Ecosystem Services and Productive Base for the Basin Plan

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A report prepared for the Murray-Darling Basin Authority by The Murray-Darling Freshwater Research Centre.

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Executive Summary

<u>Background and approach</u>

The MDFRC, together with Professor Lin Crase and Drs Rhonda Butcher and Pierre Horwitz, have consulted to produce this review of ecosystem services and the productive base. Special attention has been paid to the wider meaning of these terms and their likely impact on the formulation of the Basin Plan.

The Murray-Darling Basin Authority (MDBA) is preparing the Basin Plan, a strategic plan aimed at delivering integrated and sustainable management of water resources within the Murray-Darling Basin (MDB). This is a complex task involving planning on a very large scale, rarely tackled elsewhere (MDBA 2009a). The plan will provide a fundamental framework for future water planning arrangements and will be based on the best available scientific, social, cultural and economic knowledge, evidence and analysis.

The *Water Act 2007* (the Act) requires that the MDBA establish Sustainable Diversion Limits (SDLs) that reflect an Environmentally Sustainable Level of Take (ESLT). The ESLT for a water resource is the level at which water can be taken from that water resource which if exceeded, would compromise:

- key environmental assets (KEA) of the water resource or
- key ecosystem functions (KEF) of the water resource or
- the productive base of the water resource or
- key environmental outcomes (KEO) for the water resource.

According to the Act, environmental assets include:

- water-dependent ecosystems
- ecosystem services
- sites with ecological significance.

This report is used to test the relationship and consistencies between the current MDBA ESLT approach (based on KEA and KEF) and the delivery of ecosystem services and the productive base.

More specifically, we test the hypothesis that an ESLT that does not compromise:

- key ecosystem functions
- key water dependent ecosystems
- key sites with ecological significance.

will not compromise:

- ecosystem services or
- the productive base.

In order to objectively assess these propositions for the purposes of this report we consider ecosystem services separately to the other KEA, notwithstanding that the Act defines the former as a subset of the latter.

Key Findings

Ecosystem services are the benefits that humans obtain from ecosystems. They can be divided into provisioning, regulating, supporting and cultural services. They are influenced by ecosystem conditions and ecosystem processes. This broadly aligns with the notions of KEA and KEF respectively, as presently interpreted by the MDBA. Tracing the relationship between the value of ecosystem services and ecosystem performance is no simple task.

The notion of the productive base is not widely employed or well-supported by the literature[1]. Taken broadly it equates to ensuring that provisioning, regulating, supporting and cultural services are also supported. There would appear to be little to be gained by endeavouring to separately distinguish threats to ecosystem services from threats to the productive base and they should be treated synonymously. Thus if not compromising KEA and KEF results in the delivery of ecosystem services there are grounds for arguing that the productive base will also avoid compromise under these conditions.

It has been possible to formulate an ecosystem services classification for the Basin Plan. The proposed classification makes use of the existing work in the field. There is insufficient scope to test all elements of this approach although it is possible to make some defensible qualitative judgements about the ecosystem services pertinent to the plan. The classification appears in Table A.

[1] Economists would be familiar with the notion as representing the status of inputs (land, labour, capital and enterprise) from which outputs could be generated but there are few equivalent uses in the ecological literature.

Table A: Classification of ecosystem services based on the benefits that people receive from the Key Environmental Assets and Key Ecosystem Functions identified by the MDBA. (Note the codes depicted in column 3 are employed throughout subsequent sections of this report).

	Category	**Ecosystem services**
Productive Base	Provisioning services	Drinking water for humans and or livestock (P1) Water for irrigated agriculture (P2) Water for industry (P3) Food for humans (P4) Food for livestock (P5) Wood, reed, fibre and peat (P6) Medicinal products (P7) Other products and resources, including genetic material (P8)
	Regulating services	Groundwater replenishment (R1) Water purification/waste treatment or dilution (R2) Biological control agents for pests/disease (R3) Flood control, flood storage (R4) Coastal shoreline and river bank stabilisation and storm protection (R5) Other hydrological services (R6) Local climate regulations/buffering of change (R7) Carbon storage/sequestration (R8 Hydrological maintenance of biogeochemical processes (R9)
	Supporting services	Nutrient cycling (S1) Primary productivity (S2) Sediment trapping, stabilisation and soil formation (S3) Physical habitat (S4) Systemic consequence (ecological surprise); maintenance of desirable state (S5) Natural or near-natural wetland ecosystems (incorporates concept of resilience) (S6) Priority wetland species and ecosystems (S7) Ecological connectivity (S8) Threatened wetland species, habitats and ecosystems (S9)
	Cultural services	Science and education values (C1) Cultural heritage and identity (C2) Contemporary cultural significance (C3) Aesthetic and sense of place values (C4) Spiritual, inspirational and religious values (C5)

The project brief required that the classification of ecosystem services be deployed to analyse ecosystem services by industry, sector or activity in the Basin. This approach has allowed for the unbundling of services, albeit on the basis of qualitative assessments and the use of the available literature. The outcome is summarised in the table below:

Table B: Ecosystem services (C, P, R, S) for the MDB by industry/activity.
(where 1= Irrigated agriculture, 2=Forestry, 3=Fisheries, 4=Mining, energy, service industries and other industries, 5=Tourism and recreation and 6=Education and residential development).

