Science guidelines to support water allocation plans – ecology, hydrology and hydrogeology

Part 2: Environmental water requirements and provisions

Department of Environment, Water and Natural Resources

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1 Purpose

Water dependent ecosystems have adapted to the natural conditions to which they have historically been exposed, including flow regime. Changes to the flow regime due to water resource development will have a corresponding implication to the sustainability of these natural systems which needs to be accounted for within a Water Allocation Plan (WAP).

The purpose of *Part 2: Environmental Water Requirements and Provisions* of the Science Guidelines is to support WAP development with respect to accounting for these *environmental* implications when applying different WAP policy options, such as deciding on an appropriate Environmental Water Provision (EWP). Note that social and economic considerations are also required to be accounted for when deriving final EWPs – these considerations are outside the scope of this document.
This document supports accounting for environmental implications through:

- outlining a process to obtain information required to determine environmental water provisions (EWPs) (see Table 1) to address sections 76(4)(a)(i) and 76(4)(aab)(i)(ii)(iii) of the *NRM Act 2004*
- providing guidance on investigations that can be used to inform the process.

The information communicated in *Part 1: Introduction and Context - Science Guidelines to Support WAPs – Ecology, Hydrology and Hydrogeology* should be taken into consideration when using this part of the guidelines, particularly with regard to how it can be used within a risk management framework.

2 Questions to be considered

When determining the environmental water requirements and provisions for water-dependent ecosystems, the *NRM Act 2004* sections 76(4)(a)(i) and 76(4)(aab)(i)(ii)(iii) state:

A water allocation plan must include:

- *An assessment of the quantity and quality of water needed by the ecosystems that depend on the water resource and the times at which, or the periods during which, those ecosystems will need that water; and*
- *An assessment of the capacity of the water resource to meet environmental water requirements; and*
- *Information about the water that is to be set aside for the environment including, insofar as is reasonably practicable, information about the quantity and quality, the time when that water is expected to be made available, and the type and extent of the ecosystems to which it is to be provided; and*
- *A statement of the environmental outcomes expected to be delivered on account of the provision of environmental water under the plan.*

The questions described in Table 1 outlines a process to address these sections of the *NRM Act 2004*. They are consistent with the steps for assessing the 'risks to the resource' in accordance with DEWNR's Risk Management Framework for Water Planning and Management and the Risk Management Policy and Guidelines for Water Allocation Plans (DEWNR 2012a and 2012b respectively).

Prior to progressing the investigations outlined in Table 1, there should be a process to determine the appropriate fit-for-purpose level of investment based on:

1. the risks posed to the environment due to the current and potential levels of water resource development
2. the condition and status of water dependent ecosystems dependent upon the prescribed water resource
3. the scale at which the resource is to be managed.

This should be guided through relevant Policies outlined in documents such as South Australia's Strategic Plan, State NRM Plan, Regional NRM Plans as well as relevant State and Australian Government legislation such as the *National Parks and Wildlife Act 1972* and the *Environment Protection and Biodiversity Conservation Act 1999*. Data availability will also be a factor when considering these guidelines as it will influence the process by which questions can be answered (e.g. data driven vs. expert opinion).

Table 1. A process for addressing environmental water requirements and provisions

No.		Question	Rationale
Context setting			
1	a	*What environmental assets are dependent upon the prescribed resource?* This should include asset type, location and value.	Provides the basic information needed to set the context for risks to ecological values Enables the prioritisation of assets, determination of water requirements and development of a hydro-ecological setting For a newly prescribed area: This information can also be used in the *Minister's report on the needs of ecosystems (*a requirement under Section 164N (4) of the *NRM Act 2004* as a part of the existing user process)
	b	*What are the environmental water requirements (EWRs)?*	Required to assess risk to the environment due to changes in flow regime and ultimately determine EWPs

		This should be stated as the water regime (depth, frequency, duration and timing) required to maintain environmental assets at a low level of risk.	as outlined in the following steps
Risk assessment			
2	a	*What are the key sources of risk to water dependent ecosystems?* *Which are able to be controlled through the WAP process?*	Identifies the sources of risk to ecosystems that can be managed through the implementation of appropriate WAP policy options. Provides a focus for the testing of policy implementation scenarios (discussed under Question 3).
	b	What is the level of risk to the environment from the sources of risk identified in Question 2a? Example: What is the level of risk posed to fish populations due to varying levels of extraction from dams?	Develops a methodology that enables changes in flow regime to be related to changes in ecological condition Identifies the level of risk posed to the environment under existing conditions
	c	*What is the tolerability of risks to the environment given community values, policy guidelines and legislative requirements?*	Identifies boundaries to 'acceptable' levels of risk to the environment Guides subsequent investigation efforts in determining risk treatment options
Potential risk treatment			
3		What policy options provide treatments that manage risks to ecosystems dependent on the prescribed resource?	Tests risk treatment options under possible water allocation policy scenarios Testing of potential risk treatment scenarios will ultimately inform the agreed risk treatment in Question 4
Risk treatment			
4		*What are the agreed risk treatments/policy instruments to be incorporated into the WAP to manage the environmental impacts of water allocation?* *What are the agreed environmental outcomes in light of social and economic considerations?* *What are the environmental water provisions (EWPs)?*	**Please Note:** *Scientific investigations are not undertaken at this step. The methods used to address Questions 1–3 assist in addressing this question.* This step obtains agreement from the community and stakeholders about how the resource will be managed based on trade-offs with socio-economic factors The risk treatment decision is based on the scientific investigations undertaken to address Questions 1–3, together with other risk assessments (e.g. accounting for social and economic impacts) and community input. The decision is taken outside the scope of this document. Existing legislation, policies and plans will guide the scope of negotiation, and provide guidance to the limits of deviation from EWRs (e.g. EPBC Act, South Australia's Strategic Plan, State NRM Plan, and Regional NRM Plans). These need to be transparently stated prior to negotiation of a final position with regard to EWPs.

A key concept in these guidelines is the difference between EWRs and EWPs. EWRs represent the water regime required to maintain water dependent ecosystems at a low level of risk. EWPs represent the water regime provided to ecosystems dependent upon the prescribed resource after the needs of the environment have been balanced against social and economic needs. The embodied level of risk to ecosystems under EWR and EWP conditions is expressed in **Figure 1**.

