Identifying flood-dependent natural values on the Victorian floodplains of the River Murray and its tributaries

Victorian Environmental Assessment Council

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Summary

This report documents the methods used to identify and map flood-dependent natural values along the River Murray and its Victorian tributaries for the Victorian Environmental Assessment Council (VEAC). The report provides more detail on the flood-dependent natural assets project outlined in Appendix 11 of VEAC's Final Report on the River Red Gum Forests Investigation (VEAC 2008). The project was the first systematic attempt to map the flood requirements of natural values across most of the River Murray floodplain in Victoria, including areas outside the Murray-Darling Basin Commission's Living Murray icon sites.

Two value sets were used: ecological vegetation classes (EVCs) as a surrogate for ecosystems, and rare or threatened flora and fauna species. For each EVC, the following determinants were estimated based on the locations and conditions where each EVC occurs and its response (including that of its component species) to different flood regimes:

- the natural flooding frequency,
- the maximum period without flooding (i.e. the 'critical interval') beyond which the EVC would no longer be in a healthy state, and
- the duration of each inundation event required to maintain the EVC in a healthy state.

Pre-existing EVC mapping was used for the present project.

For each rare or threatened species, habitat was identified (usually one or more EVCs) and mapped at appropriate locations (across the species range, or at key locations such as breeding sites, for example) based on expert knowledge, scientific literature and other information on habitat requirements and occurrence such as 'Atlas' databases. Specific flood requirements (natural frequency, critical interval and duration, as above) were assigned to some threatened species but most were assigned those of the EVCs identified as habitat.

Including mosaics and complexes, 110 EVCs were found to be at least partly flood-dependent. The total current extent of these EVCs in the study area is 224,247 ha, of which 162,266 ha are on public land. In total, 124 rare or threatened vascular plant species and 62 threatened terrestrial vertebrate fauna species were classified as flood-dependent. Of these, 68 plant and 51 animal species were sufficiently well known for their distributions to be mapped reliably. Digital mapping enables the production of maps revealing a number of notable findings such as sites where flood-dependent values are concentrated.

However, the primary purpose of the digital mapping is to provide a basis for comparing the extent to which different floodplain watering events assist in sustaining the natural values of the floodplain. Because the mapping can be used for watering events of any size it can enables repeatable and transparent reporting of the outcomes of real or planned environmental watering events. It is also the first time that a comprehensive, spatially explicit identification of water requirements for natural values has been available for large parts of the floodplain, enabling robust comparisons of environmental watering options.

While the present study provides sufficient information to develop preliminary watering strategies, longer-term strategies would require further work including refinement of existing work and the incorporation of additional areas, taxa, ecological factors (such as connectivity and species richness), flooding requirement variables and new information on climate and hydrology. The present project is intended as a first step to improve knowledge and understanding of floodplain values and to provide a basis for a long-term program for the most effective possible conservation of floodplain natural values.

Introduction

In April 2005, the Victorian government requested the Victorian Environmental Assessment Council (VEAC) to undertake an investigation into the River Red Gum Forests and associated ecosystems of northern Victoria. Over the course of this investigation VEAC published three reports: a Discussion Paper for public comment in October 2006 (VEAC 2006), a Draft Proposals Paper for public comment in July 2007 (VEAC 2007) and a Final Report to the government in July 2008 (VEAC 2008). During this investigation it became clear that environmental water delivery – that is, water allocated to sustain natural values – would benefit greatly from a comprehensive and systematic cataloguing of flood-dependent natural values. In particular, a spatially explicit documentation of watering requirements would facilitate the most effective use of the scarce environmental water resource. As outlined in Appendix 11 of the VEAC Final Report, a project was conducted to this end and the present report provides more detail on methods and results of that project.

Pulsed flooding is the major factor influencing biota in river-floodplain systems (Ballinger and Mac Nally 2006). The floodplains of northern Victoria support a unique biota in an otherwise semi-arid environment because of riverine flood events resulting from rainfall in the headwaters of the region's major rivers and their tributaries in the Great Dividing Range to the south and east. These flood events also maintain ecological connectivity along the length of the floodplains, across the floodplains and between the rivers and the floodplains, thereby playing a crucial role in the landscape ecology of the region (Ballinger and Mac Nally 2006). The floodplain forests and woodlands not only provide important habitat for a range of forest-adapted plants and animals, but also act as a pathway for extending the geographic range of a number of species, particularly birds (e.g. Tzaros 2001).

VEAC (2006) highlighted the long-term environmental impact that insufficient flooding is having on the survival of riverine forests and wetlands. Since then, this impact has been exacerbated by continuing drought, while the potentially devastating impact of climate change has become more apparent (i.e. reduced rainfall and increased evapo-transpiration resulting in reduced runoff and thus greatly reduced floodplain inundation – see DSE 2008a, for example). This reduced flooding has a number of consequent adverse effects for the floodplain including an increase in the number of dead and dying trees (MDBC 2003), reduced River Red Gum *Eucalyptus camaldulensis* growth rates (VEAC 2008), fewer opportunities for water-based recreation activities particularly duck hunting (VEAC 2008), and the development of acid sulphate soils (McCarthy et al. 2006).

In recent years, artificially generated and manipulated environmental watering has been increasingly relied upon to sustain floodplain forests and wetlands. This watering requires strategic planning to ensure the most effective use of water in sustaining biodiversity assets. An essential prerequisite for such planning is a comprehensive, systematic, spatially explicit and publicly transparent inventory of flood-dependent natural values as a basis for allocating scarce and expensive water and for determining priorities for infrastructure investment to natural assets.

There are few landscape scale studies on the ecology of flooding in the Murray-Darling Basin (Walker et al. 1995; Ballinger and Mac Nally 2006). Although some areas such as Barmah forest are reasonably well known, there has been no comprehensive inventory of important natural values or flooding requirements along the Murray floodplains. Past environmental water allocations in Victoria have targeted 'icon sites' and various natural assets (e.g. stressed River Red Gum trees, colonial nesting waterbirds, various fish species; Leslie and Ward 2002, Stewart and Harper 2002), but consideration of the water requirements of the full suite of floodplain ecosystems and significant species has been limited (e.g. Ballinger and Mac Nally 2005).

For the present project, VEAC compiled data on and mapped the flood requirements for all flood-dependent ecological vegetation classes (EVCs) and most rare or threatened species along the Murray, Goulburn, Ovens and King Rivers (collectively referred to here as the River Murray floodplain). This approach highlights, for the first time, those species and ecosystems most in need of flooding and the locations where they occur. The process aims to build on the

icon sites approach to view the Murray floodplains as an interconnected system. In the long term it aims to provide a transparent, flexible and useable ecological dataset to inform decision-making, auditing and monitoring of environmental management outcomes in the northern Victorian floodplains, in accordance with VEAC's (2008) recommendations for environmental water (especially recommendation R13).

Methods

Study area

The VEAC River Red Gum Forests investigation area encompassed some 1,220,000 ha of northern Victoria from South Australian border east to the wall of the Hume Dam near Wodonga. It included the floodplain ecosystems along the River Murray and seven of its major tributaries (the Avoca, Loddon, Campaspe, Goulburn, Ovens, King and Kiewa Rivers) as well as grassy ecosystems and wetlands of the Victorian Riverina – for further details see VEAC (2006).

The present study covers only the floodplains of the Murray, Goulburn, Ovens and King Rivers within the VEAC investigation area (see Map D and Map E of VEAC 2008) – a study area of approximately 507,000 ha. It does not cover the Kerang Lakes and floodplains of the Avoca, Loddon, Campaspe and Kiewa Rivers nor any land in New South Wales or South Australia.

Ecological vegetation classes

Ecological vegetation classes (EVCs) are units in a vegetation classification system that are differentiated through a combination of floristic, life form and ecological characteristics, and through an inferred fidelity to particular environmental attributes. Since the mid-1990s, EVCs have been the principal units for native vegetation classification and mapping for land-use planning and management in Victoria (Woodgate et al. 1996; Parkes et al. 2003).

A major update of EVC typology and mapping in northern Victoria was completed in 2006 – as presented by VEAC (2006). The major determinant of vegetation type in this region is riverine flooding – as opposed to flooding or watering solely from local rainfall. Almost invariably, there is a clear distinction between the vegetation of those areas which are prone to riverine flooding and nearby areas which are not. The native vegetation in flood-prone areas is dependent on riverine flooding – even if infrequent – because without that flooding this vegetation would eventually be replaced by 'dryland' vegetation similar to that in nearby areas that are not flood-prone. Furthermore, within flood-prone areas, the major determinants for most EVCs are variations in flood regime, particularly flood frequency and duration. In short, the differentiation and mapping of EVCs in the study area was based very largely on the response of the vegetation to different flood regimes.

The present study essentially involved the documentation of key flooding requirements for each flood-dependent EVC by botanists closely involved in the circumscription and mapping of EVCs that was completed in 2006 (see Acknowledgements). The process entailed five steps as follows:

1. **Identification of flood-dependent EVCs.** A list of flood-dependent EVCs was distilled from the list of all EVCs in the VEAC (2006) investigation area. EVCs were classed as flood-dependent if likely to decline significantly in the region in the absence of flooding from adjoining rivers (as opposed to flooding or watering solely from local rainfall). Generally it was apparent that EVCs were or were not flood-dependent if they did or did not occur in nearby areas (within 10 km) not prone to riverine flooding. A key point is that riverine flooding can favour dependent EVCs ahead of others in ways other than just meeting additional water requirements. For example, flooding may affect groundwater, soil type or geomorphology to the advantage of some EVCs – such as when floodwaters prevent saline groundwater rising to the surface causing the replacement of existing vegetation by more salt-tolerant EVCs.

EVCs that occur within the floodplain and are not flood-dependent were excluded from further analysis (e.g. Plains Woodland EVC, dominated by Grey Box *Eucalyptus microcarpa*, which occurs on low ridges that would have been rarely inundated under natural conditions as well as occurring in areas adjacent to the floodplain which are not flood-prone). For details on the ecological characteristics of the main EVCs in the VEAC investigation area see appendix 7 of VEAC (2006).

2. **Estimation of the natural flood frequency (in years) for each flood-dependent EVC.** The natural flood frequency is the average frequency with which an EVC is flooded under natural conditions and is therefore, presumably, the optimal frequency of inundation for that EVC. Sustained deviation from the natural frequency will compromise the EVC health. The natural flood frequency is sometimes referred to as the natural return period.

   The natural flood frequency for each flood-dependent EVC was estimated based on what is known or surmised of the flooding requirements and tolerances of character species and the physical (including hydrological) conditions at sites of occurrence, particularly in comparison to these parameters for adjoining or similar EVCs.

3. **Estimation of the critical interval (in years) for each flood-dependent EVC.** The critical interval is the maximum period that an EVC can endure without flooding and remain in a reasonably healthy state. It is different from what might be called 'minimum flood frequency' which is the minimum average flood frequency (i.e. least frequent flooding) that an EVC can endure over a sustained period and remain in a reasonably healthy state.

   As with natural flood frequency, the critical interval for each flood-dependent EVC was estimated based on what is known or surmised of the flooding requirements and tolerances of character species and the physical (including hydrological) conditions at sites of occurrence, particularly in comparison to these parameters for adjoining or similar EVCs.

4. **Estimation of the minimum duration (in months) for each flood-dependent EVC.** This is the minimum duration of inundation required to maintain each respective EVC in reasonably healthy condition; i.e. the length of time that an EVC is continuously under water for each inundation event occurring at the frequency necessary to maintain it in a reasonably healthy state. It is worth noting that this variable is not solely a function of the duration of high river flows. For example, rates of drying or drawdown following flood recession vary according to floodplain geomorphology and greatly affect the duration of flooding in some places compared to others.

   Again, the minimum duration for each flood-dependent EVC was estimated based on what is known or surmised of the flooding requirements and tolerances of character species and the physical (including hydrological) conditions at sites of occurrence, particularly in comparison to these parameters for adjoining or similar EVCs.

5. **Mapping of the current extent of all flood-dependent EVCs.** Pre-existing mapping of the current extent of all flood-dependent EVCs was used for the present project (as presented by VEAC (2006) for example, with minor updates).. This dataset was extracted from the Department of Sustainability and Environment's Corporate Geospatial Data Library in May 2008.

   The dataset has some small areas mapped as Wetland Formation (EVC no. 74), Bare Rock/Ground (993) and Water Body – Natural or man made (998). Bare Rock/Ground is often mapped along the beds of creeks and billabongs – i.e. temporarily dry wetlands. Generally these 'EVCs' are effectively flood-dependent – without flooding they would not be wetlands or water bodies. In many cases these areas formerly supported natural wetlands which have been so substantially altered by anthropogenic water regimes that they do not group with any other EVCs that are predominantly influenced by natural water regimes. As a result, no coherent indication of flooding requirements could be inferred from the character species and site conditions which were used for estimating flooding requirements for other EVCs.

The largely artificial nature of these wetlands presents a more fundamental difficulty. In predominantly natural systems, the conservation of biodiversity is generally best served by maintaining biophysical influences (such as flooding regimes) as close as possible to the natural. In artificial systems however, it is not clear that biodiversity conservation would generally be optimised by maintaining biophysical influences in any particular artificial state. Maintaining water in an area mapped as 'Water Body – Natural or man made' would be in keeping with the name of the 'EVC', but not necessarily with biodiversity conservation objectives. This is a minor problem in the present study area because of the small spatial extent of these 'EVCs' and because their flooding requirements would be probably be met in part at least if those of adjoining EVCs were met. However in larger predominantly artificial areas– such as the Kerang wetlands – there is a need for the development of a conceptual framework to underpin the management of environmental watering generally and in particular the estimation of flooding requirements.

Several other flooding variables are also likely to influence the nature and survival of vegetation on the floodplain, including:

- depth of inundation
- season of inundation
- minimum flood frequency
- maximum flood frequency
- minimum frequency of periods without inundation
- duration of periods without inundation.

While some notes on these parameters were documented they were generally not estimated, because for most EVCs to do so would imply levels of precision and reliability beyond what is appropriate given current knowledge (especially estimating minimum flood frequency compared to critical interval). Also, some of these parameters are likely to be a function of those that were estimated. Flooding depth is likely to correlate with duration, for example, while maximum flood frequency, and the frequency and duration of inundation-free periods, are unlikely to be constraints in many places given the greatly reduced frequency and extent of recent and predicted flooding (see DSE 2008a for example), other than where wetlands are used for water storage.

Similarly, it is clear that inappropriate seasonality of flooding can substantially alter the vegetation (Bren 2005) and that most natural flooding in the study area occurs in spring between about August and December inclusive (Bren 2005, Robertson et al. 2001, VEAC 2006). Accordingly, it is assumed here that most vegetation is adapted to spring flooding and that flooding within this period is a requirement. As with other variables not estimated here, more specific requirements for seasonality may be possible to determine with further research.

Finally, no attempt was made to assess the priority that might be given to maintaining particular EVCs relative to others despite the potential usefulness of this information to water managers in prioritising and scheduling managed environmental flows. Such an assessment would depend largely on the conservation status of each EVC , with more threatened EVCs generally having higher priority. However, the existing assessments of conservation status (DSE 2008b) were made without detailed or systematic consideration of the threat posed by insufficient watering which is likely to be the pre-eminent threat to most EVCs. In fact, an assessment that incorporated insufficient flooding would require information on the location and flooding requirements of EVCs –such as that presented here - and the likelihood of those requirements being met at those locations.. In addition, water managers actually require priority assessments of *sites*, not values, for which additional factors such as vegetation condition would be required.

Rare or threatened flora

The assessment of flooding requirements for each flood-dependent rare or threatened plant taxon was undertaken by the same botanists who assessed the flooding requirements of

EVCs (see Acknowledgements). The assessments for rare or threatened taxa followed the same five steps as the EVC assessments, with minor variations as follows:

1. **Identification of flood-dependent rare and threatened plant taxa.** A list of rare or threatened plant taxa (DSE 2005[1]) recorded in the study area was generated using the Department of Sustainability and Environment's Flora Information System (FIS) database of Victorian flora records (current to May 2007). Each taxon on this list was then classed as flood-dependent or not by applying the same definition of 'flood-dependent' that was used for the identification of flood-dependent EVCs (see above) to what was known of the taxon's ecology and occurrence, including review of relevant literature and FIS data.