INDUSTRY/ACTIVITY		1	2	3	4	5	6
CULTURAL							
Science and education values	C1		X			X	X
Cultural heritage and identity	C2		X			X	X
Contemporary cultural significance	C3		X	X		X	X
Aesthetic and sense of place values	C4		X			X	X
Spiritual, inspirational and religious values	C5		X			X	X
PROVISIONING							
Water for drinking (humans or livestock)	P1	X	X			X	X
Water for irrigated agriculture	P2	X					
Water for industry	P3		X	X	X		
Food for humans	P4		X	X	X		X
Food for livestock	P5			X			
Wood, reed, fibre and peat	P6		X		X		
Medicinal products	P7						
Other products and resources, including genetic material	P8		X	X			
REGULATING							
Groundwater replenishment	R1	X	X	X	X	X	X
Water purification/waste treatment or dilution	R2	X		X	X	X	X
Biological control agents for pests/disease	R3	X	X	X		X	X
Flood control, flood storage	R4	X	X	X	X	X	X
Coastal shoreline and river bank stabilisation and storm protection	R5	X		X	X	X	X
Other hydrological services	R6	X	X	X	X	X	X
Local climate regulations/buffering of change	R7	X				X	X
Carbon storage/sequestration	R8	X	X	X		X	
Hydrological maintenance of biogeochemical processes	R9	X	X	X	X	X	X
SUPPORTING							
Nutrient cycling	S1	X	X	X		X	X
Primary productivity	S2	X	X	X	X	X	X
Sediment trapping, stabilisation and soil formation	S3	X	X	X	X	X	X
Physical habitat	S4	X	X	X	X	X	X
Systemic consequence (ecological surprise); maintenance of desirable state	S5	X	X	X	X	X	X
Natural or near-natural wetland ecosystems (incorporates concept of resilience)	S6		X	X	X	X	X
Priority wetland species and ecosystems	S7		X	X			X
Ecological connectivity	S8	X	X	X		X	X
Threatened wetland species, habitats and ecosystems	S9		X	X			X

Note: Required ecosystem services for specific industries/activities are indicated with an 'X'. Specific goods or services that are produced as a function of the ecosystem service category are indicated as highlighted cells.

The classification and the subsequent unbundling add further weight to the argument that ecosystem services and the productive base should be treated synonymously.

The MDBA approach to determining an ESLT using environmental water requirements for KEA and KEF was mapped against the likelihood of not compromising ecosystem services (given that this is synonymous with the productive base). An environmentally sustainable level of take that does not compromise KEA (water dependent ecosystems and sites with ecological significance), KEF and the water quality KEO, appears to directly address the environmental water requirements of 23 of the 31 identified ecosystem services/productive base. It is anticipated that the environmental water requirements of the remaining 8 ecosystem services will be either; a) addressed indirectly through this ESLT approach and/or b) attended to by other mechanisms that aim to maintain key environmental outcomes such as managing for biodiversity, water resource health and ecosystem function.

Immediate considerations

There are three immediate risks relating to the development of the Plan. These comprise:

- Potential for confusion amongst the community around the definition of the productive base and its overlap with ecosystem services.
- Possible gaps in the ecosystem classification.
- Inability to address the environmental water requirements of all ecosystem services directly via the provision of environmental water to KEA and KEF.

The view of the authors is that none of these risks is so severe as to prevent immediate progress of the Plan along KEA and KEF lines. Moreover, sensible strategies can be easily developed to monitor and control these risks.

Some additional work is invariably warranted to understand cultural services, in particular Indigenous cultural ecosystem services.

The immediate risks to the planning process appear manageable with a combination of articulate communication (say in the case of the productive base) and resources devoted to scanning for inconsistencies between emerging data and the rationale presented in this report.

Medium and longer term considerations

Ecosystem services as a concept is still in development, and at this stage is still relatively immature when used as a basis for water resource planning. The relationship between biodiversity and ecosystem services is not sufficiently understood; scale inconsistencies remain unresolved and establishing robust measures for calculating human value and then disaggregating it to the ecosystem service level is a developing field. These are medium and longer term tasks that should be undertaken to make for better planning.

In the longer term, it will be necessary to improve the measurement of ecosystem services in order to validate that they are not compromised. If ecosystem services are to be seriously deployed as a planning tool the MDBA will need to take on this challenge. This is a significant task, particularly in the context of valuing cultural services.

Best practice would also require that an adaptive management approach be in place to respond to some of the potential weaknesses embodied in the planning framework.

Our overall assessment is that there is already considerable investment in the KEA/KEF approach to managing water resources. What is missing is knowledge that traces the intricacies of this approach to the desired ecosystem service and productive base outcomes. We would strongly recommend that the MDBA continue to invest in research to refine and better understand these linkages.

Glossary

An * denotes a definition that is provided in the *Water Act 2007*.

For further discussion on the interpretation of these definitions, please refer to the cited references. This glossary does not provide a comprehensive review on the terms included in the *Water Act 2007*, or otherwise.

***Biodiversity** means the variability among living organisms from all sources (including terrestrial, marine and aquatic ecosystems and the ecological complexes of which they are a part) and includes:

- diversity within species and between species
- diversity of ecosystems.

***Environmental assets** includes:

- water-dependent ecosystems
- ecosystem services
- sites with ecological significance.

Ecosystem condition is the equivalent to the MDBA's task of not compromising Key Environmental Assets, thus the conditions must meet the 5 criteria for identifying key assets of the MDB, as referred to in Section 5.1.2 of Methods for Determining ESLT (March 2010).

Ecosystem components are the physical, chemical and biological mechanisms (Davis & Brock 2008) interacting within, in this document, water-dependent ecosystems.

Ecosystem functions (processes) are the dynamic forces within an ecosystem (DEWHA 2008). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the nonliving environment that result in existing ecosystems and bring about changes in ecosystems over time (Australian Heritage Commission 2002).

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber and fibre; regulating services that affect climate, floods, disease, wastes and water quality; cultural services that provide recreational, aesthetic and spiritual benefits; and supporting services such as soil formation, photosynthesis and nutrient cycling (MA 2005a & 2005c).

***Environmental water** means:

- held environmental water or
- planned environmental water.