1. **Environmental Water Requirements** – setting up the basic context that provides information about the requirements of ecosystems dependent upon the prescribed resource and provides a baseline against which impacts can be measured and reported
2. **Environmental Water Provisions** – represents the water that is to be provided to ecosystems dependent upon the prescribed resource after accounting for social and economic needs for water.

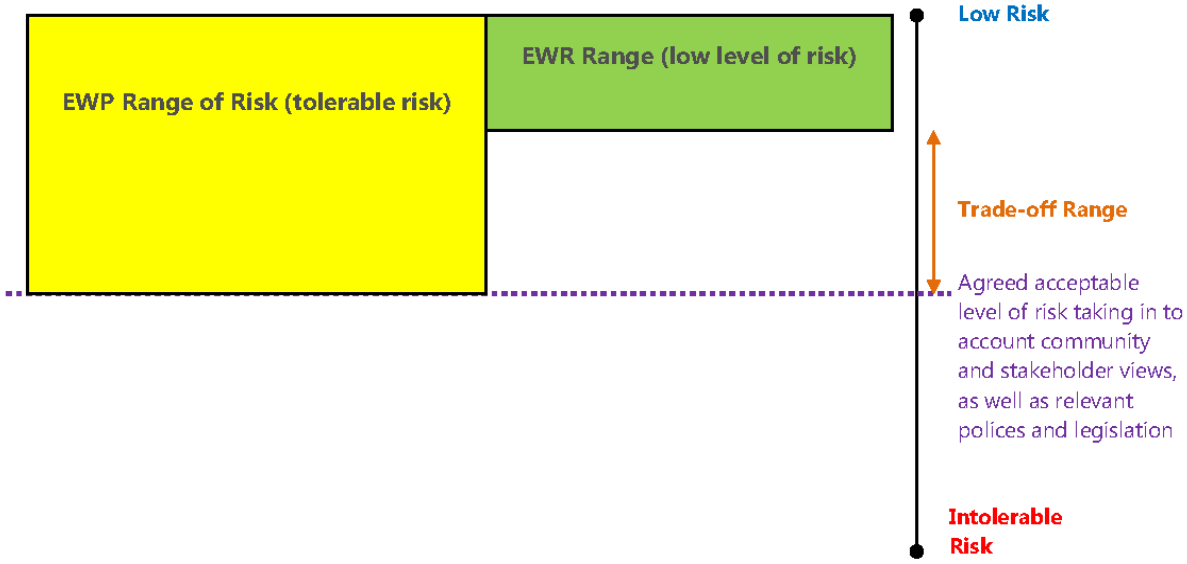

Figure 1. Conceptual diagram of the process undertaken to determine Environmental Water Requirements (EWRs) and Environmental Water Provisions (EWPs) for environmental assets

3 Investigation options

For each of the questions in **Table 1**, there are various approaches and tools that can be used to investigate the answers. This section contains methods and a number of examples that can be used when assessing the water needs of the environment (Sections 76(4)(a)(i) and 76(4)(aab)(i)(ii)(iii) of the *NRM Act 2004*) in the preparation of WAPs.

The investigations discussed in the Science Guidelines are not a definitive list and the use of new and improved methods is encouraged. Ultimately the selection of the appropriate method to be used and the level of detail in these investigations should be determined through a risk assessment process (see *Part 1: Introduction and Context* of the Science Guidelines). An initial risk assessment will help to identify the required effort and resources and identify priorities for application.

3.1 Context setting

Question 1a: What environmental assets are dependent upon the prescribed resource?

Outputs:

- List of biota dependent upon the prescribed resource
- Datasets of monitoring/survey data relevant to these biota
- Map showing location of biota
- Map showing distribution of water habitats (e.g. watercourses, wetlands, lakes, aquifers)
- List of biota/habitat value (community and conservation value)

Outcome:

- Understanding of the environmental assets that may be impacted upon by the application of WAP policy options

Overview of approach

This involves the collation of all existing data and information (including type, location and value) on the environmental assets that are reliant directly or indirectly on the prescribed water resource. This information should not only communicate the type, location and values of environmental assets but also provide evidence that they are likely to be reliant on the prescribed water resource.

The *value* of an environmental asset in this instance is information which can provide insight to a desire or requirement for it to be maintained in any given condition. In most instances this will be either an asset having some level of conservation status at either the regional, state, national or international level, or having some significance to the local community. The value of environmental assets will assist in the assessment of risk tolerability discussed under Question 2c.

Where there is no or little existing information on the presence of environmental assets within the Prescribed Water Resources Area (PWRA) other options should be considered. These may include conducting site surveys, remote surveys (e.g. satellite imagery, aerial photography), community or local expert consultation, or the development of conceptual models indicating where conditions are expected to be sufficient to support different environmental assets.

The use of remote surveys and conceptual modelling can be useful to map the possible distribution of environmental assets in very large PWRAs where there is limited scope to more comprehensively map their presence and location. It needs to be noted that the mapped distribution of assets through the use of remote surveys or conceptual models should be tested using field investigations to ensure their accuracy.

Below are some examples of water-dependent ecosystems that should be considered in this step:

Groundwater dependent ecosystems:

Wetlands and lakes

- Watercourses (including refuge pools)
- Springs and soaks
- Phreatophytic vegetation
- Hyporheic systems (saturated zone of watercourses)
- Hypogean systems (aquifer, karst and caves)
- Estuaries
- Marine discharges (diffuse and springs)

Surface water dependent ecosystems:

- Wetlands and lakes
- Watercourses (including refuge pools)
- Floodplains
- Rockholes
- Estuaries

Due to the availability of existing information the most commonly used biotic groups for assessing EWRs when considering policy implications for WAPs are:

- Fish
- Aquatic macroinvertebrates
- Vegetation

However, other aquatic biotic assets can be considered based on the hydrological and ecological characteristics of the prescribed area.

Literature review and interpretation

A literature review should be conducted as the initial stage of any investigation into determining EWRs and EWPs for Water Allocation Planning.

