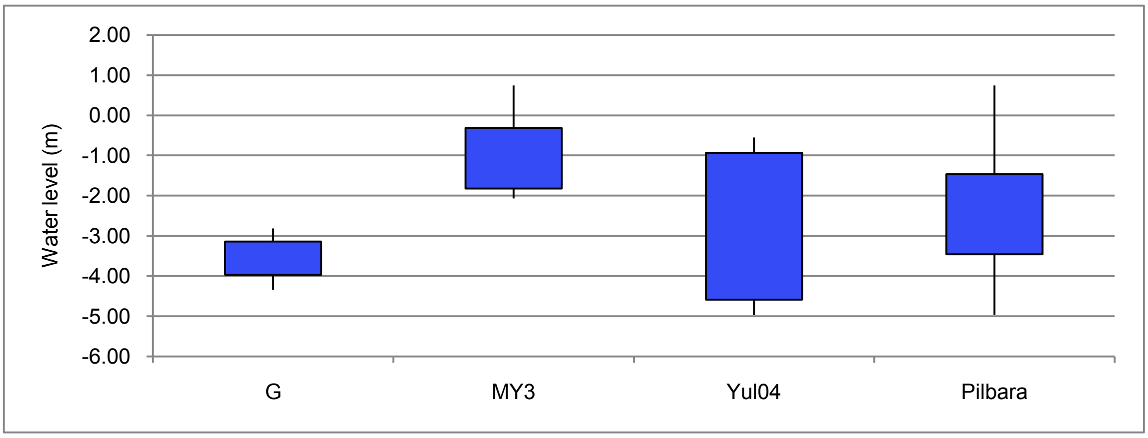
Water depth range of Atalaya hemiglauca



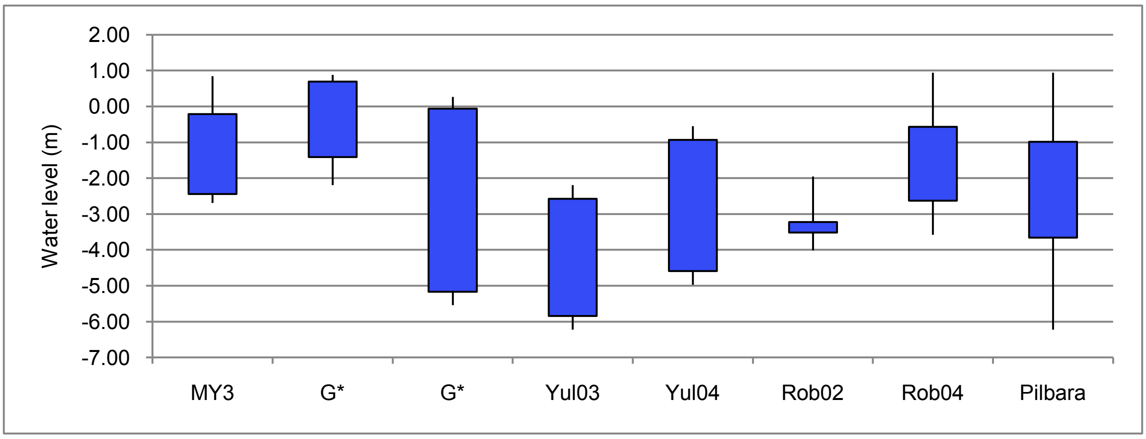
Water depth range of Melaleuca glomerata



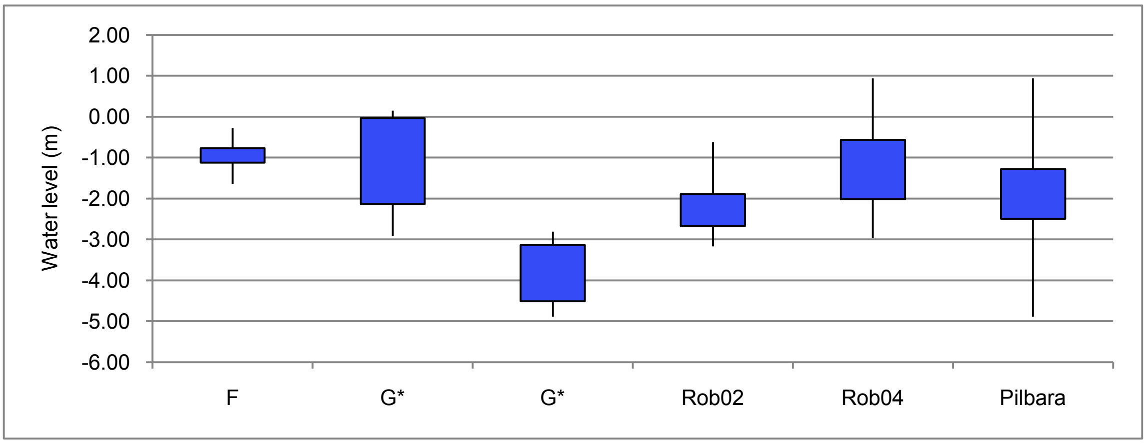
Water depth range of Melaleuca bracteata



Water level range of Sesbania formosa



Water depth range of Cyperus vaginatus



Water depth range of Typha domingensis

Glossary

Alluvium	Fragmented rock transported by a stream or river and deposited as the river floodplain.
Aquifer	A geological formation or group of formations capable of receiving, storing and transmitting significant quantities of water. Usually described by whether they consist of sedimentary deposits (sand and gravel) or fractured rock.
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact, e.g. a lake. Includes all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Ecosystem services	Benefits provided to humankind from a multitude of resources and processes supplied by natural ecosystems. Services include clean drinking water and processes such as the decomposition of wastes.
Environment	Living things, their physical, biological and social surroundings, and the interactions between them.
Groundwater	Water that occupies the pores and crevices of rock or soil beneath the land surface.
Habitat	The area or natural environment in which an organism or population normally lives. A habitat is made up of physical factors such as soil, moisture, range of temperature, and availability of light as well as biotic factors such as the availability of food and the presence of predators.
Hydrology	The study of water, its properties, movement, distribution and utilisation above, on and below the Earth's surface.
LiDAR	Light detecting and ranging
Life forms	A way of classifying plants alternatively to the ordinary species-genus-family scientific classification. Plants may be classified as trees, shrubs, herbs.
Macrophyte	A plant, especially an aquatic or marine plant, large enough to be visible to the naked eye.
Rhizome	Characteristically a horizontal stem of a plant that is usually found underground, often sending out roots and shoots.
Riparian	Plant communities along the river margins and banks or at the interface

vegetation	between land and a river or stream.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Water regime	A description of the variation of flow rate or water level over time. It may also include a description of water quality.
Wetland	Wetlands are areas that are permanently, seasonally or intermittently waterlogged or inundated with water that may be fresh, saline, flowing or static, including areas of marine water of which the depth at low tide does not exceed 6 m.

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