> ***Held environmental water** means water available under:
> (a) a water access right or
> (b) a water delivery right or
> (c) an irrigation right;

for the purposes of achieving environmental outcomes (including water that is specified in a water access right to be for environmental use).

Or:

*Planned environmental water** is water that:

1 (a) is committed by:

(i) the Basin Plan or a water resource plan for a water resource plan area or

(ii) a plan made under a state water management law or

(iii) any other instrument made under a law of a state; to either or both of the following purposes:

(i) achieving environmental outcomes

(ii) other environmental purposes that are specified in the plan or the instrument and

1 (b) cannot, to the extent to which it is committed by that instrument to that purpose or those purposes, be taken or used for any other purpose.

2 (a) is preserved, by a law of a state or an instrument made under a law of a state, for the purposes of achieving environmental outcomes by any other means (for example, by means of the setting of water flow or pressure targets or establishing zones within which water may not be taken from a water resource)

2 (b) cannot, to the extent to which it is preserved by that instrument for that purpose or those purposes, be taken or used for any other purpose

(3) The water may be committed to, or preserved for, the purpose or purposes referred to in paragraph (1)(a) or (2)(a) either generally or only at specified times or in specified circumstances.

(4) Without limiting paragraphs (1)(b) or (2)(b), the requirements of paragraphs (1)(b) or (2)(b) are taken to have been met even if the water is taken or used for another purpose in emergency circumstances in accordance with:

(a) the instrument referred to in that paragraph or

(b) the law under which the instrument is made or

(c) another law

Environmental watering plan is a plan required under item 9 of Section 22(1) of the *Water Act 2007* to protect and restore the environmental assets of the Basin. It will contain:

- environmental objectives for water-dependent ecosystems of the Basin
- targets to measure progress against these objectives
- a management framework for environmental water
- the methods used to identify environmental assets requiring water
- the principles and methods which will set the priorities for applying environmental water
- the principles to be applied in environmental watering (MDBA 2005a).

Environmentally sustainable level of take (ESLT) for a water resource means the level at which water can be taken from that water resource which if exceeded, would compromise:

- key environmental assets of the water resource or
- key ecosystem functions of the water resource or
- the productive base of the water resource or
- key environmental outcomes for the water resource (MDBA 2010).

Flow regime is the description of the characteristic pattern of a river's flow quantity, timing and variability (Poff et al. 1997).

***Groundwater** means:

- water occurring naturally below ground level (whether in an aquifer or otherwise)
- water occurring at a place below ground that has been pumped, diverted or released to that place for the purpose of being stored there
- but does not include water held in underground tanks, pipes or other works.
- it also does not include ground water that forms part of the Great Artesian Basin (as per the *Water Act 2007* definition for Basin water resources).

***International agreement** means an agreement whose parties are:

- Australia and a foreign country or
- Australia and 2 or more foreign countries.

Key ecosystem function is an ecosystem function determined to be 'key' by the MDBA for the purposes of the Basin Plan. Refer to the Method for determining the ESLT (MDBA 2010).

Key environmental asset is an environmental asset determined to be 'key' by the MDBA for the purposes of the Basin Plan. Refer to the Method for determining the ESLT (MDBA 2010).

Key environmental outcome is an environmental outcome determined to be 'key' by the MDBA for the purposes of the Basin Plan. Refer to the Method for determining the ESLT (MDBA 2010).

Productive base is as the support offered by ecosystems, ecosystem functions and ecosystem services of a water resource to provide for ecological and human (economic and social) production (Gigney et al. 2010).

***Ramsar Convention** means the Convention on Wetlands of International Importance especially as Waterfowl Habitat conducted at Ramsar, Iran, on 2 February 1971.

Resilience is the speed with which a perturbed ecosystem returns to its original state (Allaby 2005).

***Surface water** includes:

- water in a watercourse, lake or wetland
- any water flowing over or lying on land:
    - after having precipitated naturally or
    - after having risen to the surface naturally from underground.

Water Act or the Act means the *Water Act 2007 (Cth).*

***Water-dependent ecosystem** means a surface water ecosystem or a ground water ecosystem and its natural components and processes, that depends on periodic or sustained inundation, waterlogging or significant inputs of water for its ecological integrity and includes an ecosystem associated with:

- a wetland
- a stream and its floodplain
- a lake or a body of water (whether fresh or saline)

- a salt marsh
- an estuary
- a karst system; or
- a ground water system

and a reference to a water-dependent ecosystem includes a reference to the biodiversity of the ecosystem.

Water quality refers to the condition of water and its related suitability for different purposes. Water quality refers to a combination of physical, chemical and/or biological characteristics of a water body in the context of the value, or use for which the water body is being recognised. Water quality maybe a key environmental outcome or a driver of ecosystem function (Gigney et al. 2010).

***Water resource** means:

(a) surface water or ground water or
(b) a watercourse, lake, wetland or aquifer (whether or not it currently has water in it) and

includes all aspects of the water resource (including water, organisms and other components and ecosystems that contribute to the physical state and environmental value of the water resource).

Water resource health is the ability of a water resource to maintain ecological character, which includes retaining those essential ecological and hydrological functions which ultimately provide its benefits and services within itself or to the wider ecosystem. (Gigney et al. 2010).

Sites with ecological significance are A site which has recognised value associated with its ecological components (the processes, functions, attributes associated with a site) (Gigney et al. 2010).

Table of Contents

1. Introduction and context

The *Water Act 2007* (the Act) requires that the MDBA establish Sustainable Diversion Limits (SDL) that reflects an Environmentally Sustainable Level of Take (ESLT). The ESLT for a water resource is the level at which water can be taken from that water resource which if exceeded, would compromise:

- key environmental assets (KEA) of the water resource or
- key ecosystem functions (KEF) of the water resource or
- the productive base of the water resource or
- key environmental outcomes (KEO) for the water resource.