This involves the collection of existing reports, databases, technical notes and literature to map the known location of ecological assets associated with a prescribed water resource. This approach can be employed for both surface water and groundwater-dependent ecosystems. A significant proportion of surface water dependent ecosystems (e.g. wetlands, rivers) have been mapped for South Australia through a number of previous studies and can be sourced through the Biological Databases of South Australia (BDBSA) and Environmental Geographical Information System (EGIS) accessible through DEWNR. More recently groundwater dependent ecosystems (including terrestrial vegetation) have been mapped for the state in the National Atlas of Groundwater Dependent Ecosystem (http://www.bom.gov.au/water/groundwater/gde/index.shtml), as well as by Harding and O'Connor (2012). Other sources of data include the South Australian Research and Development Institute, particularly for fish and vegetation datasets, and the Environment Protection Authority for aquatic macro-invertebrate and water quality datasets.

Field Investigations

Field investigations are of use in any system to provide current validated data on the presence, distribution and condition of water dependent habitats and biota.

Field investigations will identify assets present at a particular point in time, and can be used to identify the presence, distribution and condition of water dependent biota, or can be used in a targeted way to assist in the validation of remotely

collected data such as those that have been mapped using remote sensing techniques or through the use of conceptual models.

The effort required to produce an appropriate dataset for developing EWRs and EWPs will be dependent upon the scale of management of the prescribed resource. A policy approach that manages the resource at a finer scale with many small management zones will require a higher intensity of investigation to provide data on the presence of assets for each zone than approaches that work on a more regional scale. This is due to the need to account for site-specific variations in the presence of environmental assets dependent upon the prescribed resource within each zone.

Field investigations to identify water dependent biota often involve the use of specialist contractors to sample the biotic groups of interest who can advise on appropriate methodologies based on the site specific conditions of the prescribed resource. The information collected should represent the life-history components of the biotic assets (e.g. fish, macroinvertebrates, vegetation) which are expected to reflect a response to changes in the water regime.

In groundwater systems field investigations focus largely on determining the nature of dependence of biota or habitats upon the prescribed resource (i.e. investigating the groundwater dependence of biota or habitats, and whether this dependence is obligate or facultative, seasonal or perennial). Many of these techniques are outlined in the *Australian groundwater-dependent ecosystems toolbox part 2: assessment tools* (SKM 2011).

A South Australian example of using field techniques to inform water allocation planning in the South East Natural Resources Management Board region is described in *Environmental Water Requirements of Groundwater Dependent Ecosystems in the South East Prescribed Wells Area – Field Studies to Support New and Amended Policy* (Ecological Associates 2006).

Conceptual modelling

Most useful in areas with extensive networks of potential water dependent habitats with little information on the associated water dependent biota, although it can also be applied in smaller systems.

Conceptual modelling enables the mapping of ecosystems and/or biotic assets in areas where on-ground surveys have not been conducted. Mapping the distribution of ecological assets using conceptual modelling has an elevated level of uncertainty which should be tested to ensure that WAP policies are applied appropriately.

A relevant example is the process applied for the Eastern and Western Mount Lofty Ranges PWRAs. The availability of site-specific information on the presence of water dependent assets across these areas was limited due to the extensive watercourse network. In this case conceptual models of aquatic ecosystem distribution validated through pre-existing aerial videographic mapping of water bodies were used to map the likely distribution of aquatic habitats and biotic groups. This is described in *Environmental water requirements for the Mount Lofty Ranges prescribed water resources areas* (van der Wielen and Vanlaarhoven 2009). This information was then mapped across all known watercourses for the Prescribed Areas using ESRI® ArcGIS software and incorporated existing information on the presence of watercourses, wetlands, persistent pools and baseflow from state WDE base layers accessible through DEWNR. Biotic components were then conceptually mapped to the distribution and location of these habitats based on previous survey work and expert opinion.

Remote sensing

Most useful for determining areas of groundwater dependent vegetation, and in surface water systems with large channels or flood out areas.

Remote sensing is a method that uses data obtained via satellite or aircraft monitoring equipment. Spectral analysis (NDVI – Normalised Difference Vegetation Index) was used in GDE mapping for the Eyre Peninsula and reported in the GDE Atlas, and in SKM (2009). This information was later used in the documentation of EWRs as outlined in the *Environmental Water Requirements of Groundwater Dependent Ecosystems in the Musgrave and Southern Basins Prescribed Wells Areas on the Eyre Peninsula* (Doeg *et al*. 2012). In this instance areas of groundwater-dependent vegetation communities were identified based on high summer vegetation vigour readings (i.e. vegetation was determined to be using a water source other than rainfall). This acts as an indicator that plants in an area had access to water during periods when rainfall was unlikely and hence these plants were likely to be accessing groundwater. Groundtruthing of remotely mapped data is recommended to validate results. Techniques for groundtruthing groundwater dependence of ecosystems are discussed in the *Australian groundwater-dependent ecosystems toolbox part 2: assessment tools* (SKM 2011).

Remote sensing can also be used to identify areas of surface water in systems with large channels or flood out areas. The typically low resolution of remotely sensed data makes this technique less useful for smaller systems. Imagery with higher resolutions are available, and while useful (e.g. aerial videography of the Mount Lofty Ranges - http://www.gyrovision.com.au/pdf/lofty_ranges_case.pdf) are typically significantly more expensive to conduct.

Question 1b: What are the environmental water requirements (EWRs)?

Outputs:

- Statement of environmental water requirements for the Prescribed Water Resources Area
- Outcome
- Coupled with an understanding of hydro-ecological relationship (Question 2b), allows the measurement of environmental implications resulting from deviation in the flow regime

Overview of approach

Aquatic and riparian biota have evolved life-history strategies based on the spatial and temporal presence of habitat (Poff et al. 1997; Bunn and Arthington 2002). Water regime is a major determinant of the presence, quality and availability of habitat. In such a regime a number of key flow components support evolved biological responses, such as:

- providing in-channel habitat
- stimulating fish spawning
- flushing excess sediment from the stream bed
- entraining organic material from the floodplain
- maintaining channel forms
- maintaining soil moisture for vegetation.