   As with EVCs, flooding requirements of some species may relate more to maintenance of suitable habitat conditions than to their tolerance of dry conditions (e.g. prevention of salinisation of habitat or reduced competition from species which are less tolerant of flooding). In some cases, species may draw on groundwater resources which may become depleted or saline with a long-term absence of flooding in adjacent areas.

2. - **Estimation of the natural flood frequency, critical interval and minimum duration for each flood-dependent rare or threatened plant taxon.** Each of these three parameters was defined as above for EVCs and estimated for each flood-dependent rare or threatened plant taxon based on what is known or surmised of the flooding requirements and tolerances of the taxon and the physical (including hydrological) conditions at sites of occurrence. Comparison to these parameters for adjoining or similar EVCs to those where the taxon occurs was particularly useful here. However, for many taxa there is little specific information available on flood requirements. In these cases, this process amounted to simply adopting the estimated natural flood frequency, critical interval and minimum duration of the principal EVC(s) at site(s) where the taxon had been recorded as the estimated values of these parameters for the taxon. For a relatively small number of these taxa it was not possible to identify a reliable association with any EVC and as a result no estimate was made of these parameters.

5. **Mapping of the current extent of all flood-dependent rare or threatened plant taxa.** The distribution of each flood-dependent rare or threatened plant taxon was mapped using site location records superimposed on EVC maps. Discrete EVC units or polygons of related host EVCs located at or very near the flora records were mapped as a surrogate for taxa distribution. This method required sufficiently detailed mapping and accurate species location information. However, in some cases existing mapping was not adequate to substantiate an association at such a detailed level, and a spot location representing the site record was used in place of an EVC polygon. The spot location was attributed a radius reflecting the level of site accuracy (e.g. +/- 50 m attributed a radius of approximately 50 metres). Portions of spot locations that extended beyond the state border or floodplain were excluded. In many cases where there were multiple host EVCs, these typically had very similar or identical flood dependency attributes, while for some others there was variation across the landscape. Some flora species occupy a niche between EVCs, particularly along strips where water recession occurs frequently.

   In order to reduce the possibility that sites mapped as polygons did not actually support the relevant rare or threatened plants, old records (those made prior to 1980) and imprecise records (those that could not be reliably located to within 150 metres) were not used to delineate species-occurrence polygons. As a result, no locations were mapped for some flood-dependent species, some of which may no longer occur in the study area. Additionally, the number of records does not necessarily reflect population size or number of stands. Some records reflect repeated sampling or collections from small or localised populations.

[1]Taxa listed under the *Advisory List of Rare or Threatened Plants in Victoria – 2005* (DSE 2005), the Victorian *Flora and Fauna Guarantee Act 1988* or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

As with EVCs, several other potentially useful parameters were not considered although a preliminary evaluation of the importance of the study area population to the broader (Statewide and national) conservation of each taxon was made, based on the population size and geographical extent of the species in the study area compared to elsewhere.

Threatened fauna

The assessment of flooding requirements for threatened fauna followed the same procedure as that for rare or threatened flora, with the following variations:

- Fauna records from the study area were extracted from the Department of Sustainability and Environment's Victorian Fauna Database (VFD, also known as the Atlas of Victorian Wildlife) current to May 2007 and Birds Australia's Atlas data (Birdata, accessed from www.birdata.com.au in January-May 2008). The list of threatened fauna recorded in the study area was compiled using DSE (2007[2]). Only amphibians, reptiles, birds and mammals were considered. Flooding requirements were determined through discussions with experts (see Acknowledgements, below), and review of relevant literature.
- For most threatened fauna taxa there are many more records in the study area than is typical for rare or threatened plants and their habitat requirements are usually much better known. As a result – and because animals typically are more mobile – the identification and mapping of habitat for threatened fauna was often tailored according to characteristics of particular taxa rather than tying the identification and mapping of habitat closely to the site of every record, as was usually done with flora. For example, for several highly mobile duck species that had been recorded at nearly every wetland in the study area (often just once at temporary wetlands), only sites with repeated records or high counts were identified and mapped. Similarly for many colonially breeding birds, a distinction was made between breeding and non-breeding habitat, with only the former being identified and mapped for those species where availability of non-breeding habitat was not a significant factor in their conservation status. On the other hand, for some highly cryptic species with readily identifiable habitat (such as Bitterns that favour Tall Marsh EVC), habitat patches without records were identified and mapped on the basis that the species almost certainly occurs in these patches on occasions but have not been recorded due to insufficient survey effort to detect such cryptic species.
- Reflecting this emphasis on the specific characteristics of some taxa, there were some exceptions to the exclusion of old records (those made prior to 1980) and imprecise records (those that could not be reliably located to within 150 metres) from the delineation of species-occurrence polygons. For example, older records of colonially nesting waterbirds were included on the basis that these birds breed infrequently and generation times are therefore longer. Also, older or imprecise records were often included when identifying sites with repeated records or high counts .
- As with the flora, the habitats of most fauna taxa were specified as one or more EVCs, which were then mapped as the sites for that taxon within its geographic distribution. The natural flood frequency, critical interval and minimum flood duration estimates for the EVC(s) were then assigned to the sites. However for some taxa, notably colonially nesting waterbirds, more specific information derived from site visits was available. In these instances, this information was used to map site locations and specify watering requirements.
- Some threatened fauna (but no rare or threatened flora) have been recorded in the relatively small areas mapped as Wetland Formation (EVC no. 74), Bare Rock/Ground (993) and Water Body – Natural or man made (998). As explained on page 4, flooding requirements were not assigned to these 'EVCs'. As a result flooding requirements for threatened species in these areas were estimated based on the flooding requirements and tolerances of the relevant threatened species and the physical (including hydrological) conditions at the sites.

[2] Taxa other than fish listed under the *Advisory List of Threatened Vertebrate Fauna in Victoria – 2007* (DSE 2007), the Victorian *Flora and Fauna Guarantee Act 1988* or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

Geospatial data processing
A single EVC digital geospatial layer was created incorporating all flood-dependent EVC polygons from the Department of Sustainability and Environment's Corporate Geospatial Data Library. For rare or threatened flora and fauna, a separate digital geospatial layer was created for each taxon using new polygons where necessary but mostly using pre-existing polygons – usually EVC polygons but sometimes others according to details specific to particular taxa or sites. New polygons were digitised from hand-drawn polygons on topographic maps or aerial photos. Natural flood frequency, critical interval and minimum duration estimates were assigned to all polygons within a geographic information system (ArcGIS).

To provide a visual representation of the relative number of different flood-dependent values at any one site, geospatial layers for EVCs and for each of the threatened species were overlayed, a composite layer generated and a new field for the number of distinct features attached to each resultant polygon. This process enabled the production of maps to show where concentrations of floodplain natural values occur.

Results and application

Including mosaics and complexes, 110 EVCs were found to be at least partly flood-dependent on the Murray floodplains (Table 1). The total current extent of these EVCs in the study area is 224,247 ha, of which 162,266 ha are on public land. Natural flooding frequencies ranged from as many as 3-4 flood events every four years for Aquatic Herbland and a further 20 EVCs through to one flood event in 20-40 years for Riverine Chenopod Woodland. Critical intervals to maintain healthy ecosystems ranged from one flood event every 2 years for around 30 EVCs to one flood every 30-50 years for some Black Box dominated EVCs. Minimum durations of inundation ranged from less than one month to 6-36 months.

One hundred and twenty-four rare or threatened plant taxa were classified as at least partly flood-dependent (Table 2) of which 68 were sufficiently well known for their distributions to be mapped reliably. Of the 62 threatened vertebrate fauna taxa (excluding fish) found to be flood-dependent (Table 3), 51 were sufficiently well known for their distributions to be mapped reliably.

Figure 1 is a map showing the number of flood-dependent EVCs and threatened species recorded at each location across the study area. A visual representation of the critical intervals for EVCs and threatened species is presented in Map D and Map E of VEAC (2008). While maps such as these are useful in providing context and insight for the general public and for floodplain and water managers, the primary purpose of the present project is to provide digital mapping that can be used to transparently predict the extent to which any given inundation event assists in sustaining the natural values of the floodplain. By compiling the results of these analyses for many such events, it is possible to develop floodplain watering strategies covering the entire River Murray floodplain for periods comparable to the largest estimated flood frequencies i.e. 20-40 years. The predicted outcomes of the different strategies for floodplain natural values could then be compared and the most favourable strategy adopted for implementation.

Figure 2 and Table 4 provide examples of how the digital mapping generated in the present project can be used to compare the extent to which different inundation events assist or fail to assist in sustaining floodplain natural values. The three maps in Figure 2 show the predicted extent of flooding for three different-sized floods along a sample reach of the River Murray floodplain east of Robinvale, resulting from three different flow rates along the river channel: 20, 81 and 159 gigalitres per day. Red colouring indicates areas that are flooded, while grey colouring indicates floodplain areas not flooded. The varying intensities of shading (pale, medium and dark grey or red) denote the critical intervals for specific natural values that are or are not inundated by floods of these sizes. While Figure 2 is a composite of all flood-dependent EVCs and threatened species, maps can be readily produced for individual EVCs or species or combinations thereof. Table 4 shows some results from a sample analysis of the maps: the area of each flood-dependent EVC and threatened species habitat, and the

percentage of these areas inundated by the three different flood levels. The results show, for example, that less than five percent of almost all values are inundated by a very small flood whereas over three-quarters of Floodplain Grassy Wetland EVC, half the Regent Parrot habitat and 100 percent of Silver Saltbush habitat is inundated in a large flood.

Such mapping and analyses can be used in two ways to improve floodplain watering for natural values. Firstly, as indicated above the primary purpose is to facilitate the development of medium-term floodplain watering strategies that maximise the effectiveness of whatever watering is undertaken in sustaining natural values. The essence of this comprehensive mapping approach enables the development of strategies that are highly adaptive and readily communicated to the general public, allowing transparent modification where necessary such as in response to new information or changes to key factors such as water availability.

Secondly, the mapping and analyses facilitate the identification of important areas with watering needs that are not readily met under the most favourable floodplain watering strategies. For example, Lakes Powell and Carpul near Robinvale (see Figure 2 for locations) have high concentrations of natural values (Figure 3) with critical intervals of 2-5 years but are not predicted to be inundated even in large floods (Figure 2). That is, assuming this predicted lack of flooding in these areas was confirmed by site-specific assessment (using information such as actual flooding history and terrain mapping), these areas would be prime candidates for works such as levees, regulators or pumping to meet their flooding requirements – particularly given that they are terminal lakes that would not require large volumes of water flowing down the river channel in order to meet flooding duration requirements. The use of such works could then be incorporated into watering strategies to further improve the effectiveness of floodplain watering.

Future work

The results presented here provide essential information to commence the process of formulating and selecting floodplain watering strategies in the longer term, but an enduring strategy will require further work in a number of areas, listed below.

Strategy development. The highest priority task is to use the results of the present study and inundation modelling to initiate the formulation, comparison and implementation of floodplain watering strategies. This process would greatly assist in prioritising and undertaking many of the other tasks in this list and in identifying any additional tasks that may be required. It would do so by acting as a framework to which all other tasks would be directed, maximising their relevance and workability in an applied context. In addition, implementing a floodplain watering strategy – that is, actually providing water to key sites on the floodplain – would deliver as a minimum a significant short-term benefit of maintaining natural values in the areas watered until a longer-term strategy is developed and implemented.

Overbank flows and ecological connectivity. The approach to floodplain watering taken here could be summarised as comprehensively mapping the watering requirements of key natural values with a view to meeting those water requirements as far as possible, and explicitly noting where not possible. An alternative approach would be to focus on replicating natural flooding regimes as closely as possible and assume that as a result flood-dependent natural values are maintained to the maximum extent possible. Both approaches have their relative advantages and disadvantages. The main relative disadvantage of the comprehensive mapping approach is that it predisposes the reduction of floodplain watering to little more than meeting the water requirements of specific discrete sites. Potentially this may result in a high proportion of water being artificially delivered to and held in these sites with little done for broader ecological connectivity. Under natural (unregulated) conditions flooding very largely occurred as overbank flows extending from the rivers and over the floodplain. Such flooding maintained ecological connectivity by transporting sediments, nutrients, and organisms and their propagules across and along the length of the floodplain, and between the floodplain and its rivers (Ballinger and Mac Nally 2005). Overbank floods also increased habitat heterogeneity and, especially in the early ‘pulse’ of flooding, biological productivity, landscape-scale biodiversity and river health. It is now widely recognised that this connectivity is crucial to both understanding and managing the ecology of the floodplain (e.g.

Jenkins and Boulton 2003, Ballinger and Mac Nally 2005). While the ecological benefits of extensive overbank floods and connectivity are not as easily documented and mapped as EVCs and threatened species, it should be possible – even if significant research is required – to quantify and incorporate these components into the formulation and evaluation of floodplain watering strategies.

Comparing different values and risks. The present study was initiated to inform decisions about water allocation to floodplain natural values in a likely water-constrained future. In such a future it will be necessary to compare sites and natural values to decide which of them would be the highest priority to maintain artificially under different water-availability scenarios. These decisions require a conceptual framework on which to base comparisons of different values. Such a framework would assist in comparing sites supporting different numbers of different values – comparing a site with a large proportion of the population of an endangered species with one supporting small populations of three vulnerable species, for example. As well as a framework, decisions of this sort would require incorporation of other information on such things as other sites and values watered incidental to the sites in question and the importance of study area populations of threatened species to their conservation overall. In reality, these decisions would also require the incorporation of the additional complexity of risk – as well as different values there will be different risks to those values as a result of inadequate watering.

Refining watering requirement estimates and mapping. While the watering requirement estimates and mapping presented here are the best that can be made with available knowledge, they are initial estimates and should be tested and refined. Experimental research and monitoring is required, especially for EVCs and more highly threatened species. Particular issues to investigate include potentially differing watering requirements in different parts of the distribution of an EVC or taxon, and what happens to EVCs (and at what rate) if they do not receive sufficient water.

Review the conservation status of EVCs and species. The potential threat of insufficient floodplain watering was poorly recognised and understood when the current conservation status assessments of EVCs and threatened taxa were undertaken. The present project and new information on future flooding regimes (e.g. DSE 2008c) show that insufficient watering is a major threat to floodplain biodiversity, providing both the rationale and information base for a prompt review of the conservation status of floodplain EVCs and taxa. It seems likely that as a result of this review many EVCs and taxa – including some not currently categorised as threatened – would be given a higher (i.e. more threatened) conservation status. These new assessments should then be incorporated in subsequent iterations of floodplain natural value mapping and analyses. Incorporating the flood requirements of relevant EVCs into assessments of site scale and landscape metrics for vegetation condition (e.g. Parkes et al. 2003; Newell et al. 2006) would also provide a more robust measure of condition for floodplain ecosystems.

Additional flooding requirement variables. As highlighted on page 5, the following flooding requirement variables additional to those estimated here (natural frequency, critical interval and minimum duration) are likely to be major influences for at least some EVCs and taxa. Estimates of these variables will be required for incorporation into floodplain watering strategies:

- depth of inundation
- season of inundation
- minimum flood frequency
- maximum flood frequency
- minimum frequency of periods without inundation
- duration of periods without inundation.

Minimum flood frequency over a sustained period is likely to be a significant factor for many, possibly all, EVCs and taxa.