According to the Act, environmental assets include:

- water-dependent ecosystems
- ecosystem services
- sites with ecological significance.

The Act defines water-dependent ecosystems as surface water ecosystems or ground water ecosystems, including their natural components and processes that depend on periodic or sustained inundation, waterlogging or significant inputs of water for their ecological integrity. This includes an ecosystem associated with any of the following components:

- a wetland
- a stream and its floodplain
- a lake or a body of water (whether fresh or saline)
- a salt marsh
- an estuary
- a karst system; or
- a ground water system.

The Act also states that any reference to a water-dependent ecosystem includes a reference to the biodiversity of the ecosystem.

The *Water Act 2007* does not include a definition of sites with ecological significance. However, in reviewing terms used by the MDBA in developing the Basin Plan, Gigney et al. (2010) has recommended that this be defined as site/s which has recognised value associated with its ecological components (the processes, functions, attributes associated with a site).

Water-dependent ecosystems and sites with ecological significance are deemed to be 'key' by the MDBA for the purposes of the Basin Plan if they meet at least one of five criteria. These criteria comprise the concepts of sites of significance (e.g. Ramsar sites), rarity and are representative of wetland type, vital habitat for water dependent biota, threatened species and biodiversity.

Ecosystem functions (processes) are the dynamic forces within an ecosystem (DEWHA 2008). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the nonliving environment that result in existing ecosystems and bring about changes in ecosystems over time (AHC 2002).

Productive base is the support offered by ecosystems, ecosystem functions and ecosystem services of a water resource to human economic and social production (MDBA 2009b).

According to the Act environmental outcomes include:

- ecosystem function
- biodiversity
- water quality
- water resource health.

Environmental water requirements to achieve Key Environmental Outcomes (KEO) of ecosystem functions are linked to KEF; biodiversity are linked to KEA and KEF; and water quality is linked to the Water Quality and Salinity Plan. The Environmental Watering Plan addresses water resource health in the context of these relationships but is limited because it does not determine a level of take that would not compromise the KEO of water resource health from a water resource.

The relationships between these concepts and the policy and administrative processes implied by the Act are illustrated in Figure 1.

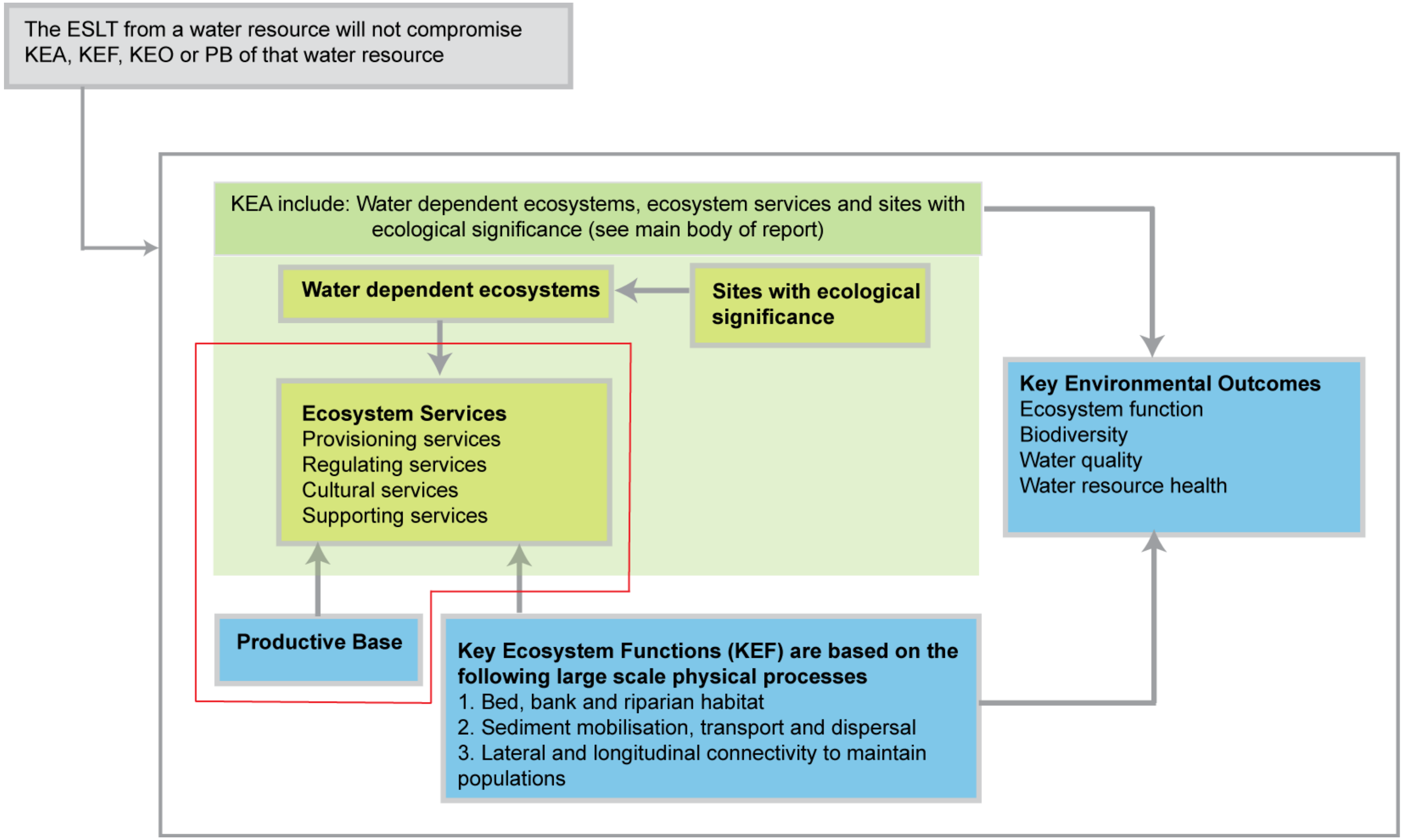

Figure 1: Relationships between core concepts and policy and administrative processes
Note: The red line indicates the key relationships presumed by the MDBA and explored as part of this report, although it is not possible to isolate all other elements. The four categories of ecosystem services match those of the Millennium Ecosystem Assessment and are defined in section 2.1.