Environmental water requirements are a statement of the water regime needed to sustain these biological responses, and hence the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk.

In data rich areas, a quantitative approach may be possible for determining EWRs, whereas in a data poor area, qualitative approaches (often using expert panels) may be all that can be generated. In both cases hypothesis testing and monitoring are required to validate EWRs over the longer term. EWRs are typically expressed in terms of depth, duration, frequency, and timing. In some situations it may also be useful to consider water quality and rate of change.

Examples

Expert Panel Method

A commonly used method in South Australia for defining EWRs for ecological assets of prescribed water resources is through the use of expert panels, particularly in data poor areas where EWRs cannot be determined through empirical methods. The approach involves a multidisciplinary panel reviewing available data and using their professional expert knowledge and experience to determine critical water requirements for the biota or ecosystems of interest.

While EWRs can be documented based on the simple presence of a biotic asset within the PWRA, in order to make informed decisions on the implications of a changing flow regime it is important to have access to additional datasets. The minimum information required to hold an effective expert panel to document EWRs is:

- distribution of water dependent assets
- cross-sections across representative key habitats supporting assets
- hydrological data (flow and/or depth).

Please note that the expert panel method can be applied (on its own or in conjunction with other methods) during all steps in the process described in **Table 1**.

An example of where this method has been successfully implemented is described in *Environmental water requirements for the Mount Lofty Ranges prescribed water resources areas* (van der Wielen and Vanlaarhoven 2009). In this instance the panel included experts in the fields of hydrology, hydrogeology, geomorphology and ecology. The presence of aquatic species collated in response to Question 1a was grouped into functional groups by the expert panel based on expert and literature knowledge on life histories, habitat preferences and species distribution with the expectations that individual taxa within a functional group would have similar water requirements. Functional groups were defined for fish, aquatic macroinvertebrates and vegetation. The EWRs of each functional group was described by the expert panel by determining the flow-dependent ecological processes required to maintain them, and the water regime components required to support those processes at a low level of risk.

Empirical methods

Where adequate data and knowledge has been obtained, various data analyses can be undertaken to answer Question 1c. These methodologies typically involve multivariate analyses of biotic and hydrologic metrics to identify causal relationships. Several of these methodologies are summarised in *Environmental flows: Saving rivers in the third millennium* (Arthington 2012). Poff *et al.* (2010) also provides a good overview of an empirical method of defining EWRs.

Ecological Associates (2006) describes a method used to quantify optimum groundwater conditions for representative wetland plant species in the South East. The study uses empirical data from replicate sampling of the representative plant species communities across the Lower South East to describe the ecosystems in which the species occur and the environmental variables relating to groundwater requirements: seasonal depth and salinity of groundwater, rainfall, soil salinity, soil moisture, soil texture and soil pH.

Quadrats were sampled for a number of representative plant species communities. Each site was equipped with a shallow monitoring well, and soil cores taken. Statistical analysis of the data from the vegetation and environmental variable monitoring was used to:

- classify quadrats according to their environmental attributes
- determine correlations between pairs of environmental variables.

The results of these analyses found that representative species could be used to define largely consistent and distinctive groundwater environments for plant communities and that data obtained could be used to set groundwater management targets to maintain plant communities where the plant communities occur. Further data collection for will increase predictive capacity to describe likely ecosystem responses to changes in surface and groundwater conditions.

3.2 Risk assessment

Question 2a: What are the key sources of risk to water dependent ecosystems?

Outputs:

- Statement of the activities that are, or will potentially impact the prescribed resource
- Categorisation of activities impacting on the prescribed resource that are able to be accounted for within a WAP

Outcomes:

- Understanding of activities that should be accounted for during the Water Allocation Planning process to manage and account for impacts upon ecosystems dependent upon the prescribed resource
- Understanding of other activities that are outside the management scope of the WAP but influence to the condition of dependent ecosystems
  - Ability to account for these impacts when setting targets and evaluating monitoring data.

Water allocation planning manages the take of water, and therefore its impacts upon the flow regime and consequently its impact upon water-dependent ecosystems. It follows then that the identified key sources of water resource risk should be those activities that influence flow regime.

Typically, these risks to the water resource and water dependent ecosystems are changes in the water regime due to:

- construction and extraction from dams/bores for commercial use
- construction and extraction from dams/wells for stock and domestic use
- direct watercourse extraction.

Management strategies of these activities within a WAP can result in varying changes to surface and groundwater regimes, and consequent impacts upon water dependent ecosystems.

Other factors that can influence the flow regime exist and therefore pose risks to water dependent ecosystems which are outside the influence of the Water Allocation Plan to control. However, policies within the WAP are able to adjust allocation regimes to account for, and minimise the risks for these activities. These include:

- land-use change causing change in runoff and groundwater recharge
- climate change causing change in runoff and groundwater recharge.

There are other factors which can impact upon ecosystems dependent upon the prescribed resource which are not able to be controlled by, nor accounted for in the WAP, but are able to be managed through other means (e.g. regional NRM plans). Awareness of these issues will help to interpret the achievement of environmental objectives that relate to the delivery of flow. These include:

- direct habitat clearance
- stock access (habitat disturbance and water quality impacts)
- pollutant inputs (e.g. pesticides, herbicides, sediments)
- infrastructure construction.

Question 2b: What is the level of risk to the environment from the sources of risk identified in Question 2a?

Output:

- A process by which the changes in flow regime options can be related to ecological condition (e.g. hydro-ecological model; targeted monitoring program)

Outcome:

- An understanding of the relationship between changes in flow regime to changes in ecological condition

This aim of this step is to provide a mechanism by which it is possible to assess the risk to identified environmental assets due to changes in water resource brought about by the activities identified in Question 1a. With an understanding of environmental water requirements and the sources of water resource risk it is necessary to develop relationships that relate the two together. As with other parts of these guidelines, the effort and investment in this process will be dependent on the risks to the resource and environmental values.

Hydro-ecological modelling

In high risk and high value systems hydro-ecological modelling may be warranted. Hydro-ecological modelling is the process by which changes in hydrological regime are related to ecological condition, and can be used to document the likely ecological implications of implementing different WAP policy options that can impact upon hydrology. Figure 2 outlines a generic conceptual hydro-ecological relationship showing a linear correlation between ecological condition and hydrological deviation.