Additional areas. Both ecologically and hydrologically, the area covered in the present study is part of and closely interconnected with the rest of the Murray Valley in Victoria, South Australia and New South Wales. For environmental watering in the Murray Valley to be as successful as possible it needs to be done as a coordinated comprehensive program covering

the whole system. There may be existing work undertaken for New South Wales or South Australia that could be combined – with modifications if necessary – with the work initiated in the present study to produce a system-wide strategy. Otherwise the methodology developed here could be applied to the appropriate areas – in New South Wales in particular and an ecologically and hydrologically based northern boundary would need to be defined (i.e. whether or not to include the floodplains of Murrumbidgee River, Lachlan River, and so on). In Victoria, the methodology developed here could be extended over a broader area – perhaps the entire Murray catchment but particularly the Kerang and Corop Lakes systems, and the floodplains of the Avoca, Loddon, Campaspe, upper Goulburn, upper King, upper Ovens, Kiewa and upper Murray Rivers. As mentioned above, inclusion of the Kerang Lakes will necessitate the estimation of flooding requirements of floodplains and wetlands that are now entirely or largely dependent on artificial flows. Restoration of flooding in these areas may lead to changes to existing EVC mapping.

Comprehensive taxonomic and ecological coverage. The present study was restricted to terrestrial vertebrates, vascular plants, and taxa classified as rare or threatened at state or national levels – principally because of time constraints and the generally poorer knowledge base for other taxa. Ultimately, though, floodplain watering strategies should be taxonomically comprehensive and include, for example, fish, invertebrates (terrestrial and aquatic), non-vascular plants and regionally significant taxa. Similarly, the list of ecological characteristics used to identify natural values to maintain should be comprehensive and expanded beyond just those for the main sites of occurrence or breeding for threatened taxa to include important characteristics such as the following:

- sites that are likely to assist the recovery of threatened taxa, especially taxa that are highly threatened
- sites of high species richness
- colony sites for colonial breeding species that are not classified as threatened (such as Cattle Egret, Yellow-billed Spoonbill, Australasian Darter, Great Cormorant, Little Black Cormorant, Little Pied Cormorant, Straw-necked Ibis and Australian White Ibis)
- sites that may be in poor condition at present but would recover with watering and be likely to support significant natural values
- corridors of habitat which are important for the movement of biota – from flight paths for the daily movements of Regent and Superb Parrots between breeding and feeding areas to corridors for longer-term movements such as in response to changing climate over the course of decades.

It is likely that some new basic ecological information, such as distribution and occurrence for many taxa, especially flora, will need to be collected to support comprehensive coverage of values. This information should also be collected and applied to mapping and estimating the water requirements of those flood-dependent taxa that were identified in the present study but for which this work could not be done due to insufficient information. EVC mapping of areas as ‘bare ground’ and ‘water body’ should also be reviewed.

Ongoing incorporation of floodplain inundation modelling, hydrology, salinisation and local climate. Some natural values on the floodplain, particularly areas with Black Box *Eucalyptus largiflorens*, are currently in very poor condition and show signs of insufficient water even though their estimated critical interval has not been exceeded. It is thought that this problem is due to insufficient local rainfall that has not been offset by floodplain inundation. That is, Black Box trees (and associated values) do not persist with local rainfall alone, but do need local rainfall when the intervals between flooding events is large. In such circumstances, the effects of annual or longer variations in local rainfall could be a significant influence on floodplain watering strategies and warrant further investigation. Similarly, improvements in inundation models and information on the effects of groundwater and soil salinity have the potential to impact significantly on the formulation and selection of watering strategies and should be sought out and incorporated into those strategies as the improvements and new information becomes available.

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Table 1. Flood-dependent Ecological Vegetation Classes (EVCs) in the VEAC River Red Gum Forests investigation area. V = variable**.**

EVC No.	Ecological Vegetation Class (EVC)	Natural flood frequency (yrs)	Critical interval (yrs)	Minimum duration (months)
806	Alluvial Plains Semi-arid Grassland	1 in 2-15	25	1.5-6
653	Aquatic Herbland	3-4 in 4	2	6-1
1043	Aquatic Herbland/Floodplain Grassy Wetland Mosaic	7-10 in 10	2	3-9
1044	Aquatic Herbland/Floodway Pond Herbland	3-4 in 4	2	6-12
1045	Aquatic Herbland/Riverine Swamp Forest Mosaic	3-4 in 4	2	6-12
1047	Aquatic Herbland/Tall Marsh Mosaic	3-4 in 4	2	6-12
334	Billabong Wetland Aggregate	variable	2 (v)	>6
297	Billabong Wetland Aggregate/Red Gum Swamp Mosaic	variable	2 (v)	>6
807	Disused Floodway Shrubby Herbland	1 in 10-20	25 (v)	2-6 (v)
1022	Drainage-line Aggregate	3-5 in 5	2	2-12
1023	Drainage-line Aggregate/Riverine Swamp Forest Mosaic	3-4 in 5	3	4-7
1025	Drainage-line Aggregate/Sedgy Riverine Forest Mosaic	1-3 in 5	5	1-2
168	Drainage-line Aggregate/Tall Marsh Mosaic	3-5 in 5	2	2-12
809	Floodplain Grassy Wetland	7-10 in 10	2	3-9
1049	Floodplain Grassy Wetland/Floodway Pond Herbland Mosaic	7-10 in 10	2	3-9
1051	Floodplain Grassy Wetland/Riverine Swamp Forest Mosaic	7-10 in 10	2	3-9
1052	Floodplain Grassy Wetland/Riverine Swampy Woodland Mosaic	7-10 in 10	2	3-9
1054	Floodplain Grassy Wetland/Spike-sedge Wetland Mosaic	7-10 in 10	2	3-9
1055	Floodplain Grassy Wetland/Tall Marsh Mosaic	7-10 in 10	2	3-9
56	Floodplain Riparian Woodland	3-5 in 10	7	<1
1033	Floodplain Riparian Woodland/Floodway Pond Herbland Mosaic	6-9 in 10	3	4-10
1031	Floodplain Riparian Woodland/Grassy Riverine Forest Mosaic	2-4 in 4	4	1-4
1032	Floodplain Riparian Woodland/Riverine Grassy Woodland Mosaic	3-5 in 10	7	<1

EVC No.	Ecological Vegetation Class (EVC)	Natural flood frequency (yrs)	Critical interval (yrs)	Minimum duration (months)
1034	Floodplain Riparian Woodland/Riverine Swamp Forest Mosaic	3-4 in 5	3	4-7
1035	Floodplain Riparian Woodland/Sedgy Riverine Forest Mosaic	1-3 in 5	5	1-2
1037	Floodplain Riparian Woodland/Tall Marsh Mosaic	3-5 in 5	2	6-11
172	Floodplain Wetland Aggregate	3-4 in 4	2	2-9
810	Floodway Pond Herbland	6-9 in 10	3	4-10
945	Floodway Pond Herbland/Riverine Swamp Forest Complex	3-5 in 5	3	3-8
1058	Floodway Pond Herbland/Riverine Swamp Forest Mosaic	6-9 in 10	3	4-10
1060	Floodway Pond Herbland/Tall Marsh Mosaic	6-9 in 10	3	4-10
106	Grassy Riverine Forest	2-4 in 4	4	1-4
1015	Grassy Riverine Forest/Drainage-line Aggregate Mosaic	2-4 in 4	4	3-6
811	Grassy Riverine Forest/Floodway Pond Herbland Complex	2-4 in 4	4	3-6
1029	Grassy Riverine Forest/Floodway Pond Herbland Mosaic	2-4 in 4	4	3-6
1017	Grassy Riverine Forest/Riverine Grassy Woodland Mosaic	2-4 in 4	4	1-4
812	Grassy Riverine Forest/Riverine Swamp Forest Complex	3-5 in 5	3	3-6
1030	Grassy Riverine Forest/Riverine Swamp Forest Mosaic	3-5 in 5	3	3-6
1062	Grassy Riverine Forest/Riverine Swampy Woodland Mosaic	2-4 in 4	4	1-4
1063	Grassy Riverine Forest/Sedgy Riverine Forest Mosaic	2-4 in 4	4	1-4
1065	Grassy Riverine Forest/Tall Marsh Mosaic	3-5 in 5	2	6-11
813	Intermittent Swampy Woodland	1-3 in 5	7	2-6
822	Intermittent Swampy Woodland/ Riverine Grassy Woodland Complex	1-5 in 10	10	<1-3
107	Lake Bed Herbland	variable	2-5 (v)	6-36
808	Lignum Shrubland	1 in 4-10	15	2-4
104	Lignum Swamp	1 in 2-8	15	2-6
823	Lignum Swampy Woodland	1 in 2-8	15	2-4
1038	Low Rises Woodland/Riverine Swampy Woodland Mosaic	1-3 in 5	5	<1-2

EVC No.	Ecological Vegetation Class (EVC)	Natural flood frequency (yrs)	Critical interval (yrs)	Minimum duration (months)
1048	Mosaic of Aquatic Herbland/Floodway Pond Herbland-Riverine Swamp Forest Complex	3-4 in 4	2	6-12
1046	Mosaic of Aquatic Herbland/Sedgy Riverine Forest-Riverine Swamp Forest Complex	3-4 in 4	2	6-12
1039	Mosaic of Drainage-line Aggregate/Floodway Pond Herbland-Riverine Swamp Forest Complex	3-5 in 5	3	3-8
1021	Mosaic of Drainage-line Aggregate/Grassy Riverine Forest-Riverine Swamp Forest Complex	3-5 in 5	3	3-6
1024	Mosaic of Drainage-line Aggregate/Sedgy Riverine Forest-Riverine Swamp Forest Complex	3-4 in 5	3	2-5
1056	Mosaic of Floodplain Grassy Wetland/Floodway Pond Herbland-Riverine Swamp Forest Complex	7-10 in 10	2	3-9
1050	Mosaic of Floodplain Grassy Wetland/Grassy Riverine Forest-Riverine Swamp Forest Complex	7-10 in 10	2	3-9
1053	Mosaic of Floodplain Grassy Wetland/Sedgy Riverine Forest-Riverine Swamp Forest Complex	7-10 in 10	2	3-9
1036	Mosaic of Floodplain Riparian Woodland/Sedgy Riverine Forest-Riverine Swamp Forest Complex	3-4 in 5	3	2-5
1057	Mosaic of Floodway Pond Herbland/Grassy Riverine Forest-Riverine Swamp Forest Complex	6-9 in 10	3	3-10
1059	Mosaic of Floodway Pond Herbland/Sedgy Riverine Forest-Riverine Swamp Forest Complex	6-9 in 10	3	3-10
1020	Mosaic of Grassy Riverine Forest/Floodway Pond Herbland-Riverine Swamp Forest Complex	3-5 in 5	3	3-8
1016	Mosaic of Grassy Riverine Forest/Plains Grassy Woodland-Grassy Woodland Complex	2-4 in 4	4	1-4
1019	Mosaic of Grassy Riverine Forest/Sedgy Riverine Forest-Riverine Swamp Forest Complex	2-4 in 4	4	1-4
1061	Mosaic of Grassy Riverine Forest-Riverine Swamp Forest Complex/Riverine Swamp Forest	3-4 in 5	3	4-7
1042	Mosaic of Riverine Grassy Woodland/Floodway Pond Herbland-Riverine Swamp Forest Complex	3-5 in 5	3	3-8
1072	Mosaic of Riverine Swamp Forest/Floodway Pond Herbland-Riverine Swamp Forest Complex	3-5 in 5	3	3-8
1074	Mosaic of Riverine Swampy Woodland/Sedgy Riverine Forest-Riverine Swamp Forest Complex	3-4 in 5	3	2-5
1078	Mosaic of Sedgy Riverine Forest/Floodway Pond Herbland-Riverine Swamp Forest Complex	3-5 in 5	3	3-8
1075	Mosaic of Sedgy Riverine Forest/Sedgy Riverine Forest-Riverine Swamp Forest Complex	3-4 in 5	3	2-5
1080	Mosaic of Sedgy Riverine Forest-Riverine Swamp Forest Complex/Floodway Pond Herbland-Riverine Swamp Forest Complex	3-5 in 5	3	3-8
1079	Mosaic of Sedgy Riverine Forest-Riverine Swamp Forest Complex/Tall Marsh	3-4 in 5	3	2-5
1083	Mosaic of Tall Marsh/Floodway Pond Herbland-Riverine Swamp Forest Complex	3-5 in 5	3	3-8
125	Plains Grassy Wetland	2-3 in 3	3	3-8

EVC No.	Ecological Vegetation Class (EVC)	Natural flood frequency (yrs)	Critical interval (yrs)	Minimum duration (months)
238	Plains Grassy Woodland/Creekline Grassy Woodland/Floodplain Riparian Woodland Mosaic	3-5 in 10	7	<1
292	Red Gum Swamp	2-3 in 3	3	4-9
333	Red Gum Swamp/Plains Grassy Wetland Mosaic	2-3 in 3	3	4-9
103	Riverine Chenopod Woodland	1 in 10-25 (1 in 20-40 *Atriplex* community)	30-50	<1-3
321	Riverine Chenopod Woodland/Lignum Swamp Mosaic	1 in 2-8	15	2-6
295	Riverine Grassy Woodland	2-3 in 10	7	<1
1027	Riverine Grassy Woodland/Grassy Riverine Forest-Riverine Swamp Forest Complex	3-5 in 5	3	3-6
870	Riverine Grassy Woodland/Plains Woodland Complex	2-3 in 10	7	<1
871	Riverine Grassy Woodland/Plains Woodland/Gilgai Wetland Complex	2-3 in 10	7	<1
872	Riverine Grassy Woodland/Plains Woodland/Riverine Chenopod Woodland Complex	1 in 10-25 (1 in 20-40 *Atriplex* community)	30-50	2-4
873	Riverine Grassy Woodland/Riverine Chenopod Woodland/Wetland Mosaic	2-3 in 10	7	<1
1028	Riverine Grassy Woodland/Riverine Swamp Forest Mosaic	3-4 in 5	3	4-7
1040	Riverine Grassy Woodland/Riverine Swampy Woodland Mosaic	1-3 in 5	5	<1-2
1041	Riverine Grassy WoodlandSedgy Riverine Forest Mosaic	1-3 in 5	5	<1-2
814	Riverine Swamp Forest	3-4 in 5	3	4-7
1067	Riverine Swamp Forest/Riverine Swampy Woodland Mosaic	3-4 in 5	3	4-7
1068	Riverine Swamp Forest/Sedgy Riverine Forest Mosaic	3-4 in 5	3	4-7
1069	Riverine Swamp Forest/Sedgy Riverine Forest-Riverine Swamp Forest Complex	3-4 in 5	3	4-7
1070	Riverine Swamp Forest/Spike-sedge Wetland Mosaic	2-4 in 4	4	1-4
1071	Riverine Swamp Forest/Tall Marsh Mosaic	3-5 in 5	2	6-11
815	Riverine Swampy Woodland	1-3 in 5	5	<1-2
1099	Riverine Swampy Woodland/Plains Grassy Wetland Mosaic	2-3 in 3	3	3-8
1073	Riverine Swampy Woodland/Sedgy Riverine Forest Mosaic	1-3 in 5	5	1-2

EVC No.	Ecological Vegetation Class (EVC)	Natural flood frequency (yrs)	Critical interval (yrs)	Minimum duration (months)
804	Rushy Riverine Swamp	3-4 in 5	2	3-9
816	Sedgy Riverine Forest	1-3 in 5	5	1-2
817	Sedgy Riverine Forest/Riverine Swamp Forest Complex	3-4 in 5	3	4-7
1076	Sedgy Riverine Forest/Spike-sedge Wetland Mosaic	2-4 in 4	4	1-4
1077	Sedgy Riverine Forest/Tall Marsh Mosaic	3-5 in 5	2	6-11
200	Shallow Freshwater Marsh	2-3 in 3	3	4-9
818	Shrubby Riverine Woodland	1-3 in 5	7	<1
819	Spike-sedge Wetland	2-4 in 4	4	1-4
1081	Spike-sedge Wetland/Tall Marsh Mosaic	3-5 in 5	2	6-11
820	Sub-saline Depression Shrubland	1 in 10-15	25	2-3
821	Tall Marsh	3-5 in 5	2	6-11
1087	Tall Marsh/Aquatic Herbland Mosaic	3-4 in 4	2	6-12
1084	Tall Marsh/Non-Vegetation Mosaic	3-4 in 4	2	6-12
1090	Tall Marsh/Open Water Mosaic	3-4 in 4	2	6-12
1082	Tall Marsh/Riverine Swamp Forest Mosaic	3-5 in 5	2	6-11
Flood-dependent EVCs found in the VEAC River Red Gum Forests Investigation area but not in the present study				
291	Cane Grass Wetland	2-4 in 5	5	3-9
942	Lignum Swampy Woodland/Lake Bed Herbland Mosaic	variable	2-5 (v)	6-36
943	Lignum Swampy Woodland/Plains Grassland Mosaic	1 in 2-8	15	2-4
855	Plains Woodland/Lignum Swamp Mosaic	1 in 2-8	15	2-6
856	Plains Woodland/Red Gum Swamp Mosaic	2-3 in 3	3	4-9
110	Riverine Chenopod Woodland/Plains Grassland Mosaic	1 in 10-25 (1 in 20-40 *Atriplex* community)	30-50	<1-3
946	Riverine Swampy Woodland/Lignum Swamp Mosaic	1 in 2-8	15	2-6

Note that broad EVCs Water Body – natural or man made (998) and Wetland Formation (74) are at least in some cases flood-dependent. Bare Rock/Ground (993) has in some cases been mapped for dry creek beds or billabongs which would be flood-dependent, particularly in the northwest of the study area.