Given the timelines within which the MDBA must establish an ESLT and the extant knowledge and techniques for enumerating the various concepts in Figure 1, this report is used to test the relationship and consistencies between the ESLT approach and the non-compromise of ecosystem services and the productive base. We explore the proposition that an ESLT that satisfies the requirement to not compromise key ecosystem functions, key water dependent ecosystems and key sites of ecological significance will, by and large, meet other requirements specified in the Act; namely not compromising ecosystem services and the productive base.

More specifically, we expect that an ESLT that will not compromise:

- key ecosystem functions
- key water dependent ecosystems and
- key sites with ecological significance

will not compromise:

- ecosystem services or
- the productive base.

Whilst Figure 1 endeavours to encapsulate the conceptual linkages as specified in the Act, there is some doubt as to whether this reflects the conceptual framework employed more broadly in the literature. In order to objectively assess these propositions we intentionally separate environmental assets (as specified above) from ecosystem services, for the purposes of this report, notwithstanding that the Act places the latter as a subset of the former.

There are also basic problems because several important terms remain undefined by the Act. For instance, the Act separately specified the notion of 'productive base' without offering a clear definition. This term is not widely employed in the literature and there are some grounds for viewing it as a subcomponent of the goal assigned to managing ecosystem services.

The report itself is divided into six additional parts:

- Section 2 defines ecosystem services and the notion of the productive base.
- Section 3 identifies a classification system for ecosystem services as applicable to the Basin.
- Section 4 specifically explains why ecosystem services and the productive base are unlikely to be compromised if KEA and KEF water requirements are not compromised by the ESLT.
- Section 5 is used to analyse risks and gaps.
- Section 6 offers responses to risks identified for the current version of the Plan.
- Section 7 explores options for a more enduring approach to the formulation of the Plan.

2. Conceptual foundations of ecosystem services and the productive base

2.1 Ecosystem services defined

Scientific effort to discuss and define 'ecosystem services' became prevalent in the 1970s, although the concept as such is much older. Mooney and Ehrllich (1997) contend that the concept of ecosystem services owes its formal origin to the term 'environmental services' which first appeared in a 1970 report titled *Study of Environmental Problems.*

Later, ecosystem functions that assist humans became known as ‘public service functions of the global environment’, ‘nature’s services’ and then progressively refined to ‘ecosystem services’ in 1981 (Mooney and Ehrlich 1997).

These definitions of ecosystem services are unequivocally anthropocentric because they focus on the fundamental needs of humans, needs which are derived from ecosystems –in the form of subsistence, protection, understanding, leisure, creation, identity and freedom (Max-Neef 1991).

Costanza et al. (1997) defines ecosystem services as the benefits human populations derive, directly or indirectly, from ecosystem functions. Daily (1997) defines ecosystem services as ’The wide array of conditions and processes through which ecosystems, and their biodiversity, confer benefits on humanity; these include the production of goods, life-support functions, life fulfilling conditions, and preservation of options’.

However, the most widely accepted contemporary definition of ecosystem services emanates from the Millennium Assessment (2005a) which simply states that ’ecosystem services are the benefits people obtain from ecosystems’. The Millennium Ecosystem Assessment (MA) (2005b) classifies ecosystem services into four groups including:

- **Provisioning services** include those which provide, or produce, goods such as food, fibre, fuel, genetic resources, biochemicals, natural medicines and pharmaceuticals, ornamental resources and fresh water.
- **Regulating services** include benefits gained from regulation of ecosystems such as air quality regulation, climate regulation, water regulation, erosion regulation, water purification and waste treatment, disease regulation, pest regulation, pollination and natural hazard regulation.
- **Cultural services** can include non-material benefits such as cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of space, cultural heritage values and recreation and ecotourism.
- **Supporting services** are those which underpin the other services and include soil formation, photosynthesis, primary production, nutrient cycling and water cycling. (Figure 2).

In the context of this project an ecosystem service would be considered compromised if the ESLT leads to a measurable decline in the service. Any measurable decline in supporting services would lead to the compromise of other ecosystem services. The supply of services is often modified to enhance production of particular goods. This is most often the case with provisioning services which produce food, fibre and water. Many of the provisioning services rely on water extraction or manipulation (i.e. river regulation) often leading to conflicts with environmental objectives. Whilst the ESLT does not directly account for some provisioning services (see section 4), the intent is that sustainable use of water underpins the maintenance of all ecosystem services.