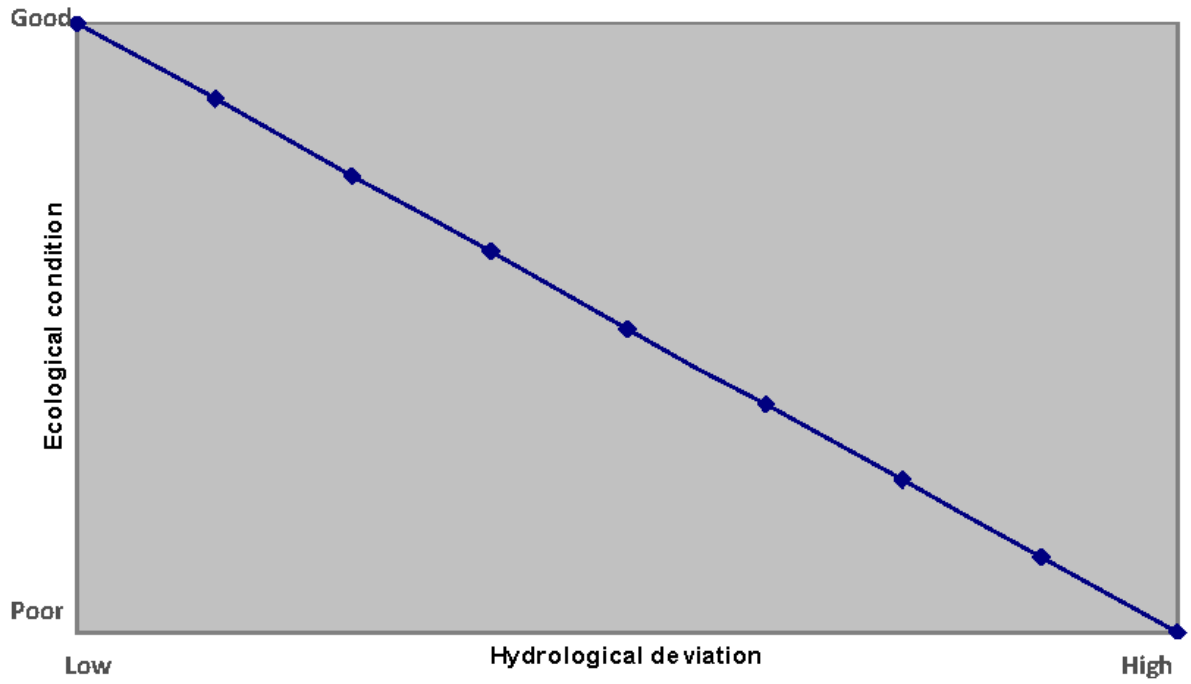

Figure 2. Conceptual hydro-ecological relationship

The most accurate hydro-ecological models require access to ecological data that provides information on an aspect of ecological condition over time (e.g. fish population diversity, size or recruitment; macro-invertebrate community richness, or presence of flow responsive species; vegetation vigor, recruitment or diversity) that can be associated with hydrological flow data over the same time period. Hydrological deviation is generally expressed as 'metrics' that are relevant to ecological processes. For example, in a surface water system the *duration of a defined low flow* will be important in providing a riffle habitat for dependent macroinvertebrate taxa. Any deviation in hydrological conditions that reduces this *duration* will be expected to influence these associated ecological condition. In this example the hydrological deviation will be represented as *duration of low flow,* and the ecological condition can be represented as the diversity of riffle dwelling aquatic macroinvertebrates.

An example of ecologically relevant hydrological metrics can be found in Vanlaarhoven and van der Wielen (2009), as well as in Kennard (2010).

In the absence of measured data, conceptual hydro-ecological models can be developed using experts to provide hypothesised responses of ecosystems components to changes in hydrological conditions that can later be tested with the development of an appropriate monitoring and evaluation program. An example of such a monitoring program is the Verification of Water Allocation Planning Program (VWASP) being implemented by the AMLR NRM Region.

The complexities and scope of developing hydro-ecological model is too great to be explored in detail within the scope of this report, however an overview of methods can be found in Arthington (2012), and more specific examples and methodologies can be found in Poff *et al.* (2010) and Chessman *et al.* (2011). The development and application of hydro-ecological modelling within a South Australian water planning context can be found for the Western and Eastern Mount Lofty Ranges PWRAs (Vanlaarhoven and van der Wielen, 2009; Vanlaarhoven, 2010).

Adaptive management through monitoring

In low risk, low value systems it may be more appropriate to account for the relationship between water regime and ecological condition to be accounted for in an adaptive way through the implementation of the WAP. The Baroota Draft WAP proposes to monitor the health of vegetation over the life of the plan along with associated hydrological variables (surface and groundwater regime), and to adapt WAP policies based on measured responses.

Two options have been presented here for relating changes in water regime to ecological impacts. However, there are many different approaches which could be taken depending on available resources, risks to the resource and value of ecosystems.

Question 2c: What is the tolerability of risks to the environment given community values, policy guidelines and legislative requirements?

Output:

- Interpretation of hydro-ecological relationships identified in Q. 2b with respect to the tolerability of risks to the sustainability of environmental values (i.e. what level of environmental deviation is considered to be tolerable)

Outcome:

- Understanding on the acceptable limits of ecological change based on legislative requirements, policy guidelines and community values

This step aims to provide insight into the ecological consequences of changes in flow regime through determining the tolerability of risks, and provides a mechanism for making informed decisions when accounting for the environmental implications of balancing the provision of environmental water against social and economic needs. The product of answering this question is a decision on a tolerable level of environmental condition, and a corresponding tolerable level of hydrological deviation (Figure 3).