Table 2. Flood requirements of rare or threatened flora.

Conservation status: E = endangered, V= vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* ; e = endangered, v = vulnerable, r = rare, k = poorly known on the *Advisory List for Rare and Threatened Plants in Victoria – 2005*, L= Listed under the Victorian *Flora and Fauna Guarantee Act 1988*.

Wetland/Floodplain Dependent: Y - Taxa apparently requiring/responding to inundation, W - Taxa not dependent on riverine flooding, H - Taxa occurring in habitats which are prone to at least some inundation.

Importance of Study Area Population: M - moderate - regional and state survival not dependent on populations within study area, but more than incidental relevance of distribution within study area (including Northern Plains populations largely extinct), H - high - substantial proportion of at least northern populations within study area, or very few localities in total or Northern Plains populations largely extinct.

Relevant Flood-Dependent EVCs: numbers refer to EVC numbers in Table 1.

Mapped: ✓ = Yes, × = No

Name and conservation status	Wetland/ floodplain dependent*	Importance of study area population	Relevant flood-dependent EVCs	Mapped	Additional information
Native Scurf-pea *Cullen australasicum* (e, L)	Y	H	107	×	
Hoary Scurf-pea *Cullen cinereum* (e, L)	Y	H	107	✓	Drying phase of shallow lakes
Small Scurf-pea *Cullen parvum* (e, L)	Y (in north)	H	816 (upper edge), 815	✓	Upper edge of flooded zone, flood-dispersed seed pods
Annual Flat-sedge *Cyperus nervulosus* (e, L)	Y	H	1022 / 814, Riparian	×	
Slender Love-grass *Eragrostis exigua* (e)	Y	H	1022	✓	
Grey Billy-buttons *Craspedia canens* (e, L)	W/Y	H?	172, 125 &/or 815?	×	
Plains Spurge *Euphorbia planiticola* (e, L)	W/Y?	H?	107 / 813?	×	
Keeled Goosefoot *Chenopodium carinatum* (v)	H/Y?	H?	985 / 810 / 1022 /Riparian?	×	
Jerry-jerry *Ammannia multiflora* (v)	Y	H	1022, 808, 107, 806	✓	Annual of creeklines, Lacustrine - following recession
Small Water-fire *Bergia trimera* (v)	Y	H	107	✓	Restricted to drying phase of Lake beds and lagoons
Mueller Daisy *Brachyscome muelleroides* (V, e, L)	Y/H	H	295, 815	✓	
Water-shield *Brasenia schreberi* (v, L)	Y	H	334, 653/998	×	
Western Water-starwort *Callitriche cyclocarpa* (V, v, L)	Y	H	1022 / 998, 810, 945, 812	✓	Floodways and wetlands - small seasonal aquatic, required shallow open habitat
Lax Flat-sedge *Cyperus flaccidus* (v)	Y	H	1022 / 814, Riparian	×	Verges of drainage-lines / floodways
Dwarf Flat-sedge *Cyperus pygmaeus* (v)	Y	H	1022 / 814, Riparian	✓	Verges of drainage-lines / floodways
Bearded Flat-sedge *Cyperus squarrosus* (v)	Y	H	1022 / 814, Riparian	✓	
Button Rush *Lipocarpha microcephala* (v)	Y	H	810, 1022, 172, 998	✓	Annual of sandy floodways - following recession
Lagoon Spurge *Phyllanthus lacunarius* (v)	Y	H	808	✓	Restricted to drying phase of Lake beds and lagoons
Glistening Dock *Rumex crystallinus s.s.* (v)	Y	H	806 / 107, 808, 811	×	Post-recession annual of low herblands

Name and conservation status	Wetland/ floodplain dependent*	Importance of study area population	Relevant flood-dependent EVCs	Mapped	Additional information
Yellow Pea-bush *Sesbania cannabina* var. *cannabina* (v)	Y?	H?	810 / 172?	×	
Lagoon Nightshade *Solanum lacunarium* (v)	Y	H	808, 806	✓	Restricted to drying phase , shallow wetlands / verges of lakes and lagoons
Wavy Marshwort *Nymphoides crenata* (v)	Y	H	1022, 653, 809, 945, 172, 334, 810 (marginal)	✓	Aquatic herb, floodways and related wetlands
Twin-leaf Bedstraw *Asperula gemella* (r)	Y	H	808, 104, 823, 106 (north-west only), 818, 103, 813	✓	
Reader's Daisy *Brachyscome readeri* (r)	Y/H	H	295, 815	✓	
Cotton Sneezeweed *Centipeda nidiformis* (r)	Y	H	810, 809, 945	✓	
Veiled Fringe-sedge *Fimbristylis velata* (r)	Y	H	1022, 810, 172	×	
Dwarf Brooklime *Gratiola pumilo* (r)	Y	H	1022	×	
Hydrilla *Hydrilla verticillate* (r)	Y	H	653, 998, 1022	×	
Brown Beetle-grass *Leptochloa fusca* subsp. *fusca* (r)	Y	H	810/1022?	×	
Small Monkey-flower *Mimulus prostrates* (r)	W/Y	H	813?, 823 / 808?	×	
Mallee Cucumber *Mukia micrantha* (r)	Y	H/M	107, 806, 810 (north-west)	✓	Restricted to drying phase of shallow lakes
Water Nymph *Najas tenuifolia* (r)	Y	H	653, Riparian, 998	×	
Sandhill Spurge *Phyllanthus lacunellus* (r)	Y	H	806, 107, 808	✓	
Dwarf Bitter-cress *Rorippa eustylis* (r)	Y	H	810, 811, 812, 817	✓	Annual of flood-prone sites
Floodplain Fireweed *Senecio glandulosus* (r)	Y	H	295 / 56?	×	
Yakka Grass *Sporobolus caroli* (r)	Y/H	H/M	103	✓	
Sweet Fenugreek *Trigonella suavissima* (r)	Y	H	107, 813	✓	Restricted to drying phase of lakes/lagoons and associated floodways
Common Joyweed *Alternanthera nodiflora* (k)	Y	H	809, 813, 806, 808, 1022, 810	✓	
Common Hornwort *Ceratophyllum demersum* (k)	Y	H	653, 998 / Riparian	×	
Native Couch *Cynodon dactylon* var. *pulchellus* (k)	Y	H	816, 106, 817, 812, 823 (north-west), 295, 1022, 945, 813, 818, 809 (marginal), 811	✓	
Yelka *Cyperus victoriensis* (k)	Y	H	1022 / 814, Riparian	×	Verges of drainage-lines / floodways
Tall Cup-grass *Eriochloa crebra* (k)	Y	H	813/1022?, potentially 806, 823	×	
Summer Fringe-sedge *Fimbristylis aestivalis* (k)	Y	H	1022, 810, 172	✓	
Native Peppercress *Lepidium pseudohyssopifolium* (k)	Y	H	806, 818, 103, 813, 106, 808, 295, 811 (minor)	✓	
Indian Chickweed *Mollugo verticillate* (k)	Y?	H?	56 / 172?	×	

Name and conservation status	Wetland/ floodplain dependent*	Importance of study area population	Relevant flood-dependent EVCs	Mapped	Additional information
Velvet Knotweed *Persicaria attenuate* (k)	Y	H	107, 810, 172	×	Restricted to drying phase of Lake beds and lagoons/billabongs
Tongue Dock *Rumex stenoglottis* (k)	Y	H	810 / 1022?	×	
Smooth Blue-rod *Stemodia glabella s.s.* (k)	Y	H	818, 813	×	
Perfoliate Pondweed *Potamogeton perfoliatus s.l.* (k)	Y	M/H	653, Riparian, 998	×	
River Swamp Wallaby-grass *Amphibromus fluitans* (V)	Y	H	814, 809, 1022, 804 (minor 821, 945, 815, 817)	✓	
Curly Flat-sedge *Cyperus rigidellus* (e, L)	Y	M	1022 / 814, Riparian	×	
Umbrella Grass *Digitaria divaricatissima* (v)	Y	M	103, 813	×	
Cane Grass *Eragrostis australasica* (v)	Y	M	808, extending into 823, 103	✓	
Ridged Water-milfoil *Myriophyllum porcatum* (V, v, L)	Y	M	125, 653	×	
Small-flower Tobacco *Nicotiana goodspeedii* (r)	Y	M	107, 813	×	
Slender Water-ribbons *Triglochin dubia* (r)	Y	M	823, 1022, 808?	×	
Plains Billy-buttons *Craspedia haplorrhiza* (k)	Y	M	808, 104	×	
Pale Spike-sedge *Eleocharis pallens* (k)	Y	M	806, 172	✓	
Hypsela *Hypsela tridens* (k)	Y	M	945, 1022, 810, 998, 334, 172	×	
Slender Bitter-cress *Cardamine tenuifolia* (k)	W/Y	M	56	×	
Dwarf Darling-pea *Swainsona luteola* (e, L)	H?	H	103	×	
Straggly Lantern-bush *Abutilon oxycarpum* var. *malvaefolium* (e L)	H	H	103	✓	
Silky-heads *Cymbopogon obtectus* (e)	H	H	106 / 56?	×	
Winged Peppercress *Lepidium monoplocoides* (E, e, L)	H	H	103	✓	
Fat Spectacles *Menkea crassa* (e L)	H	H	103	×	
Yellow Tails *Ptilotus nobilis* var. *nobilis* (e)	H	H	103	✓	
Slender Sunray *Rhodanthe stricta* (e, L)	H	H	295 (or interface with very infrequently flooded 803?)	×	
Woolly Copperburr *Sclerolaena lanicuspis* (e)	H	H	807 / 808 / 103?	×	
Salt Copperburr *Sclerolaena ventricosa* (e, L)	H	H	808?	×	
Violet Swainson-pea *Swainsona adenophylla* (e, L)	H	H	295 / 1088	×	
Hairy Darling-pea *Swainsona greyana* (e, L)	H	H	818	✓	Restricted to very localised flood-plain habitat, flood-dispersed seed pods
Pop Saltbush *Atriplex holocarpa* (v, L)	H	H	103, 107, 808	×	
Spreading Saltbush *Atriplex limbate* (v, L)	H	H	103	✓	

Name and conservation status	Wetland/ floodplain dependent*	Importance of study area population	Relevant flood-dependent EVCs	Mapped	Additional information
Billabong Daisy *Brachyscome aff. gracilis* (Kings Billabong) (v, L)	H	H	813	✓	Restricted to very localised flood-plain habitat
Yellow Garland-lily *Calostemma luteum* (v)	H	H	818, 103	×	
Darling Lily *Crinum flaccidum* (v, L)	H	H	1022 / 818 & 103	×	
Riverine Flax-lily *Dianella porracea* (v)	H	H	103	✓	
Pale Flax-lily *Dianella* sp. aff. *longifolia* (Riverina) (v)	H	H	816, 295	✓	
Flycatcher *Drosera indica* (v)	H	H	813	×	
Tall Nut-heads *Epaltes cunninghamii* (v)	H	H	103, 813	×	
Bignonia Emu-bush *Eremophila bignoniiflora* (v, L)	H	H	103, 818	✓	Shrub of Black Box Woodlands, with flood-dispersed seed pods
Poverty Bush *Sclerolaena intricate* (v)	H	H	820, 808	✓	
Pale Swamp Everlasting *Helichrysum* aff. *rutidolepis* (Lowland Swamps) (v)	H	H (riverine form)	295, 815, 816	✓	Herbs of upper floodplain zones, habitat flood maintained
Dwarf Old-man Saltbush *Atriplex nummularia subsp. omissa* (r)	H	H	103	×	
Garland Lily *Calostemma purpureum s.l.* (r)	H	H	818, 103	✓	
Riverina Bitter-cress *Cardamine moirensis* (r)	H	H	106, 812, 814, 816, 817, 811, (& 809, 810)	✓	Restricted to flood maintained habitat, vulnerable to gross habitat changes
Spreading Emu-bush *Eremophila divaricata* subsp. *divaricata* (r)	H	H	103, 813	✓	
Spotted Emu-bush *Eremophila maculata* var. *maculata* (r)	H	H	103, 813	✓	
Woolly Minuria *Minuria denticulata* (r)	H	H	808	×	
Squat Picris *Picris squarrose* (r)	H	H	818, 295 (and extending into 945 and 811 during sustained dry period)	✓	
Bundled Peppercress *Lepidium fasciculatum* (k)	H	H	808, 104, 823, 103	✓	
Warty Peppercress *Lepidium papillosum* (k)	H	H	103, 806, 808	✓	
Tangled Copperburr *Sclerolaena divaricate* (k)	H	H	808, 104, 823, also 103?	✓	
Bluish Raspwort *Haloragis glauca f. glauca* (k)	H	M	813, 107, 823	✓	
Weeping Myall *Acacia pendula* (e, L)	H/N	H	103	✓	
Soda Bush *Neobassia proceriflora* (e)	H/N	H	103	✓	
Small-leaf Bluebush *Maireana microphylla* (e)	H/N	H/M	295	✓	
Pale Plover-daisy *Leiocarpa leptolepis* (e, L)	H/N	M	103, 295	✓	
Desert Lantern *Abutilon otocarpum* (v)	H/N	H	103, 813	✓	

Name and conservation status	Wetland/ floodplain dependent*	Importance of study area population	Relevant flood-dependent EVCs	Mapped	Additional information
Yarran *Acacia melvillei* (v)	H/N	H	103	✓	
Dwarf Amaranth *Amaranthus macrocarpus* var. *macrocarpus* (v)	H/N	H	103	✓	
Silver Saltbush *Atriplex rhagodioides* (v)	H/N	H	103	✓	
Purple Love-grass *Eragrostis lacunaria* (v)	H/N	H	103, 813, 806 / marginal 809	✓	
Spear-fruit Copperburr *Sclerolaena patenticuspis* (v)	H/N	H	extending into 807, 103 from drier shrublands?, possibly 808?	✓	
Annual Bitter-cress *Cardamine paucijuga s.s.* (v)	H/N	M	56/172?	✓	
Mealy Saltbush *Atriplex pseudocampanulata* (r)	H/N	H	103	✓	
Prickly Bottlebrush *Callistemon brachyandrus* (r)	H/N	H	103	✓	
Blue Burr-daisy *Calotis cuneifolia* (r)	H/N	H	818, 295	×	
Finger Grass *Dactyloctenium radulans* (r)	H/N	H	103	✓	
Goat Head *Malacocera tricornis* (r)	H/N	H	103, 808, 820	✓	
Smooth Minuria *Minuria integerrima* (r)	H/N	H	103, 815	×	
Mallee Annual-bluebell *Wahlenbergia tumidifructa* (r)	H/N	H	103?, 815?	×	
Wimmera Woodruff *Asperula wimmerana* (r)	H/N	M	823	✓	
Spiny Lignum *Muehlenbeckia horrida subsp. horrida* (r)	H/N	M	107, 806, 813	×	
Flat-top Saltbush *Atriplex lindleyi subsp. lindleyi* (k)	H/N	H	103	×	
Bladder Saltbush *Atriplex vesicaria subsp. minor* (k)	H/N	H	103	×	
Ferny Small-flower Buttercup *Ranunculus pumilio* var. *politus* (k)	H/N	H	817, 814	×	
Austral Trefoil *Lotus australis* var. *australis* (k)	H/N	H (riverine form)	818, 295	×	
Leafless Bluebush *Maireana aphylla* (k)	H/N	M	103	×	
Desert Spinach *Tetragonia eremaea s.s.* (k)	H/N	M	808. 806, 103	✓	
Annual Spinach *Tetragonia moorei* (k)	H/N	M	103	✓	
Native Madder *Synaptantha tilleacea* var. *tilleacea* (v)	?	H?	810?	×	
Long Erygnium *Erygnium paludosum* (v)	Y	M	104, 823	✓	
Swamp Buttercup *Ranunculus undosus* (v)	Y	M	104, 823	✓	

*Where populations also occur in non-flooded Chenopod Shrubland communities or adjacent dry woodland habitats, they are denoted H/N unless there is information to suggest that the occurrences within EVC 103 are of only incidental importance to overall populations.