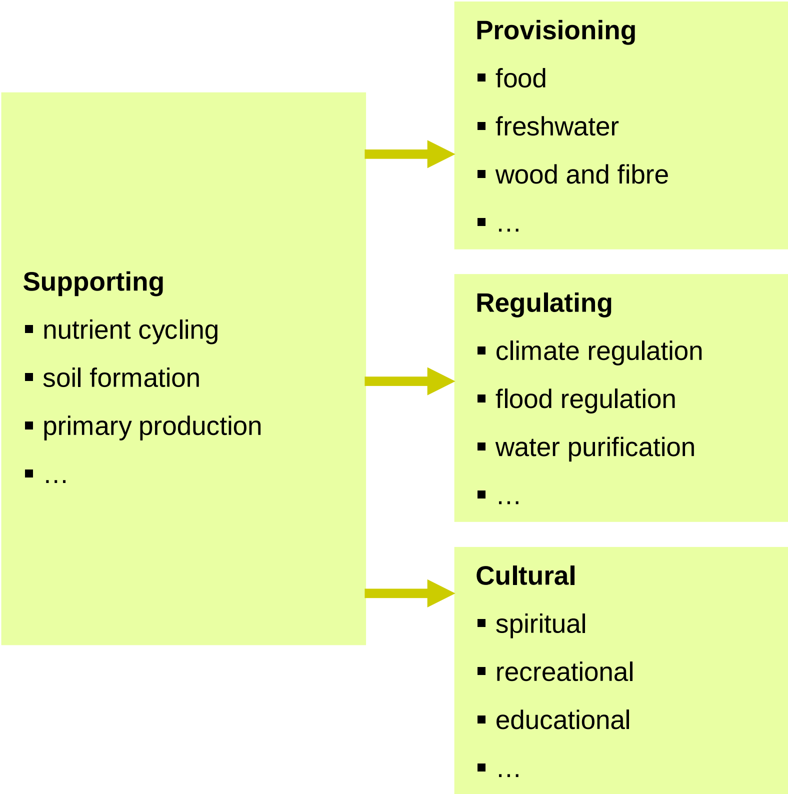

Figure 2: Ecosystem service categories as depicted by MA (2005a)

Given the prominence of humans as the beneficiaries of these services, the Millennium Ecosystem Assessment goes further by defining human well-being as:

> ’Human well-being has multiple constituents, including basic material for a good life, freedom of choice and action, health, good social relations, and security. […] The constituents of well-being, as experienced and perceived by people, are situation dependent, reflecting local geography, culture and ecological circumstances’ (MA 2005c, p. 27).

The notion of ecosystem services has gained widespread support, at least at a conceptual level (see, for example DSE 2008). Regrettably, however, the measurement of these services and their application to management and policy domains remains largely unresolved (ICSU-UNESCO-UNU 2008).

The basic proposition underpinning much of the policy application, of ecosystem services, is that improved or superior ecosystems should, by virtue of the superior ecosystem services, deliver higher states of human well-being (see, for instance, MA 2005b & 2005c).

However, several complicating factors arise. Firstly, if we contemplate ecosystem services as deriving from ecosystem *condition* and *processes* (as in the case of Daily (1997)), it no longer becomes feasible to simply link the calibre of ecosystem condition (however measured) with higher states of human well-being. In this case, the calibre of processes must also be included in the equation[2].

[2] Ramsar (2008) has adopted a scheme that differs slightly: ecosystem components, processes and services. Whilst not specifically addressed in this report, some aspects of the Ramsar approach are given greater attention later.

Ecosystem processes relate to system dynamics and the mechanisms that underpin them. Ecosystem processes are provided by ecosystem functions, at least as defined by MDBA.

There is some variation in the literature around the nomenclature employed for these activities. However, for the task at hand it is useful to consider Daily's (1997) notion of 'ecosystem condition' to align with the MDBA's ambition of 'not compromising KEA'. Ecosystem processes, as described by Daily (1997), align with the intention to 'not compromise KEF'.

It is important to understand that there are many challenges to tracing the relationship between components of an ecosystem and ecosystem services. Numerous limitations are described in the literature including feedback effects (Tallis and Kareiva 2006), complexities of scale and time (Rodriguez et al. 2006) and trade-offs between ecosystem services (Nelson et al 2008). [3]

Ecosystem services are the benefits that humans obtain from ecosystems. They can be divided into provisioning, regulating, supporting and cultural services. They are influenced by ecosystem condition and ecosystem processes. This broadly aligns with the notions of KEA and KEF respectively, as presently interpreted by the MDBA. Tracing the relationship between the value of ecosystem services[4] and ecosystem performance is no simple task.

[3] These issues are addressed in more detail later in the report.
[4] We argue later that understanding 'value' of ecosystem services is important since this provides a basis for measuring whether such services risk being compromised.

2.2 The productive base defined: relationship between ecosystem services and the productive base

Although somewhat reductionist in character, the conceptual framework offered by Cork et al. (2001) offers a useful starting point for considering the relationship between the productive base and the concept of ecosystem services. This is reproduced as Figure 3 for convenience.