Tolerability

Tolerability is measured against one or a number of objectives, therefore it is important prior to completing this step to identify the information required to state these objectives. This information will include consideration of a number of different policy drivers, as well as community/stakeholder values. Sources of information that should be considered include:

- Regional NRM Plan
- State NRM Plan
- South Australia's Strategic Plan
- *National Parks and Wildlife Act 1972*
- *Environment Protection and Biodiversity Conservation Act 1999*
- Convention on Wetlands of International Importance (Ramsar Convention)
- Bilateral migratory bird agreements (JAMBA, CAMBA, ROKAMBA)
- Local community values

This information can then be used to interpret hydro-ecological relationships identified in Question 2b with regard to determining the acceptable level of deviation in ecological condition. This may be done through identifying 'breakpoints' in non-linear relationship, or expert opinion identifying thresholds of probable concern in a linear relationship. Note that this definition of tolerability may be an iterative process as the Water Allocation Planning process takes into account social and economic needs for water to inform tradeoffs.

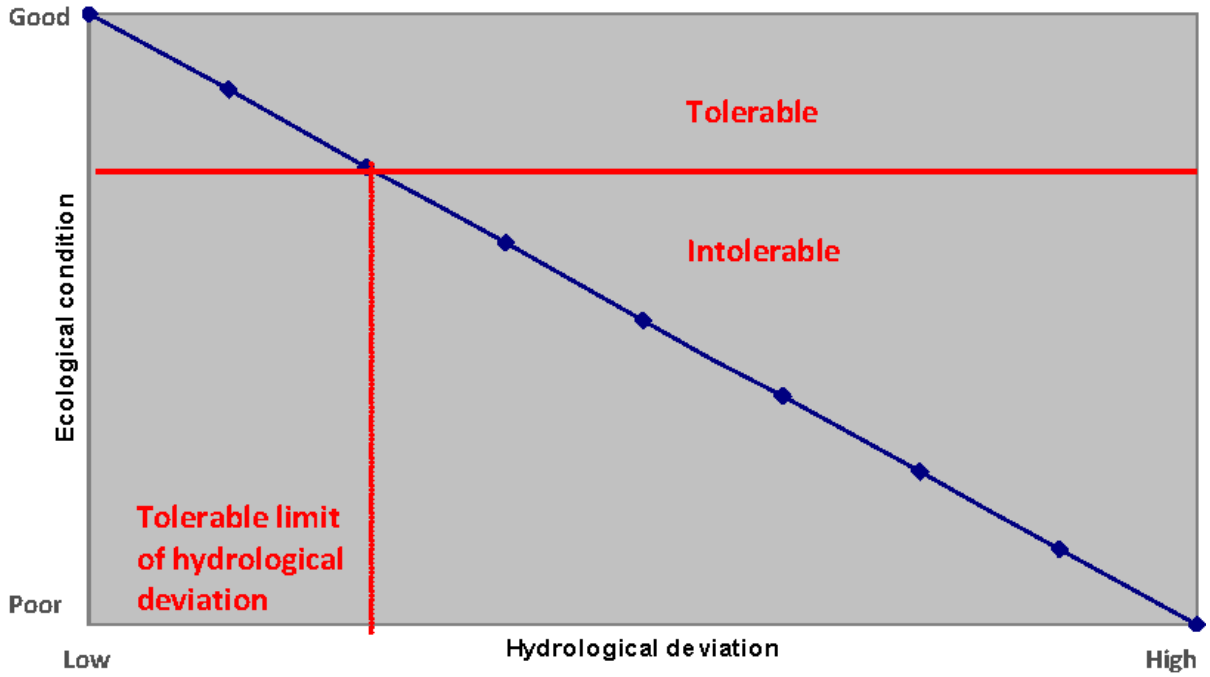

Figure 3. Conceptual linear hydro-ecological relationship showing limits of tolerability

3.3 Potential risk treatment

Question 3: What policy options provide treatments that manage risks to ecosystems dependent on the prescribed resource?

Output:

- Documented ecological implications of applying various WAP policy options

Outcomes:

- Ability to transparently relate the implementation of WAP policy options to likely ecological responses
- Ability to account for the environmental component of EWPs when balancing against social and economic needs for water

As with other parts of these guidelines, the effort and investment in this process will be dependent on the risks to the resource and environmental values, and will depend upon the level of investment in previous steps.

Answering Questions 2b and 2c provides a foundation that allows environmental tradeoffs to be transparently reported when balancing against social and economic needs, and can provide a decision point on the tolerability of change in ecological condition as brought about due to changes in the water regime.

The next step of this process is determining the relationship between the measures of hydrological change and the implementation of various policy options available in the development of a WAP. These policy options include:

- Dam and well extraction limits
- Dam capacity limits
- Threshold flow rates for watercourse extractions
- Managing timing and method of water capture (e.g. low flow bypasses, or other methods of providing flows back to surface water systems)
- Well and dam placement restrictions
- Well extraction rates

This step requires a hydrological model to predict the influence of applying these different WAP policy options on the flow regime. This information can then be used to determine the correlation between the hydrological effects of applying those policy options against the deviation of hydrological metrics. Through this it is possible to relate the application of WAP policy options against an expected ecological implication and its associated level of tolerability.

Options for areas where the level of risk to the resource and environmental value have not warranted investment in the derivation of hydro-ecological models include monitoring of environmental assets and their relationship to hydrological drivers to ensure that stated environmental objectives from the WAP are being achieved. This option is being considered for the Baroota PWRA.

There are many different approaches which could be taken above those presented above depending on available data/resources, risks to the resource and value of ecosystems.

3.4 Risk treatment

Question 4: What are the agreed policy instruments (risk treatments) to be incorporated into the WAP to manage the environmental impacts of water allocation?

Output:

- Documented environmental objectives expected to be achieved through transparent linkages between the implementation of specific WAP policy options and expected environmental condition

Outcome:

- Transparent and justifiable EWPs with clear linkages between the implementation of WAP policy options and expected ecological outcomes

Exploration of the methods required to answer this question are outside the scope of this guideline. There are no scientific investigations undertaken at this step. The methods and investigations applied in answering Questions 1–3 will inform the outcome of Question 4, together with other risk assessments, community and policy input.

4 Summary

This section contains a summary of the methods and data sources that can be used when assessing the environmental water requirements and provisions (Sections 76(4)(a)(i) and 76(4)(aab)(i)(ii)(iii) of the *NRM Act 2004*) in the preparation of WAPs. Undertaking a risk assessment process will help to identify the effort and resources required and identify priorities for application.