Table 3. Flood requirements of rare or threatened fauna.
Conservation status: E = endangered, V= vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*; ce = critically endangered, e = endangered, v = vulnerable, d = data deficient, n = near threatened on the *Advisory List for Threatened Vertebrate Fauna in Victoria – 2007*; L= Listed under the Victorian *Flora and Fauna Guarantee Act 1988*.
Importance: notes on importance of study area population, **EVC:** Ecological Vegetation Class, **VFD:** Victorian Fauna Database/Atlas of Victorian Wildlife, **FFG:** Victorian *Flora and Fauna Guarantee Act 1988*.

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Brown Quail *Coturnix ypsilophora* (n)	1. All areas of Floodplain Riparian Woodland, Spike Sedge Wetland, Intermittent Swampy Woodland and mosaics or complexes containing one or more of these in Gunbower and Lower Goulburn from (1) its junction with the Murray to Wyuna and including Kanyapella, (2) Loch Garry upstream (to furthest point upstream in study area), and (3) Hattah-Kulkyne National Park and Murray-Kulkyne Park. 2. All areas of these EVCs and mosaics or complexes containing either of them within 2 km of all record sites marked on hand-annotated map.	as per EVCs	as per EVCs	Habitat/Location: Very widespread but thin along or just outside entire study area. Habitat described by Emison et al. (1987) as 'grass and sedge flats ... grassy River Red Gum forests and ... wet woodlands and forests containing grasses, sword-sedges and gahnias'. In instances where there are 3 or more recent records all suitable EVC areas in blocks have been selected (there are 2 records in each of Barmah and Lower Ovens). Importance: 'Only' near threatened, widespread outside study area in Australia and, to a lesser extent, Victoria.
Blue-billed Duck *Oxyura australis* (e, L)	1. Lakes Ranfurley and Hawthorn and Hattah-Kulkyne National Park: all areas of Lake Bed Herbland. 2. At Kings Billabong: polygons of Bare Rock/Ground. 3. Lake Powell : all areas of Lake Bed Herbland. 4. At Reedy Swamp: all areas of Tall Marsh/Open Water Mosaic. 5. At Gemmill Swamp: Spike-sedge Wetland/Tall Marsh Mosaic.	as per EVCs; 1 in 2 for 993	as per EVCs 6-12 m for 993	Habitat/Location: Included is non-breeding habitat (open wetlands) where there are two or more records, and breeding habitat where there is one or more records – excluding sewage farms in both cases (where there are many records incidentally) and old or imprecise records. The only breeding records in the study area are at Wodonga Sewage Farm (excluded) and Lake Tullamook near Lake Brockie in the Hattah Lakes. Habitat determinations are as per Marchant and Higgins (1990) and Emison et al. (1987) – note that the requirement of deep wetlands for breeding excludes about half a dozen otherwise appropriate sites with single records (including at Lindsay Island, south of Kings Billabong, near Wangaratta and near Lake Moodemere) Importance: Although endangered in Victoria, the study area probably supports less than 10% of the Victorian population and the species is widespread and at least relatively common outside the study area in Victoria and Australia.
Musk Duck *Biziura lobata* (v)	1. Kings Billabong: areas of Bare Rock/Ground. 2. Hattah-Kulkyne National Park and Lakes Powell and Carpul: all areas of Lake Bed Herbland. 3. Vinifera Forest: all areas of Spike-sedge Wetland and Tall Marsh. 4. Gunbower Forest: all areas of Spike-sedge Wetland. 5. Loch Garry: all areas of Billabong Wetland Aggregate and Rushy Riverine Swamp. 6. Reedy Swamp: all areas of Tall Marsh/Open Water Mosaic. 7. Gemmill Swamp: Spike-sedge Wetland/Tall Marsh Mosaic. 8. Barmah Lake: all areas of Water Body – natural or man made. 9. Top Island (Barmah Forest): all areas of Tall Marsh, Rushy Riverine Swamp, and Mosaic of Tall Marsh/Floodway Pond Herbland-Riverine Swamp Forest Complex within 1 km of record (145.0025E, -35.86917S). 10. Lake Moodemere: Water Body – natural or man made, Floodplain Wetland Aggregate and Tall Marsh/Aquatic Herbland Mosaic. 11. Ryans Lagoon: all areas of Billabong Wetland Aggregate.	as per EVCs; 1 in 2 for 993 & 998	as per EVCs 6-12 m for 993 & 998	Habitat/Location: Only sites with two or more records in suitable habitat (except sewage farms) (there are a dozen or so sites in the study area with fewer than two records or where little or no suitable habitat exists). EVCs reflect habitat descriptions of Marchant and Higgins (1990) and Emison *et al*. (1987): deep, open wetlands. Breeding records at Lake Bulla, Gemmill Swamp and Reedy Lake. Importance: Although vulnerable in Victoria, the study area probably supports less than 10% of the Victorian population and the species is widespread and at least relatively common outside the study area in Victoria and Australia.

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Freckled Duck *Stictonetta naevosa* (e, L)	1. Breeding sites: all areas with one or more records of Lake Bed Herbland, Lignum Swamp, Lignum Shrubland Lignum Swampy Woodland and mosaics or complexes containing one or more of these in the recommended Hattah-Kulkyne National Park, Murray-Kulkyne Park and Lakes Powell and Carpul Nature Conservation Reserve. 2. Non-breeding sites: all areas of Tall Marsh/Open Water Mosaic at Reedy Swamp, Water Body – natural or man made, Tall Marsh/Aquatic Herbland Mosaic and Floodplain Wetland Aggregate at Lake Moodemere, and Bare Rock/Ground as per annotated map at Kings Billabong.	as per EVCs; 1 in 2 for 993 & 998	as per EVCs 6-12 m for 993 & 998	Habitat/Location: Choice of EVCs corresponds with breeding and non-breeding habitat (whichever applies) as described in Marchant and Higgins (1990), with emphasis on open water for non-breeding sites. Lakes Konardin, Mournpall and Powell are three of only seven recorded breeding sites in Victoria and the Hattah Lakes more broadly are a major concentration of records in general. Records not resulting in polygons either too old and imprecise (W of Robinvale), too haphazard for reliable interpretation (Lindsay Is, NW of Merbein, Yambuna, NW of Cobram), and/or in wetlands where habitat suitability is entirely artificial (NW of Cobram, Lake Mulwala, sewage farms). Importance: study area sites (excluding sewage farms) probably contribute less than 10% of Victorian population and Victoria is largely a non-breeding staging area: on this basis, the breeding sites/areas could be highly important.
Australasian Shoveller *Anas rhynchotis* (v)	1. Lake Walla Walla and in Hattah-Kulkyne National Park: all areas of Lake Bed Herbland and adjoining (within 200 metres) Intermittent Swampy Woodland and Lignum Shrubland. 2. Kings Billabong: areas of Bare Rock/Ground as per annotated map and adjoining (within 200 metres) Intermittent Swampy Woodland and Lignum Shrubland. 3. Loch Garry: all areas of Billabong Wetland Aggregate and Rushy Riverine Swamp. 4. Reedy Swamp: all areas of Tall Marsh/Open Water Mosaic. 5. Lake Moodemere: Water Body – natural or man made, Floodplain Wetland Aggregate, Tall Marsh/Aquatic Herbland Mosaic, and adjoining (within 200 metres) Drainage Line Complex.	as per EVCs; 1 in 2 for 998 & 993	as per EVCs 6-12 m for 998 & 993	Habitat/Location: Choice of EVCs corresponds with habitat as described by Emison et al. (1987), with dense bordering grassy/rushy areas included for breeding (up to 200 m as per Marchant and Higgins (1990)). Numerous scattered records along all floodplains except Kiewa (but thin along much of the Murray) – only those on still water bodies discernible on the VFD included here, except the following sites where there is only one record each (inclusion not justified given the mobility of this species): Lake Cullulleraine, NW of Reedy Swamp, Gemmill Swamp, NW of Dugays Bridge. Tram Swamp (Barmah Forest) also excluded: the two records there are too imprecise. Hattah Lakes are a major site. Importance: The study area sites (excluding sewage farms) probably support less than 10% of Victorian population, and main reason for current conservation status is based on low total population in Victoria, small area of occupancy and habitat degradation.
Hardhead *Aythya australis* (v)	1. Lake Walla Walla, Lakes Hawthorn and Ranfurley, Hattah-Kulkyne National Park and Lakes Powell and Carpul: all areas of Lake Bed Herbland. 2. Merbein Common: all areas of Alluvial Plains Semi-arid Grassland and Bare Rock/Ground. 3. Kings Billabong: areas of Bare Rock/Ground. 4. Gemmill Swamp: Spike-sedge Wetland/Tall Marsh Mosaic. 5. Reedy Swamp: Tall Marsh/Open Water Mosaic 6. Along the Ovens River just (for 2 km) upstream of the Hume Bypass: Floodplain Wetland Aggregate.	as per EVCs; 1 in 2 for 993	as per EVCs 6-12 m for 993	Habitat/Location: Only sites with three or more records (except sewage farms which are excluded – note that all three breeding records in the study area are in sewage farms) (there are in the order of 20 sites in the study area with fewer than three records). EVCs reflect habitat descriptions of Marchant and Higgins (1990) and Emison et al. (1987): (large) deep, open (~permanent) wetlands, especially with abundant aquatic vegetation. Importance: The study area sites (excluding sewage farms) probably support less than 10% of Victorian population, and main reason for current conservation status is based on low total population in Victoria, small area of occupancy and habitat degradation.

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Pied Cormorant *Phalacrocorax varius* (n)	*Breeding sites:* All areas of all flood-dependent EVCs within 1 km of breeding records, except full extent of Intermittent Swampy Woodland and Lake Bed Herbland at and around Lake Bitterang and Lake Hattah *Non-breeding sites:* 1. Lakes Ranfurley and Hawthorn (between Mildura and Merbein) and Hattah-Kulkyne National Park: all areas of Lake Bed Herbland. 2. Kings Billabong: areas of Bare Rock/Ground, and Lignum Swamp, Lignum Shrubland (808) and Floodway Pond Herbland. 3. Ovens River downstream of the existing Regional Park/State Forest boundary: all areas of Water Body – natural or man made, Floodplain Wetland Aggregate, Floodplain Riparian Woodland/Riverine Swamp Forest Mosaic and Riverine Swampy Woodland.	*Breeding sites:* as per EVCs *Non-breeding sites:* as per EVCs; 1 in 2 for 993 and 998	*Breeding sites:* 5 months *Non-breeding sites:* as per EVCs 6-12 m for 993 and 998	Habitat/Location: Recorded nesting sites only (including those in Barmah forest from 1969) but Marchant and Higgins (1990) says breeding "probably sparsely throughout range in suitable places" and also "inland, nest in trees" (as opposed to on or near the ground or on cliffs). Sites identified for specific delineation (as opposed to 1 km radius) because likely nesting and feeding habitats at these sites are discrete. Some breeding sites shown by Emison et al. (1987) – near Rutherglen, and perhaps Wangaratta (although this could be Lake Mokoan) and Lake Boga (could be The Marshes) – are not in the VFD dataset. Also, some records need checking because they are at times when the sites may not have been flooded (e.g. Lake Hattah 2001). Note though that Pied Cormorants are not obligate colonial breeders, are not especially restricted in terms of potential sites, and do not require trees to be inundated at time of nesting (hence minimum flood frequency and duration both as per EVCs unlike restricted obligate colonial breeders below). Non breeding sites mapped if there were 8 or more records. Importance: The six study area nesting sites are part of a Victorian total of around 50, and the species is 'only' near threatened.
Little Egret *Egretta garzetta* (e, L)	*Breeding sites:* All DSE wetland polygons and other points with breeding records and the surrounding 2 km (for both). *Non-breeding sites:* 1. Lakes Ranfurley and Hawthorn: all areas of Lake Bed Herbland . 2. Lakes Hattah, Little Hattah, Lockie, Yerang, Mournpall, Bulla and Arawak: all areas of Lake Bed Herbland. 3. Ovens River c. 1.5 km E of Hume Highway (Wangaratta Bypass): all areas of Floodplain Riparian Woodland and Floodplain Wetland Aggregate within 1 km of record site. 4. Ovens River c. 4 km E of Hume Highway (Wangaratta Bypass): all areas of Floodplain Riparian Woodland, Floodplain Wetland Aggregate and Water Body – natural or man made within 1 km of record site. 5. Ovens River SE of Whorouly: all areas of Swampy Woodland, Drainage Line Aggregate, Floodplain Wetland Aggregate and Water Body – natural or man made within 1 km of record site	*Breeding sites:* 1 in 5 *Non-breeding sites:* as per EVCs; 1 in 2 for 998	*Breeding sites:* 5 months *Non-breeding sites:* as per EVCs 6-12 m for 998	Habitat/Location: All post-1960 breeding records in VFD and literature selected and mapped. Non-breeding records are sites with two or more post-1970 records. Importance: High - the study area nesting sites are the largest in Victoria (there are few in Victoria outside the study area) and the species is endangered.
Eastern Great Egret *Ardea modesta* (v, L)	Breeding sites only: all DSE wetland polygons and other points with breeding records and the surrounding 2 km (for both).	1 in 5	5 months	Habitat/Location: Non-breeding records are too numerous, widely dispersed and of insufficient habitat specificity to warrant or allow singling out.