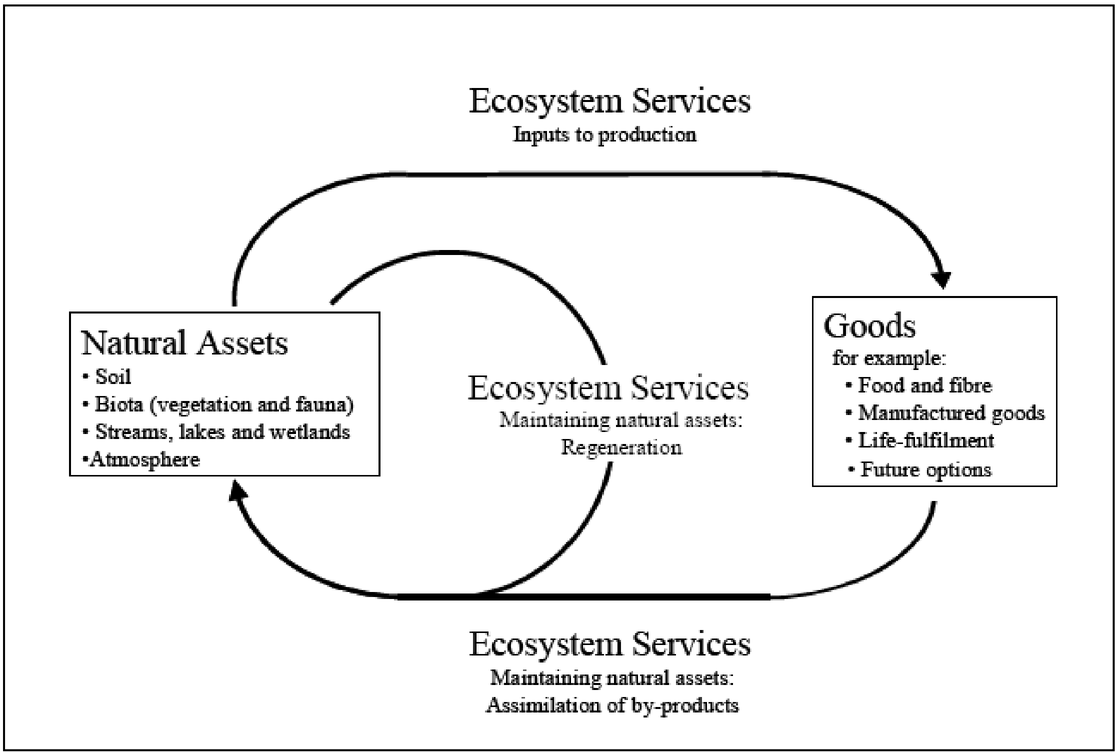

Figure 3: Conceptual framework defining ecosystem services as three types of transformations (Source: Cork et al. 2001, p. 157).

Cork et al. (2001) deployed the model in Figure 3 in an effort to engage with a range of stakeholders who lacked specialist ecological knowledge. The aim was to familiarise the stakeholders with the ecosystem services concept. Starting with Natural Assets and moving clockwise, the first flow of ecosystem services relates to the conversion of natural assets into goods. This flow loosely equates to the provisioning services defined in the MA (2005b). The assimilation of by-products back into the natural assets is the second service and might be considered analogous to regulating services. The third transformation is the internal regeneration among natural assets which is required to maintain them. This approximates the notion of supporting services. Cultural services are more difficult to overtly conceptualise in this model but can be considered as the broader benefits accrued by humans appreciating the fact that the other services are being delivered. This could include Indigenous appreciation of service delivery.

As noted earlier, the Water Act requires that the ESLT does not compromise the productive base or ecosystem services offered by the Basin's water resources. The productive base is not defined in the Act and is a term not widely employed in the literature. To date, the MDBA has employed the following definition:

> ’The productive base of a water resource is the support offered by ecosystems, ecosystem functions and ecosystems services of that water resource to human economic and social production’ (MDBA website 2009).

Notwithstanding the effort to define the productive base, ambiguity around the notion of the productive base (and other related concepts) persists. This confusion was succinctly encapsulated by Hamstead (2009) when undertaking some recent work on behalf of the National Water Commission:

> ‘The terms “key environmental assets, or ecosystem function and productive base of the resource” seem to be a grab bag of terms intended to capture the attributes of a river or aquifer system that underpin its capacity to meet “environmental and other public benefit outcomes” as well as supply water for towns, industry and agriculture’ (Hamstead 2009, p. 15).

Pointedly, Hamstead (2009, p. 15) asks ’Does the “productive base” refer to the capacity to supply water quantity and quality for economic purposes, or does it refer to ecologic primary production purposes?’[5].

In the context of the conceptual model offered by Cork et al. (see Figure 3), the former interpretation (i.e. economic purposes[6]) would appear to pertain largely to the transformation of natural assets into goods, which we have argued is analogous to provisioning services under the MA (2005b). If this is taken as the definition of the productive base then this simply equates to ensuring the delivery of one form of ecosystem service.

If the definition of productive base pertains to ecologic primary production, then the other two transformational processes in Figure 3 (i.e. regulating and supporting services) come into play. Cultural services are similarly delivered by the maintenance of the productive base. Needless to add, there is little clear distinction between the maintenance of ecosystem services and the preservation of the productive base[7].

Hamstead (2009, p. 37) contends that the productive base could be lost if natural storage is lost or water quality diminishes to the point where the resource is of no practical use. Examples offered in this context include the compaction of aquifers, extensive eutrophication and salinisation. Importantly, Hamstead (2009, p. 37) notes that ‘Of course, these same attributes (that lead to diminution of the productive base) also underpin ecosystem functioning and the condition of ecological assets’. And thus, in this interpretation, protecting the productive base is no different to protecting ecosystem functions and ecological assets.

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[5] Notwithstanding the importance of the distinction, there are other important nuances not addressed by Hamstead here. For example, ecological concepts of production (growth, vigour, primary and secondary production, biomass, standing crop, etc) are not defined or distinguished.

[6] An assumption here is that Hamstead interprets ‘economic’ in a relatively narrow way.

[7] Of course this does not resolve other rudimentary issues, like defining the maximum risk one is willing to bear should it be deemed appropriate to deplete the productive base temporarily with a view to it regenerating at some point in the future. It is not feasible to deal with this question within this report although additional work in this field is recommended.

The notion of the productive base is not widely employed or well-supported by the literature[8]. Taken broadly it equates to ensuring that provisioning, regulating, supporting and cultural services are also supported. There would appear to be little to be gained by endeavouring to separately distinguish threats to ecosystem services from threats to the productive base and henceforth they are treated synonymously. Thus if not compromising KEA and KEF results in the delivery of ecosystem services, there are grounds for arguing that the productive base will also avoid compromise under these conditions.

3 Ecosystem services: terminology and classifications

3.1 Definitions and existing classifications

As seen in the previous section there are a number of definitions for ecosystem services currently on offer (Daily 1997; Costanza et al. 1997; MA 2005a & 2005c). For the purposes of the Basin Plan and the implementation of the Water Act, ecosystems services are defined in accordance with the Millennium Ecosystem Assessment. This has subsequently been adopted by the Ramsar Convention (Ramsar Convention 2005 Resolution 1X.1 Annex A).