Table 2. Summary of the methods and data sources for assessing the requirements of water dependent ecosystems

Question	Method	Information/data needed	Potential information sources	Considerations
1a. What environmental assets are dependent upon the prescribed resource?	Literature review	Decision on target water dependent biota upon which EWRs will be based	Biological Databases of South Australia (DEWNR) South Australian Research and Development Institute (fish and vegetation) Native Fish Australia (SA) inventories EPA and Australian Water Quality Centre (aquatic macroinvertebrates) DEWNR mapping layers Scientific reports	Relies on the validity of previous work
	Field investigations	Decision on target water dependent biota upon which EWRs will be based Existing biotic information/previous survey sites Location of water dependent habitats. Scale of management (to inform the number of sites to be surveyed).	Specialist contractor staff are generally required to conduct field investigations See 'Literature review' method in this table for sources of information.	Provides up-to-date, validated local data Relatively resource intensive Single survey in time and space can misrepresent larger patterns

Question	Method	Information/data needed	Potential information sources	Considerations
	Conceptual modelling	Decision on target water dependent biota upon which EWRs will be based. Existing biotic information/previous survey sites. Location of water dependent habitats. Current understanding on the distribution of local water dependent biota. Habitat preferences of target water dependent biota. Scale of management (to inform the number of sites to be surveyed)	See 'Literature review' method in this table for sources of information.	Cost effective method of deriving information on the possible distribution of biotic assets across large areas. Mapping is based on expert and literature information rather than actual field observations. Without validation, may reflect an inaccurate distribution of assets, and therefore provide an invalid basis for the application of WAP policy options.
	Remote sensing	Radiation reflectance or emission data collected via aircraft or satellite (e.g. spectral reflectance data for use in calculating a NDVI – Normalised Difference Vegetation Index) The following are necessary for interpreting results: • Depth to groundwater mapping/data • Surface water mapping • Vegetation distribution mapping	Bureau of Meteorology Biological Databases of south Australia (DEWNR) DEWNR mapping layers Scientific reports Groundwater Data (DEWNR application) LANDSAT	

Question	Method	Information/data needed	Potential information sources	Considerations
1b. What are the environmental water requirements?	Expert Panel	All existing data available relating to the presence, distribution and condition of biota in the study area. Cross-sections across representative habitats Hydrological data (e.g. flow/depth)	Professional experts in the fields of hydrology, hydrogeology, geomorphology and ecology See 'Literature review' method in this table for sources of information	Cost and time effective method of deriving EWRs Relies heavily on assumptions Without validation, may reflect an inaccurate EWR, and therefore provide a misleading basis for the application of WAP policy options
	Empirical data analysis	Time series ecological response data for biota dependent upon the prescribed resource Time series hydrological data at some location as ecological data	Ecological field survey/monitoring results Biological Databases of south Australia (DEWNR) South Australian Research and Development Institute (fish) Native Fish Australia (SA) inventories EPA and Australian Water Quality Centre (aquatic macroinvertebrates) Well watertable monitoring results – WaterConnect Surface water flow monitoring results – WaterConnect Water quality assessment (especially salinity) taken at the relevant aquatic ecosystem sites (EPA/WaterConnect)	Locally derived, validated water requirements for biota dependent on the prescribed resource High data requirements Can be time intensive to analyse data to determine water requirements

Question	Method	Information/data needed	Potential information sources	Considerations
2a. What are the key sources of risk to water-dependent ecosystems?	Workshop with relevant technical and policy experts	Activities/processes affecting water resources in the Prescribed Area	Technical and policy experts with knowledge of Water Allocation Planning (DEWNR/regional staff)	Activities that are able to be managed through the Water Allocation Planning process need to be identified (e.g. dam construction) Activities that are not able to be managed but are able to be accounted for in Water Allocation Planning need to be identified (e.g. climate change) Activities that are not able to be managed, nor accounted for in Water Allocation Planning should to be identified (e.g. land management practices). These activities may be able to be managed through other planning processes (e.g. regional NRM plans)
2b. What is the level of risk to the environment from the sources of risk identified in Question 2a?	Hydro-ecological modelling	See 'What are the EWRs – Empirical Analysis' method in this table for required information.	See 'What are the EWRs – Empirical Analysis' method in this table for information sources	Locally derived, validated ecological responses to changes in flow conditions High data requirements Can be time intensive to investigate relationships and develop hydro-ecological models

Question	Method	Information/data needed	Potential information sources	Considerations
	Adaptive Water Allocation Planning informed through appropriate monitoring	Distribution and hypothesised response of biological assets to flow within the prescribed area	See 'Literature review' and 'field investigations' method in this table for sources of information on distribution of assets See 'What are the EWRs' and in this table for information sources to determine a hypothesised response to flow	Requires lower initial investment in investigations Risk that policies may not deliver a flow that leads to the desired ecological response due to an insufficient understanding of the relationship between the application of WAP policies and flow and corresponding response of ecosystems
2c. What's the tolerability of risks to the environment given community values, policy guidelines and legislative requirements?	Literature review of policies and legislation that pertains to the management of ecological assets within the prescribed area. Community consultation to determine community values with respect to ecosystems dependent on the prescribed resource	Policy and Legislation that pertains to the management of ecological assets within the prescribed area. Community values with respect to ecosystems dependent on the prescribed resource	Regional NRM Plan State NRM Plan South Australia's Strategic Plan *National Parks and Wildlife Act 1972* *Environment Protection and Biodiversity Conservation Act 1999* Convention on Wetlands of International Importance (Ramsar Convention) Bilateral migratory bird agreements (JAMBA, CAMBA, ROKAMBA) Community members Stakeholders	N/A

Question	Method	Information/data needed	Potential information sources	Considerations
3. What policy options provide treatments that manage risks to ecosystems dependent on the prescribed resource?	Use results from question on 'What is the level of risk to the environment from the sources of risk' to determine the relationship between the application of WAP policies on hydrological regime and corresponding implication for ecological systems	Output of all above steps	Output of all above steps	This is likely to be an iterative process where ecosystem implications are traded off against socio-economic needs