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Intermediate Egret *Ardea intermedia* (ce, L)	*Breeding sites:* All DSE wetland polygons and other points with breeding records and the surrounding 2 km (for both). *Non-breeding sites:* 1. Merbein Common: all areas of Alluvial Plains Semi-arid Grassland, Floodway Pond Herbland and Bare Rock/Ground – make sure the bend of the river northwest of the main block is included. 2. Hattah Lakes: all areas of Lake Bed Herbland at Lakes Konardin, Yelwell, Mournpall, Lockie, Hattah, Brockie and Nip Nip. 3. Guttram Forest: the areas of Floodway Pond Herbland/Riverine Swamp Forest Complex and Tall Marsh at Reed Bed (the record site near the southern end of the forest). 4. Gunbower Creek at Wee Wee Rup (upstream of Cohuna): all areas of Water Body – natural or man made within 2 km of records (A3016235, A3028385, A3132742 – all a the same spot) 5. Echuca: the area of Tall Marsh at/near record no. A3161469 6. Ovens River c. 1.5 km E of Hume Highway (Wangaratta Bypass): all areas of Floodplain Riparian Woodland and Floodplain Wetland Aggregate within 1 km of record site. 7. Brookfield (S of Everton): all areas of Billabong Wetland Aggregate, Drainage Line Aggregate, Floodplain Wetland Aggregate and Water Body – natural or man made (998) within 1 km of record site 8. Mt Ochtertyre (S of Howlong): all areas of Floodplain Wetland Aggregate and Billabong Wetland Aggregate 9. Ryans Lagoon (E of Wodonga): all areas of Drainage Line Aggregate, Floodplain Wetland Aggregate and Billabong Wetland Aggregate	*Breeding sites:* 1 in 5 *Non-breeding sites:* as per EVCs; 1 in 2 for 993 & 998	*Breeding sites:* 5 months *Non-breeding sites:* as per EVCs 6-12 m for 993 & 998	Habitat/Location: All post-1960 breeding records in VFD and literature selected and mapped. Non-breeding records are sites with two or more post-1970 records. Importance: Very high - the study area nesting sites are the only ones in Victoria and the species is critically endangered.
Nankeen Night-Heron *Nycticorax caledonicus* (n)	Breeding sites only: all DSE wetland polygons and other points with breeding records and the surrounding 2 km (for both).	1 in 5	5 months	Non-breeding records are too numerous, widely dispersed and of insufficient habitat specificity to warrant or allow singling out.
Australian Little Bittern *Ixobrychus dubius* (e, L)	All areas of Tall Marsh and mosaics or complexes containing it upstream of Guttram forest inclusive, and all areas of Intermittent Swampy Woodland within 2 km of the records at Hattah Lakes.	as per EVC	as per EVC	Habitat/Location: Tall Marsh EVC (i.e. '*Typha* swamps') is the primary habitat in region based of expert knowledge and records. Intermittent Swampy Woodland is only conceivable habitat at Hattah Lakes. Note that some records (e.g. on Gunbower Creek about 1 km NNW of Cohuna) have little if any of this habitat and recent record in Deniliquin where much of the *Typha* was under a River Red Gum canopy. Note that there are a few recent precise records (e.g. N of Moyhu on the King River) not close to any Tall Marsh – given the tendency of this species to sometimes inhabit artificial wetlands (often highly so, and often small), such sites are probably best discounted. Somewhat countering this, there are fairly large areas of Tall Marsh mapped for this species where there are no recent precise records (e.g., between Barmah forest and Moyhu, Wodonga and Murchison) – but old, imprecise and nearby (outside study area) records indicate that they are likely to occur in at least parts of these areas. Importance: Although endangered in Victoria, the study area only contributes about 25% of the Victorian population and the species is widespread albeit uncommon, scattered and declining elsewhere in Australia.

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Australasian Bittern *Botaurus poiciloptilus* (L)	All areas of Tall Marsh and mosaics or complexes containing it upstream of Swan Hill, and Intermittent Swampy Woodland at Lake Yerang (Hattah-Kulkyne NP).	as per EVC	as per EVC	Habitat/Location: Tall Marsh EVC (i.e. '*Typha* swamps') is the primary habitat in region based of expert knowledge and records. Intermittent Swampy Woodland is only conceivable habitat at Hattah Lakes. Note that some records have little if any of this habitat – perhaps best discounted given this species' tendency to sometimes inhabit artificial habitats such as rice fields and densely vegetated margins of channels. Importance: Although endangered in Victoria, the study area only contributes about 25% of the Victorian population and the species is reasonably widespread albeit uncommon and declining elsewhere in Australia.
Glossy Ibis *Plegadis falcinellus* (n)	1. Lake Walla Walla and Hattah Lakes: all areas of Lake Bed Herbland. 2. Gunbower Forest: all areas of Spike-sedge Wetland and Floodway Pond Herbland/Riverine Swamp Forest Complex. 3. Loch Garry: all areas of Billabong Wetland Aggregate and Rushy Riverine Swamp. 4. Reedy Swamp: all areas of Tall Marsh/Open Water Mosaic. 5. Barmah Forest: all areas of Floodplain Grassy Wetland, Aquatic Herbland/Tall Marsh Mosaic, Floodplain Grassy Wetland/Riverine Swamp Forest Mosaic , Aquatic Herbland/Floodplain Grassy Wetland Mosaic, and Aquatic Herbland. 6. Ovens River downstream of the existing Regional Park/State Forest boundary: all areas of Water Body – natural or man made, Floodplain Wetland Aggregate, and Floodplain Riparian Woodland/Riverine Swamp Forest Mosaic. 7. Ryans Lagoon (E of Wodonga): all areas of Drainage Line Aggregate, Floodplain Wetland Aggregate and Billabong Wetland Aggregate.	as per EVCs	as per EVCs	Habitat/Location: No breeding records in the study area (but several in the Kerang Lakes and Marchant and Higgins (1990)). Use of non-breeding areas based on there being only 63 records in the River Red Gum Forests Investigation area (mostly in the Kerang Lakes). Importance: This species is only near threatened in Victoria
Royal Spoonbill *Platalea regia* (v)	*Breeding sites:* All DSE wetland polygons and other points with breeding records and the surrounding 2 km (for both). *Non-breeding sites:* 1. Lake Walla Walla and Hattah Lakes: all areas of Lake Bed Herbland. 2. Gunbower Forest: all areas of Spike-sedge Wetland and Floodway Pond Herbland/Riverine Swamp Forest Complex. 3. Loch Garry: all areas of Billabong Wetland Aggregate and Rushy Riverine Swamp. 4. Reedy Swamp: all areas of Tall Marsh/Open Water Mosaic. 5. Barmah Forest: all areas of Floodplain Grassy Wetland, Aquatic Herbland/Tall Marsh Mosaic, Floodplain Grassy Wetland/Riverine Swamp Forest Mosaic , Aquatic Herbland/Floodplain Grassy Wetland Mosaic, and Aquatic Herbland. 6. Ovens River downstream of the existing Regional Park/State Forest boundary: all areas of Water Body – natural or man made, Floodplain Wetland Aggregate, and Floodplain Riparian Woodland/Riverine Swamp Forest Mosaic. 7. Ryans Lagoon (E of Wodonga): all areas of Drainage Line Aggregate, Floodplain Wetland Aggregate and Billabong Wetland Aggregate.	*Breeding sites:* 1 in 5 *Non-breeding sites:* as per EVCs	*Breeding sites:* 5 months *Non-breeding sites:* as per EVCs	Habitat/Location: All post-1960 breeding records in VFD and literature selected and mapped. Non-breeding records are sites with three or more post-1970 records. Importance: High - the study area nesting sites are the largest in Victoria (there are few in Victoria outside the study area) and the species is vulnerable.

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
White-bellied Sea-Eagle *Haliaeetus leucogaster* (v, L)	1. Lake Walla Walla, Hattah-Kulkyne National Park and Lakes Powell and Carpul: all areas of Lake Bed Herbland. 2. Kings Billabong: polygons of Bare Rock/Ground, and Lignum Swamp, Lignum Shrubland and Floodway Pond Herbland. 3. Baillieu Lagoon: all areas of Spike-sedge Wetland. 4. Loch Garry: all areas of Billabong Wetland Aggregate. 5. Reedy Swamp: all areas of Tall Marsh/Open Water Mosaic 6. Barmah Lake: all areas of Water Body – natural or man made. 7. Ovens River downstream of the Murray Valley Highway: all areas of Water Body – natural or man made, Floodplain Wetland Aggregate, Floodplain Riparian Woodland/Riverine Swamp Forest Mosaic and Riverine Swampy Woodland. 8. Lake Moodemere: Water Body – natural or man made, Floodplain Wetland Aggregate, Tall Marsh/Aquatic Herbland Mosaic and Drainage Line Complex.	as per EVCs; 1 in 2 for 993 & 998	as per EVCs 6-12 m for 993 & 998	Habitat/Location: Sites with two or more post-1970 records. Importance: Moderate - the study area supports almost the entire inland population of this vulnerable species.
Red-chested Button-quail *Turnix pyrrhothorax* (v, L)	Riverine Swamp Forest around Gunbower and Guttrum forest records. Intermittent Swampy Woodland around Lindsay Island record, while White Cliffs record in drainage line not mapped as a distinct EVC.	as per EVC	as per EVC	Habitat/Location: Conole and Mac Nally (2001) state that records of this species in Gunbower forest are in "areas of bare ground and abundant leaf litter, little or no understorey and patches of tussock grass or sedges". The records in Gunbower equate to Riverine Swamp Forest EVC. Importance: Considered vulnerable and listed on the FFG, it is suggested that these species may be more numerous in riverine forests than first thought (Conole and Mac Nally 2001).
Brolga *Grus rubicunda* (v, L)	All polygons of Floodplain Grassy Wetland and mosaics or complexes containing it in Barmah forest.	as per EVC	as per EVC	Habitat/Location: Expert opinion of former habitat and occurrence; note there are many VFD and Birdata records close to the study area, but few id any actually within it. Importance: although vulnerable in Victoria, there are now no regular sites in the study area; Victorian stronghold is shallow wetlands on the central northern plains immediately south of the study area and in south-west Victoria, and is numerous in at least parts of its extensive distribution outside study area in Australia. A distinctive feature of the approach for this species is the objective is entirely recovery, as opposed to (at least partly) maintaining existing populations. This recovery will require habitat to be reinstated, which has not been explicitly addressed in specifying areas and flood frequency and duration here – further work is required to properly specify requirements for recovery.
Baillon's Crake *Porzana pusilla* (v, L)	Areas of wetland EVCs at Baillieu Lagoon where there are known records not in VFD and around VFD records at Kings Billabong,	as per EVC	as per EVC	Habitat/Location: based on VFD records at Kings Billabong and unpublished records at Baillieu Lagoon. Importance: Despite being vulnerable in Victoria, there are few records in the study area and much of the Victorian range is to the south.
Latham's Snipe *Gallinago hardwickii* (n)	Wetland EVCs around VFD records and a polygon of Riverine Chenopod Woodland south of Beveridge Island	as per EVC	as per EVC	Habitat/Location: This species prefers open, shallow wetlands and grasslands. Records based on those in VFD and Birdata. Importance: few records in the study area and much of the Victorian range is to the south. Considered near threatened in Victoria
Australian Painted Snipe *Rostratula australis* (V, ce, L)	Wetlands around Lake Hattah and at Lake Yerang	as per EVC	as per EVC	Habitat/Location: Inhabits shallow, vegetated, temporary or infrequently filled wetlands, sometimes where there are trees such as River Red Gum or shrubs such as lignum or samphire. Poorly known species due to its secretive nature. Records from VFD and Birdata and experts. Possibly more regularly occurs than records suggest, particularly due to their known occurrence in parts of the Kerang Lakes. Importance: few records in the study area, with more in Kerang Lakes area to the south. Listed as nationally vulnerable, considered critically endangered in Victoria (and listed on the FFG Act).

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Bush Stone-curlew *Burhinus grallarius* (e, L)	Nearest Riverine Chenopod Woodland areas at Lindsay Island, Wallpolla Island, Hattah-Kulkyne National Park and Kanyapella Basin.	as per EVC	as per EVC	Habitat/Location: EVC from expert opinion understanding of habitat and occurrence, namely Riverine Chenopod Woodland EVC. In the southern section of study area found within Plains Woodland vegetation adjoining floodplain (e.g. Wyuna) which is not flood-dependent with the exception of Kanyapella Basin. In NW (Hattah, Wallpolla Is, Lindsay Is) – records from floodplain vegetation. Importance: Although considered endangered in Victoria and listed on the FFG, floodplain vegetation does not represent suitable habitat for most of the species range in Victoria. However, it does represent important habitat in NW Victoria and into SA along the Murray (see also Gates and Paton 2005).
Gull-billed Tern *Gelochelidon nilotica* (e, L)	1. Lake Bed Herbland at Lake Mournpall (north of Lake Hattah) and Lakes Hawthorn and Ranfurley (between Mildura and Merbein). 2. The Riverine Chenopod Woodland polygon at Lake Cullulerainе – which is actually open water.	as per EVCs; 1 in 2 for Lake Cullulerainе	as per EVCs 6-12 m for Lake Cullulerainе	Habitat/Location: There are potential difficulties identifying areas for this species given the birds' propensity to forage/transit over just about any open habitat, wet or dry (Higgins and Davies 1996). However there are only 11 records in the study area (none breeding) – in the open-water polygons identified here and at three sites along the River Murray for which no areas are identified here (the records are old, imprecise, may relate to bird in transit, the river is outside the study area and/or the upshot for this species would be just to have water in the river): just upstream of Lock 7 (2 records), Red Cliffs (1) and near Barham (3). Importance: Although endangered in Victoria, the study area only contributes about 10% of the Victorian population. More pertinently, perhaps, the main reason for its conservation status is presumably that it is a restricted colonial breeder and there are no breeding records in the study area. Extensive distribution and at least reasonably common outside study area in Victoria, Australia and the world
Caspian Tern *Hydroprogne caspia* (n, L)	1. Lake Bed Herbland at Lake Walla Walla Lake Mournpall (north of Lake Hattah) and Lakes Hawthorn and Ranfurley (between Mildura and Merbein). 2. Bare Rock/Ground as per annotated map at Kings Billabong.	as per EVCs; 1 in 2 for 993	as per EVCs 6-12 m for 993	Habitat/Location: Only sites with four or more records (except Mildura sewage farm – records at Chaffeys Bend generally are taken as from the sewage farm or river – little if any other suitable habitat appears to exist in this area; note that there is a breeding record just outside the study area at Koorlong, south of Mildura Airport). Open water 'EVCs' reflect habitat descriptions of Higgins and Davies (1996) and Emison et al. (1987). Importance: Only near threatened and presumably so because it is a restricted (semi-colonial) breeder and there are no breeding records in the study area. The study area only contributes about 20% of the Victorian population – the species has an extensive distribution and is at least reasonably common outside study area in Victoria, Australia and the world.
Whiskered Tern *Chlidonias hybrida* (n)	The main areas(s) of Floodplain Grassy Wetland at Steamer Plain (Barmah Forest).	as per EVCs	as per EVCs	Habitat/Location: There are only three breeding records, all in Barmah Forest (1964, 1968, 1979 – the last of which is the basis of the areas(s) delineated and is the same site as the 1964 record). Non-breeding records are too numerous, widely dispersed and of insufficient habitat specificity to warrant or allow singling out.
Diamond Dove *Geopelia cuneata* (n, L)	Riverine Chenopod Woodland or Riverine Grassy Woodland (and or complexes/mosaics) around records	as per EVCs	as per EVCs	Habitat/Location: Emison et al. (1987) state that Diamond Doves occur in River Red Gum forests and woodlands in the mid and upper Murray Valley. In NSW they are also observed in Sandhill and Callitris dominated areas but this does not necessarily equate with EVCs from Victorian records. VFD records and Birdata records are mostly around areas of Riverine Chenopod Woodland or Riverine Grassy Woodland EVCs Importance: Reasonable proportion of Victorian distribution is within study area. FFG listed and Near Threatened
Superb Parrot *Polytelis swainsonii* (V, e, L)	Breeding sites from detailed maps prepared by experts (details confidential)	1 in 3 yrs	1 month	Habitat/Location: Breeding sites in Barmah Forest well mapped as part of recovery actions for this species. Water requirements of nest sites based on discussions with botanists and Rick Webster. Importance: High because study area contains all current Victorian breeding sites (which are flood-dependent) of this species which is endangered in the state.

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Regent Parrot *Polytelis anthopeplus monarchoides* (V, v, L)	Breeding sites from detailed maps prepared by experts (details confidential)	1 in 5-7 yrs	1 month	Habitat/Location: Breeding sites mapped by Rick Webster based on site visits. Water requirements of nest sites follow discussions with botanists and Rick Webster. Breeding birds regularly fly along treed floodplain between breeding sites and feeding and non-breeding areas it may be possible to map these with further investigation but not done here. Importance: High because study area contains most current Victorian breeding sites (which are flood-dependent) of this vulnerable subspecies.
Black-chinned Honeyeater *Melithreptus gularis* (n)	All areas of Riverine Swamp Forest and mosaics or complexes around VFD and Birdata records upstream of Gunbower forest inclusive.	as per EVCs	as per EVCs	Habitat/Location: EVCs from expert opinion understanding of habitat and occurrence; all records downstream of Gunbower forest are old, imprecise and/or outside study area, except one at Hattah Lakes (which is oldish and somewhat imprecise) and too remote to extend the distribution this far. Importance: 'only' near threatened; extensive distribution outside study area in Victoria and Australia – stronghold is drier woodlands, notably Box-Ironbark
Painted Honeyeater *Grantiella picta* (v, L)	All areas of Riverine Chenopod Woodland and Riverine Grassy Woodland and mosaics or complexes containing one or more of these within 5 km of all selected record sites.	as per EVCs	as per EVCs	Habitat/Location: EVCs from expert opinion understanding of habitat and occurrence; note Birdata record near Wodonga. Importance: although vulnerable in Victoria, there are few if any regular sites in the study area, Victorian stronghold is drier woodlands (notably Box-Ironbark) and is numerous in at least parts of its extensive distribution outside study area in Australia
Hooded Robin *Melanodryas cucullata* (n, L)	All areas of Riverine Chenopod Woodland and Riverine Grassy Woodland and mosaics or complexes containing one or more of these. Include all Riverine Chenopod Woodland in northern lobe of Kings Billabong. The Lindsay Island record is within Semi-arid Chenopod Woodland, the record in northern Hattah is Riverine Grassy Forest and the area south of Gadsen Bend is Lignum Swampy Woodland.	as per EVCs	as per EVCs	Habitat/Location: EVCs from Chris Tzaros, Paul Peake & Rick Webster understanding of habitat and occurrence. Chris Tzaros notes sandy rises, Black Box and Red Gum that's less likely to be flooded are the main habitats in the study area. Requires fallen timber and no reeds or sedges. Importance: although near threatened in Victoria, and listed on the FFG, the study area represents only a small proportion of the state's population
Grey-crowned Babbler *Pomatostomus temporalis* (e, L)	All areas of the following EVCs where they intersect with records: 1) For the Nyah-Vinifera area, the following EVCs are relevant: Grassy Riverine Forest, Sedgy Riverine Forest/Riverine Swamp Forest Complex, Sedgy Riverine Forest, Riverine Swamp Forest. 2) In the stretch between Tocumwal to Echuca, key EVCs are Grassy Riverine Forest, Riverine Grassy Woodland and Riverine Swamp Forest. 3) For the Gunbower area: Riverine Grassy Woodland, Riverine Swamp Forest and Grassy Riverine Forest are relevant – see individual maps. 4) At Lake Carpul: Lignum Swamp Woodland	as per EVCs	as per EVCs	Habitat/Location: EVCs expert opinion understanding of habitat and occurrence and informed by VFD and Birdata records. Occurs mostly on edges of floodplain country, often in Black Box. More common on the Loddon floodplain. Importance: considered endangered in Victoria, and listed on the FFG, the study area represents only a small proportion of the state's population
Apostlebird *Struthidea cinerea* (L)	All areas of Riverine Chenopod Woodland and Riverine Grassy Woodland and mosaics or complexes containing one or more of these downstream of Narrung SF inclusive.	as per EVCs	as per EVCs	Habitat/Location: EVCs chosen based on expert opinion of habitat and occurrence; Narrung SF chosen to encompass Jan78 record in VFD (Rick Webster has recorded them between Yungera and Boundary Bend in recent years – not in VFD) – all records upstream of here are old, imprecise and/or outside study area, except one (or two?) from just SE of Koondrook 24/12/99 which not mapped here (surely if there was a group resident there it would be well-known); Emison et al. (1987): 'Black Box woodlands along the floodplain'. Importance: although much of this species' Victorian distribution is within the study area (but note that the population in NE Vic is in Yellow and Grey Box, Buloke and White Cypress-Pine EVCs outside the study area, and they also occur in Cypress-Pine and Belah adjacent to the areas where they do occur in the study area in NW Vic) it is 'only' FFG-listed (not on the Advisory List) and abundant in southern New South Wales. Note, though, that it has declined significantly in Victoria (and South Australia) but also earlier in the 20th century has expanded significantly in some areas (NSW mostly: Higgins et al. 2006).

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Diamond Firetail *Stagonopleura guttata* (v, L)	All areas of Riverine Chenopod Woodland, Riverine Grassy Woodland and Riverine Grassy Forest and mosaics or complexes containing one or more of these. For Macreadie Island also include Lignum Swampy Woodland.	as per EVCs	as per EVCs	Habitat/Location: EVC determinations from Rick Webster, Paul Peake, James Fitzsimons, Mark Antos. Distribution based on VFD records but include also Birdata records where not in VFD. A fauna survey at Macreadie Island and Burra Forest found a total of 11 birds at six of the survey sites which included the EVCs Grassy Riverine Forest, Lignum Swampy Woodland, Riverine Chenopod Woodland, Riverine Grassy Woodland (Lumsden *et al*. 2007). Note will also occur in Plains Woodland (e.g. Gunbower but this isn't flood-dependent. Also recorded in Black Box woodland with lignum understorey near Swan Hill. Importance: Reasonably widespread. Not threatened nationally but FFG listed in Victoria and vulnerable in both Vic and NSW. The study area would probably supports <20% of statewide population.
Giles' Planigale *Planigale gilesi* (n, L)	All areas of Lignum Swampy Woodland and Riverine Chenopod Woodland and mosaics or complexes containing one or more of these.	as per EVCs	as per EVCs	Habitat/Location: EVCs based on FFG Action Statement which states: "Within Victoria, it has been recorded only on alluvial floodplains with grey cracking soils, in or near Black Box (*Eucalyptus largiflorens*) woodlands with a patchy, but dense, understorey of Tangled Lignum (*Muehlenbeckia cunninghamii*), Nitre Goosefoot (*Chenopodium nitrariaceum*) or Old-man Saltbush (*Atriplex nummularia*)" (Bennett and Lumsden 1994). This equates to Lignum Swampy Woodland and Riverine Chenopod Woodland. Records from the VFD that insect with these EVCs and the two records from Woolley (2004) that intersect with these EVCs are the polygons. Importance: Only relatively recently discovered Victoria (Lumsden et al. 1988) and entirely restricted to the study area. Considered near threatened in Victoria and listed on the *FFG Act 1988*.
Squirrel Glider *Petaurus norfolcensis* (e, L)	All polygons of Floodplain Riparian Woodland and mosaics or complexes containing it upstream (including along tributaries to end of study area) of Brereton Rd in Gunbower forest.	as per EVCs	as per EVCs	Habitat/Location: EVC from Rick Webster's clear and Paul Peake's understanding of habitat and occurrence (reasonable-sized healthy stands of *Acacia dealbata* being the key requirement); distribution based on VFD records (note that records don't quite extend all the way to the upstream extremes of the study area on the Ovens, King and Kiewa but go close enough); Rick Webster has records close to the Murray in NSW about 10 km downstream of Echuca; Brereton Rd is just the first decent boundary heading downstream from the most downstream record. Importance: reasonably widespread and not threatened nationally, but endangered in Victoria where the study area probably supports about 20% of the population – would be highly important if proportion of Victorian population is higher.
Southern Myotis *Myotis macropus* (n)	Floodplain Riparian Woodland along the Ovens and Goulburn Rivers that are within 1 km of record plus Lagoon Wetland and Floodplain Wetland Complex that are within 1 km of records. For Barmah, Include 'Water Bodies' EVC downstream of Barmah Bridge along the Murray for 1km and all water bodies EVC along Murray upstream of Barmah Bridge to Barmah Lake and include Water Body of Barmah Lake.	as per EVC	as per EVC	Habitat/Location: EVC derived from associations with requirement for water (i.e. EVCs surrounding a watercourse or billabong) with advice from experts. Barmah EVCs determined from findings of Law and Anderson (1999) of records of the species on the Murray at Barmah Bridge, Moira Lake and an unpublished record between these sites. Barmah Lake included as they were recorded on Moira Lake Law and Anderson's (1999) comment re detectability over large waterbodies (which may possibly explain lack records from Loyn et al. 2003). Importance: limited range in northern Victoria and southern NSW
Broad-shelled Turtle *Macrochelodina expansa* (e, L)	Watercourse and billabong EVCs around records.	as per EVC	as per EVC	Habitat/Location: Requires open water be it part of a river channel or billabong. Importance: although considered endangered in Victoria and listed on the FFG, it is likely to occur along the entire stretch of the Murray and associated creeks and billabongs. Flooding would provide further habitat in currently dry billabongs (e.g. Meathrel et al. 2002, 2004)
Murray River Turtle *Emydura macquarii* (d, L)	Watercourse and billabong EVCs around records.	as per EVC	as per EVC	Habitat/Location: Requires open water be it part of a river channel or billabong. Importance: Considered depleted in Victoria and listed on the FFG, it is likely to occur along the entire stretch of the Murray and associated creeks and billabongs. Flooding would provide further habitat in currently dry billabongs (e.g. Meathrel *et al*. 2002, 2004)

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Eastern Bearded Dragon *Pogona barbatus* (d)	Riverine Chenopod Woodland and Riverine Grassy Woodland around records.	as per EVC	as per EVC	Habitat/Location; Expert opinion suggests this species is a woodland generalist. The riverine forests constitute a relatively small proportion of its habitat in Victoria but maintaining the health of these forests and woodlands is considered important for the species. EVC are Riverine Grassy Woodland and Riverine Chenopod Woodlands (based on site records and advice from experts). Records from VFD plus Lumsden et al. (2007). The record of this species in Neds Corner (Malone 2005) is most likely erroneous and should be Central Bearded Dragon. Importance: considered data deficient in Victoria and limited range in study area.
Tree Goanna *Varanus varius* (v)	Lindsay and Wallpolla Islands – all creeklines with Intermittent Swampy Woodland. In Gunbower, all records of Riverine Chenopod Woodland. In Hattah all areas of the following EVCs around the groups circled on the maps: Riverine Chenopod Woodland, Intermittent Swampy Woodland, Lignum Swampy Woodland and Riverine Grassy Woodland. At other localities Shrubby Riverine Forest or Intermittent Swampy Woodland (around Mildura) or Grassy Riverine Forest (Macreadie Island) areas at records should be selected	as per EVC	as per EVC	Habitat/Location: Around Gunbower, records seem to be restricted to Black Box country (i.e Riverine Chenopod Woodland). Around Hattah it's not as clear cut and their distribution seems to intersect with Riverine Chenopod Woodland, Intermittent Swampy Woodland, Lignum Swampy Woodland and possibly Riverine Grassy Woodland. Intermittent Swampy Woodland occurs on the creeks connecting the River with the lakes and around the lakes themselves. At Wallpolla and Lindsay Islands most records appear to be associated with the creeks which are Intermittent Swampy Woodland. Records to the east of Gunbower in the study area are mostly associated with Plains Woodland (i.e. Grey Box). Records from VFD plus Lumsden et al. (2007). Importance: Although vulnerable in Victoria, has a relatively wide range and is more common in other parts of the state.
Eastern Water Skink *Eulamprus quoyii* (n)	Creekline and/or billabong vegetation around records	as per EVC	as per EVC	Habitat/Location: Associated with freestanding water, including the Murray River. Importance: Near threatened in Victoria but locally abundant in the northwest. VFD records plus records from Malone (2004). This part of Victoria is at the southern tip of its Australian distribution.
Beaked Gecko *Rhynchoedura ornata* (ce, L)	Riverine Chenopod Woodland around records	as per EVC	as per EVC	Habitat/Location Advice from Peter Robertson: Few records including in Belah woodland and lowland hopbush country. Brown (2002) states Belah and riverine woodland as broad habitat. Recently trapped in floodplain woodland (Riverine Chenopod Woodland EVC) at Neds Corner (Malone 2004) and past site records in VFD from Wallpolla Island indicates the same EVC Importance: critically endangered in Victoria but more records in non-floodplain
Inland Carpet Python *Morelia spilota metcalfei* (e, L)	EVCs along watercourses where there are records for Lindsay and Wallpolla Islands (including Riverine EVCs in places where records adjoin Murray). Suitable EVCs along river between Merbein and Mildura. Suitable EVCs along river around Kings Billabong. All Red Gum and Black Box dominated EVCs in the Hattah-Kulkyne NP and Murray Kulkyne Park in the study area. All Red Gum and Black Box EVCs in the Gadsen Bend forests All riverine vegetation between Belsar Island and Nyah-Vinifera forest (inclusive). Vegetation along Murray 1km upstream and downstream of record north of Winlaton. Red Gum and Black Box habitats in zone of Gunbower forest near Gannawarra, Red Gum and Black Box habitats in zone of Barmah Island and record SE of Barmah Island and record SE of Barmah Lake.	as per EVC	as per EVC	Habitat/Location: Site records from VFD. Habitat preferences from Peter Robertson. More common in Red Gum than in Black Box but when in Black Box usually with lignum understorey. Tree cover is important and habitat is enhanced with water nearby Requires hollows and coarse woody debris (Allen et al. 2003, Robertson 2007). Robertson and Hurley (2001) highlight areas of high to low habitat potential for the species in the floodplain forests of northwestern Victoria. Importance: Riverine habitat is particularly important for this taxon in Victoria and Victoria is important in the national distribution of the taxon. Considered endangered and listed on the *FFG Act 1988*.
De Vis' Banded Snake *Denisonia devisi* (v)	Lake Bed Herbland, Floodway Pond Herbland, Shallow Freshwater Marsh, Intermittent Swampy Woodland at site records	as per EVCs	as per EVCs	Habitat/Location: Site records from DSE (see also Clemann et al. 2007) and advice on EVCs from expert opinion. Watercourse-reliant as frogs are the main diet. Importance: Recently discovered and nearest known site locality is some 500 km away at Broken Hill in NSW. Vulnerable on the Vic Advisory list and range restricted

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Red-naped Snake *Furina diadema* (v, L)	Nearest Intermittent Swampy Woodland or Shrubby Riverine Woodland to records except Wallpolla Creek where it is Lignum Swampy Woodland	as per EVCs	as per EVCs	Habitat/Location: Site records from VFD with advice from Peter Robertson as to habitat preference. Peter Robertson suggests the species occurs in lower lying habitats on Lindsay and Wallpolla Islands. Not in chenopod shrublands and more in Red Gum than Black Box. Importance: Restricted range of northwest Victoria where there are a few records, including recent records from Neds Corner (Crouch 2006), vulnerable and FFG listed
Giant Bullfrog *Limnodynastes interioris* (ce, L)	Floodplain Riparian Woodland around record at Ovens, and Riverine Grassy Woodland around record at Gunbower	as per EVCs	as per EVCs	Habitat/Location: EVC determination based on site localities and descriptions of habitat by Conole and Mac Nally (2000). Importance: Very few records in Victoria, where the Red Gum forests of the Murray are extent of its habitat. Very rare in NSW Murray Floodplain Forests also (NSW Atlas records, Webster et al. 2003)
Brown Toadlet *Pseudophryne bibronii* (e, L)	Barmah record: add to Drainage Line Complex and Dugays Bridge record add to nearest Lagoon Wetland polygon.	as per EVCs	as per EVCs	Habitat/Location: EVC determination based on discussions with experts – margins of wetlands. A flood could assist in the movement of tadpoles but heavy rain could also facilitate this. Records near Koondrook are too old or imprecise to include at this locality, but the species most likely occurs in Gunbower Forest (Horrocks et al. 1989) Importance: Study area represents only a small part of the Victorian population, although the species is considered endangered in Victoria and listed on the FFG
Growling Grass Frog *Litoria raniformis* (V, e, L)	Various creekline or wetland EVCs where recent (i.e. post 1980) records occur	as per EVCs	as per EVCs	Habitat/Location: Expert opinion suggests the floodplain Growling Grass Frogs need to be close to some permanent water but can also utilise temporary wetlands (e.g. Ramamurthy 2007). Previously distributed along the floodplains of the Murray, most recent records are from the NW of the state. A similar pattern is evident in NSW (DEC 2005). Wetlands with *Typha* or *Phragmites* or macrophytes are preferred. Records from VFD and Ramamurthy (2007). Importance: Nationally vulnerable and endangered in Victoria, it has contracted in range dramatically since the 1980s, thus an important population
Species considered but not assigned watering requirements or mapped				
Square-tailed Kite *Lophoictinia isura* (v, L)	-	-	-	Too few records and fewer breeding records. Habitat/Location: Debus and Silveira (1989) suggests that this species tends to be faithful to an area and is known to use traditional nest sites and that all Victorian nest sites and surrounding foraging areas should be protected from disturbance. Debus and Silveira (1989) may a rough calculation of one pair per 1200 km^2 of habitat. A small number of records in the study area concentrated mainly in the NW around Hattah-Kulkyne National Park. Considering the records from the far southwest of NSW are post 1980 (NPWS 1999), the records for far northwest Victoria are likely to still be viable despite being pre 1980. Polygons could be mapped to include the following options 1) draw a polygon around clusters of records where there are known breeding sites (including across the border) plus apply a 1000 ha buffer around other point localities (although if it's a circle this will only pick up a relatively small amount of true habitat if on some of the narrow stretched or 2) apply a 2000 ha buffer around all points (including NSW) due to the lack of detailed. However, the lack of records (despite systematic surveys, e.g. Webster 2004, Webster and Rogers 2006) and the lack of breeding records means allocating a polygon of preferred habitat is difficult. Watering of reasonably substantive areas of forest which results in a increase in the numbers of breeding passerines is likely to favour the Kite.
Grey Falcon *Falco hypoleucos* (e, L)	-	-	-	Flood-dependence unclear and too few records in study area, mostly in the northwest where it is known to have bred near Lake Cullulleraine (Venn 1997)