5 Definitions

Aquatic Ecosystem	*The stream channel, lake or estuary bed, water and/or biotic communities and the habitat features that occur therein*
DEWNR	*Department of Environment, Water and Natural Resources*
Ecosystem	*Any system in which there is an interdependence upon and interaction between, living organisms and their immediate physical, chemical and biological environment*
Ecological Values	*The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems (ARMCANZ & ANZECC, 1996).*
Environmental Asset	*Flora and fauna species of significance and significant aquatic habitats*
Environmental Water Provisions (EWPs)	*The part of environmental water requirements that can be met. Environmental water provisions may refer to:* • *unregulated flows in rivers and water in wetlands and aquifers;* • *specific volumetric allocations and/or releases from storages;* • *water levels maintained in wetlands; and* • *water in transit for other users, the pattern of flow of which may be defined to meet an environmental need (ARMCANZ & ANZECC, 1996)*
Environmental Water Requirements (EWRs)	*Descriptions of the water regimes needed to sustain the ecological values of aquatic ecosystems at a low level of risk. These descriptions are developed through the application of scientific methods and techniques or through the application of local knowledge based on many years of observation (ARMCANZ & ANZECC, 1996)*
Estuaries	*Semi-enclosed water bodies at the lower end of a freshwater stream that are subject to marine, freshwater and terrestrial influences and experience periodic fluctuations and gradients in salinity*
Facultative groundwater dependent ecosystem	*An ecosystem* that does not depend solely on access to groundwater as a water supply, but also can subsist on surface derived water.
Groundwater	*Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground*
Groundwater Dependent Ecosystems (GDEs)	*Environmental assets supported by groundwater – i.e. Persistent pools, baseflow supported sections of watercourses and groundwater fed wetlands*
Hypogean	*Located under the Earth's surface; underground*
Obligate groundwater dependence	*An ecosystem that will only exist where it has regular access to groundwater. Has a higher dependence on groundwater than Facultative GDEs.*
Phreatophytic vegetation	*Vegetation that exists in a climate more arid than its normal range by virtue of its access to groundwater*
PWA	*Prescribed Wells Area*
PWC	*Prescribed Watercourse*
PWRA	*Prescribed Water Resources Area*
Surface water	*Water flowing over land (including a watercourse) after having fallen as rain or hail or having precipitated in any other manger, or after rising to the surface naturally from underground; water held in a dam or reservoir*
Water-dependent ecosystems	*Those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground; the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems (ARMCANZ & ANZECC, 1996)*

6 References

Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and Australian and New Zealand Environment and Conservation Council (ANZECC) (1996) *National Principles for the Provision of Water for Ecosystems*, Commonwealth of Australia, Sydney

Arthington, A. (2012) *Environmental flows: Saving rivers in the third millennium*. Freshwater ecology series. The Stephen Bechtel fund.

Department of Environment, Water and Natural Resources (DEWNR) (2012a) Risk Management Framework for Water Allocation Plans, DEWNR, Government of South Australia.

Department of Environment, Water and Natural Resources (DEWNR) (2012b) Risk Management Policy and Guidelines for Water Allocation Plans, DEWNR, Government of South Australia.

Department of Environment, Water and Natural Resources (DEWNR) (in prep.) Guidelines – Environmental Water Requirements and Provisions (unpublished).

Department of Water, Land and Biodiversity Conservation (DWLBC) and the South Australian Murray-Darling Basin Natural Resources Management Board (SAMDB NRM Board) (2009) *Assessment of the Needs of Water-dependent Ecosystems for the Marne Saunders Prescribed Water Resources Area*, Government of South Australia, South Australia, Adelaide

Doeg, T., Muller, K., Nicol, J. and Vanlaarhoven, J. (2012) *Environmental Water Requirements of Groundwater Dependent Ecosystems in the Musgrave and Southern Basins Prescribed Wells Areas on the Eyre Peninsula*, DFW Technical Report 2012/16, Government of South Australia, through Department for Water, Adelaide. (http://www.waterconnect.sa.gov.au)

Ecological Associates (2006) *Environmental water requirements of underground water dependent ecosystems in the South East PWA - field studies to support new and amended policy*. Prepared for REM.

Harding, C. and O'Connor, P. (2012) *Delivering a Strategic Approach for Identifying Water-dependent Ecosystems at Risk: A preliminary assessment of risk to water-dependent ecosystems in South Australia from groundwater extraction*, DFW Technical Report 2012/03, Government of South Australia, through Department for Water, Adelaide.

Kennard, M. J., Pusey, B. J., Olden, J. D., MacKay, S. J., Stein, J. L. & Marsh, N. (2010) *Classification of natural flow regimes in Australia to support environmental flow management*. Freshwater Biology 55, Issue 1, PP 171-193.

Poff, N. Leroy; Richter, Brian D.; Arthington, Angela; Bunn, Stuart; Naiman, Robert J.; Kendy, Eloise; Acreman, Mike; Apse, Colin; Bledsoe, Brian P.; Freeman, Mary C.; Henriksen, James; Jacobson, Robert B.; Kennen, Jonathan G.; Merritt, David M.; O'Keeffe, Jay H.; Olden, Julian D.; Rogers, Kevin; Tharme, Rebecca E.; Warner, Andrew. (2010) *The ecological limits of hydrologic alteration (ELOHA): A new framework for developing regional environmental flow standards*. Freshwater Biology 55: 147–170.

Sinclair Knight Merz (SKM) (2009) *Eyre Peninsula Groundwater Dependent Ecosystem Scoping Study*. Eyre Peninsula Natural Resources Management Board. Port Lincoln.

Sinclair Knight Merz (SKM) (2011) *Australian groundwater-dependent ecosystems toolbox part 2: assessment tools*, Waterlines report, National Water Commission, Canberra.

van der Wielen M. and Vanlaarhoven, J. M. (2009) *Environmental water requirements for the Mount Lofty Ranges prescribed water resources areas*. DWLBC Report 2009/29. Department of Water, Land and Biodiversity Conservation and South Australian Murray-Darling Basin Natural Resources Management Board, Government of South Australia. (https://www.waterconnect.sa.gov.au)