Name and conservation status	Sites mapped	Minimum flood frequency	Flood duration	Notes
Swift Parrot *Lathamus discolour* (E, e, L)	-	-	-	Pattern of records insufficiently coherent to reliably interpret and relatively few records but habitat is clearly flood-dependent.
Azure Kingfisher *Ceyx azureus* (n)	-	-	-	Clearly dependent on water but contribution of flooding requires confirmation.
Powerful Owl *Ninox strenua* (v, L)	-	-	-	Clearly flood-dependent but no reliable basis could be formulated for delineating sites. Scattered records in floodplain country including one at Yambuna on the Goulburn, 2 NW of Cobram, and approximately 6 records along the between Wangaratta and the junction with the Murray in 1996.
Barking Owl *Ninox connivens* (e, L)	-	-	-	Clearly flood-dependent but no reliable basis could be formulated for delineating sites. Habitat/Location Scattered records along the Murray including Lindsay Island and Mullroo Creek, Pental Island, Gunbower forest. All records east of Echuca are from the early 1980s, although there are recent records from Pericoota and Moira State Forests (part of Barmah-Millewa complex (Parker et al. 2007).
Ground Cuckoo-shrike *Coracina maxima* (v, L)	-	-	-	Habitat/Location: Presence in Victoria is sporadic and Rick Webster advice is that while they occur on the edge of the floodplain in black box country, they do not inhabit Red Gum forests. Due to sporadic records they are not included. Importance: Considered vulnerable in Victoria, and listed on the FFG, there are only a handful of records from Victoria (from Birdata, none in VFD)
Lined Earless Dragon *Tympanocryptis lineata* (e, L)	-	-	-	Too few records in study area
Samphire Skink *Morethia adelaidensis* (e, L)	-	-	-	No records in floodplain areas in the study area. Occurs in some areas of flood-dependent vegetation around Kerang, but no records in Murray floodplain.
Common Death Adder *Acanthophis antarcticus* (d, L)	-	-	-	Habitat/Location Too few (if any) reliable records in study area
Rugose Toadlet *Uperoleia rugosa* (v, L)	-	-	-	Probably dependent on local rainfall than flood events

'study area' = the study area for this project (as opposed to the VEAC River Red Gum Forests investigation study area for instance, although they have identical boundaries in many areas) – the floodplains of the Murray, Goulburn and Ovens Rivers as shown on the maps generated by VEAC.

Unless stated otherwise, where polygons are based on circles of a particular radius around sites of selected records (e.g., marked on maps) the length of the radius is chosen to give a good chance of including the actual site where the animal(s) was and sufficient surrounding habitat to support a population unit (breeding pair, colony, etc.); records are selected if they are reasonably recent (post-1969 for infrequently recorded species or records in clusters not mapped otherwise, post-1979 for others) and precise (generally ± 2 mins (~ 3 km) or less; ± 5 mins (~ 9 km) for records of infrequently recorded species in clusters not mapped otherwise), and with a reasonable chance the record was actually in the study area/habitat.

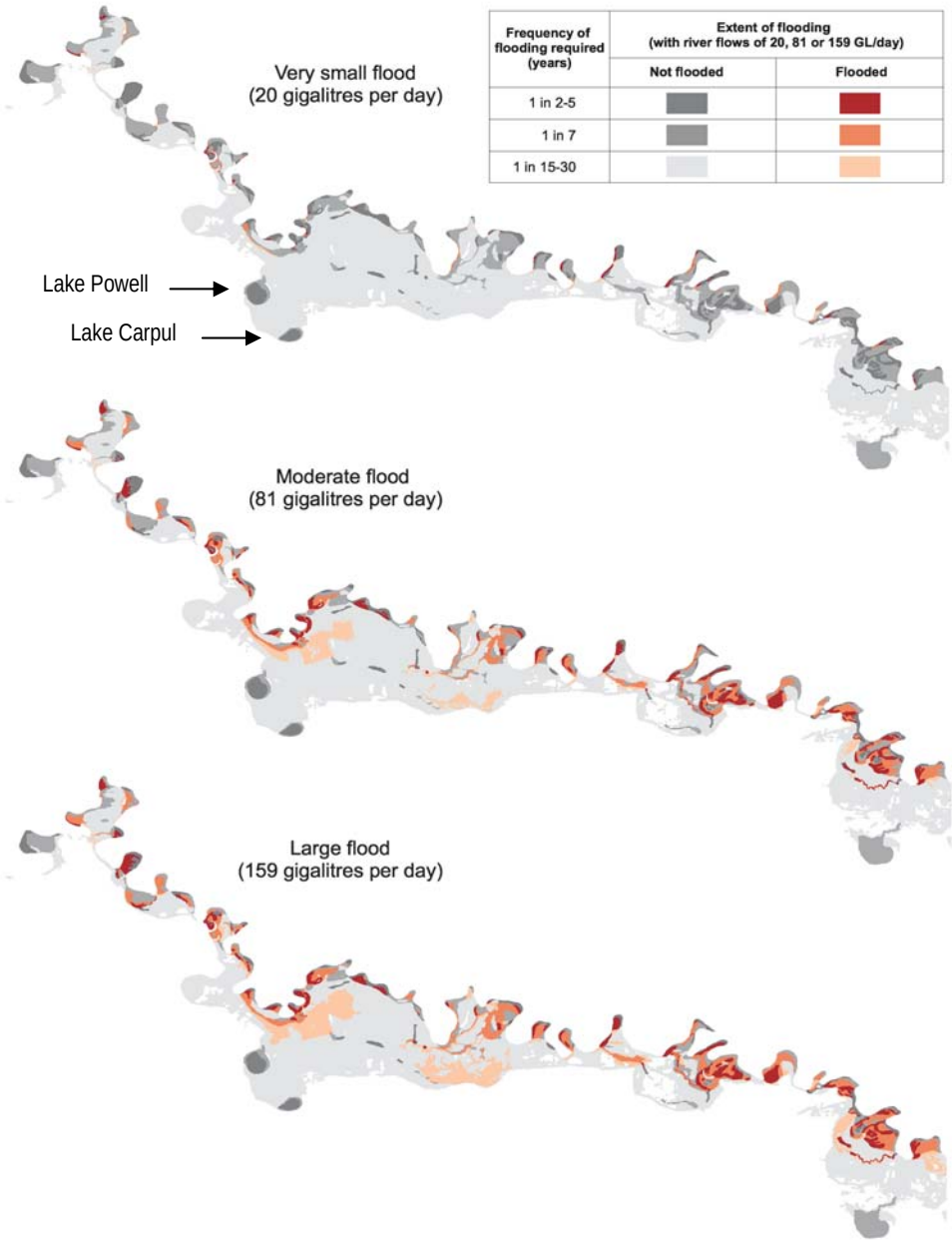

Figure 2. Examples of coverage of flood-dependent natural values for various flood scenarios in the Robinvale area

Notes:

1. The primary purpose of the maps in this figure is to provide an example of how the digital natural asset mapping generated in this project can be applied. It is not intended that they represent actual outcomes of applying these amounts of environmental water. As a result, many important but complicating factors have not been incorporated. These factors include flood duration, timing, the significance of assets including in comparison with priorities in other areas and the difference between the longest possible period without inundation ('critical interval') and average frequency of flooding. These maps and resultant tables are best considered in the context of a period of several years with knowledge of prior flood events in order to prioritise sites most requiring water at any given point in time. While the maps shown above are a combination of the natural values, they can be also be usefully generated for individual EVCs or species.

2. The flooding extents shown in red are based on outputs from the CSIRO River Murray Floodplain Inundation Model (RiM-FIM) which is derived from satellite imagery of actual floods. While the RiM-FIM provides inundation extents for a range of river flows, these are not necessarily derived from actual floods (i.e. the inundation extent for a particular flow may be inferred from satellite images of floods of other sizes) and should be considered as indicative only. In particular, flow in the River Murray of 159 gigalitres per day may flood a greater area than that shown here. For comparison, the typical flow in this part of the River Murray in September is around 9 gigalitres per day. Flood extent data was provided by the Department of Sustainability and Environment.

Table 4. Area and percentage of natural values in the Robinvale area inundated by various environmental water volumes

		Percent of mapped EVC or habitat covered by various flood extents		
	Area (ha)	Very small	Moderate	Large
Ecological Vegetation Class				
Floodplain Grassy Wetland	63	3	71	77
Floodway Pond Herbland	370	1	37	47
Grassy Riverine Forest	678	2	27	35
Grassy Riverine Forest/Floodway Pond Herbland Complex	567	2	22	28
Intermittent Swampy Woodland	1,433	1	27	38
Lake Bed Herbland	130	0	0	0
Lignum Shrubland	3,550	0	5	12
Lignum Swamp	562	0	2	7
Lignum Swampy Woodland	5,488	0	5	11
Riverine Chenopod Woodland	5,035	0	5	8
Riverine Grassy Woodland	980	0	4	9
Shallow Freshwater Marsh	394	0	42	51
Shrubby Riverine Woodland	1,972	1	24	37
Spike-sedge Wetland	17	0	62	71
Sub-saline Depression Shrubland	82	0	0	0
Tall Marsh	42	0	9	21
Threatened Fauna				
Apostlebird	6,746	0	3	7
Blue-billed Duck	434	0	0	0
Brown Quail	35	0	0	0
Inland Carpet Python	16,452	0	12	19
Diamond Dove	168	0	0	0
Diamond Firetail	121	0	2	6
Freckled Duck	2,700	0	2	3
Grey-crowned Babbler	215	0	0	0
Hardhead	592	0	0	0
Musk Duck	592	0	0	0
Nankeen Night-Heron	1,690	0	4	6
White-bellied Sea-Eagle	550	0	0	0
Regent Parrot	321	1	29	49
Rare or Threatened Flora				
Annual Spinach	89	0	2	3
Bluish Raspwort	249	0	13	20
Common Joyweed	259	0	0	0
Cotton Sneezeweed	88	0	42	65
Desert Lantern	84	0	0	3
Desert Spinach	43	0	4	11
Dwarf Bitter-cress	77	0	0	0
Goat Head	559	0	2	4
Hoary Scurf-pea	81	0	10	15
Mealy Saltbush	42	0	0	0
Native Couch	729	1	22	35
Native Peppercress	518	1	9	13
Pale Plover-daisy	41	2	5	7
Pale Spike-sedge	26	0	0	0
Purple Love-grass	182	0	0	0
Reader's Daisy	380	0	2	7
Riverina Bitter-cress	132	1	25	39
Riverine Flax-lily	69	0	0	0
Silver Saltbush	23	8	79	100

		Percent of mapped EVC or habitat covered by various flood extents		
	Area (ha)	Very small	Moderate	Large
Smooth Minuria	38	0	0	0
Spear-fruit Copperburr	432	0	6	13
Spiny Lignum	71	0	0	0
Spotted Emu-bush	236	0	2	3
Spreading Emu-bush	776	2	14	18
Squat Picris	509	2	33	55
Summer Fringe-sedge	381	0	1	5
Sweet Fenugreek	86	0	0	0
Tangled Copperburr	127	0	5	14
Twinleaf Bedstraw	1376	1	5	9
Warty Peppercress	150	0	6	9
Yakka Grass	189	0	1	4
Yarran	367	1	5	7

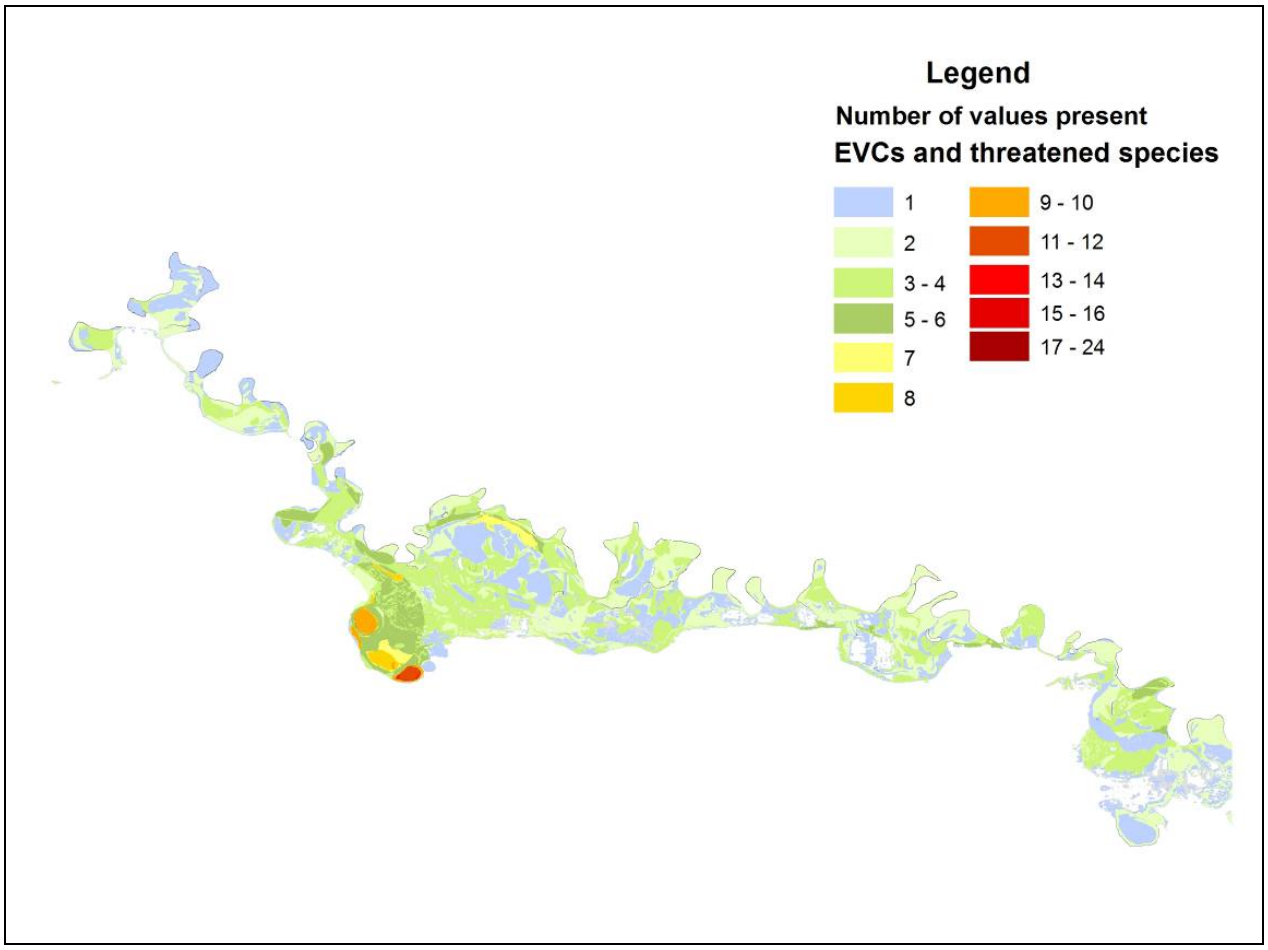

Figure 3. Enlargement of Figure 1 showing compilation of flood-dependent natural values in the Robinvale area