All ecosystem services are interrelated to some degree and classification of ecosystem services can be undertaken in a number of ways (Costanza 2008). However, one size does not fit all (Costanza 2008; Fisher et al. 2008; Limburg 2009). Thus, while the MA provides presumably the most widely accepted categorisation (i.e. provisioning, regulating, cultural and supporting services) it is important to understand that these categories were developed, in part, with the aim of simply promoting general acceptance of the concept itself.

Several additional and arguably more context-specific classifications have been derived from the Millennium Ecosystem Assessment. These include the classification of ecosystem services for describing the ecological character of Ramsar sites (e.g. DEWHA 2008; Bruaman et al. 2007; Ramsar 2009). In contrast to the MA list of services, the DEWHA national framework for describing ecological character includes 13 supporting services, which reflect an emphasis on the ecological attributes of Ramsar wetlands. The ecosystem services described for wetlands by the MA, DEWHA (2008) and the Ramsar Convention (2009) are shown in Table 1.

[8] Economists would be familiar with the notion as representing the status of inputs (land, labour, capital and enterprise) from which outputs could be generated but there are few equivalent uses in the ecological literature.

Table 1: MA ecosystem services for wetlands and derived classifications (MA 2005b; DEWHA 2008; Ramsar 2009 Resolution X.15)

MA service category	MA Wetland specific	DEWHA (2008)	Ramsar (2009)
Provisioning services	• Food (Production of fish, wild game, fruits and grains) • Freshwater (Storage and retention of water for domestic, industrial and agricultural use) • Fibre and fuel (Production of logs, fuel wood, peat, fodder) • Biochemical (Extraction of medicines and other materials from biota) • Genetic material (Genetic resistance to plant pathogens, ornamental species and so on)	• Water supply • Drinking water • Domestic farm water supply • Stock watering • Irrigation • Aquaculture • Provision of aquatic foods for human consumption • Wetland products, such as animal and plant material • Biochemical products • Genetic resources • Ornamental species	• Drinking water for humans and or livestock • Water for irrigated agriculture • Water for industry • Food for humans • Food for livestock • Wood, reed, fibre and peat • Medicinal products • Other products and resources, including genetic material
Regulating services	• Climate regulation (Sources of and sink for greenhouse gases, influence local and regional temperature, precipitation and other climatic processes) • Water regulation (hydrological flows) (Groundwater recharge/discharge) • Water purification and waste treatment (Retention, recovery and removal of excess nutrients and other pollutants) • Erosion regulation (Retention of soils and sediments) • Natural hazard regulation (Flood control, storm protection) • Pollination (Habitat for pollinators)	• Maintenance and regulation of hydrological cycles and regimes • Maintenance and regulation of air quality • Maintenance and regulation of climate • Coastal shoreline stabilisation and storm protection • Bank stabilisation and erosion protection • Biological control of pest species and diseases and support of predators of agricultural pests • Pollution control and detoxification through trapping, storage and/or treatment of contaminants • Natural hazard reduction	• Groundwater replenishment • Water purification/waste treatment or dilution • Biological control agents for pests/ disease • Flood control, flood storage • Soil, sediment and nutrient retention • Coastal shoreline and river bank stabilisation and storm protection • Other hydrological services • Local climate regulations/buffering of change • Carbon storage/sequestration

MA service category	**MA Wetland specific**	**DEWHA (2008)**	**Ramsar (2009)**
Cultural services	• Spiritual and inspirational (Source of inspiration, many religions attach spiritual and religious values to aspects of wetland ecosystems) • Recreation (Opportunities for recreational activities) • Aesthetic (Many people find beauty or aesthetic value in aspects of wetland ecosystems) • Educational (Opportunities for formal and informal education and training)	• Recreation • Tourism • Science and education • Aesthetic amenity (including unique or representative land and waterscapes) • Cultural heritage and identity • Spiritual and inspirational	• Recreational hunting and fishing • Water sports • Nature study pursuits • Other recreation and tourism • Educational values • Cultural heritage • Contemporary cultural significance • Aesthetic and sense of place values • Spiritual and religious values • Important knowledge systems and importance for research
Supporting services	• Soil formation (Sediment retention and accumulation of organic matter) • Nutrient cycling (Storage, recycling, processing and acquisition of nutrients)	• Hydrological processes • Food webs • Physical habitat • Nutrient cycling • Primary production • Sediment trapping, stabilisation and soil formation • Biodiversity • Special ecological, physical or geomorphic features • Distinct or unique wetland species • Threatened wetland species, habitats and ecosystems • Priority wetland species and ecosystems • Natural or near-natural wetland ecosystems • Ecological connectivity	None identified as services: Nutrient cycling and primary production are identified as processes.

3.2 Classification of ecosystem services for the Basin Plan

The classification recommended for the initial phase of the Basin Plan is one based on the broad categories of the MA, but also employs specific examples as described by DEWHA (2008) and Ramsar (2009). These relate to the ecosystem services provided by water-dependent ecosystems, and with greater acknowledgement and management attention given to, sites with ecological significance.

It is important to note that both the DEWHA and Ramsar classification systems were developed for describing ecological character. The services included in each classification relate to the Ramsar criteria for listing a site of international importance, as well as attempting to clarify how to describe 'components, processes and services' for maintaining ecological character.

The Ramsar approach represents an attempt to reduce the overlap between ecological processes/functions and ecosystem services. The DEWHA approach includes non-human environmental benefits as well as human benefits. As both of these classifications are based on water dependent ecosystems they are considered well-suited to form the basis of a classification for the Plan.

The guiding principles underlying the approach to ESLT and other key parts to the Plan have been employed to develop the classification of ecosystem services. These include:

- ensuring consistency with the Water Act
- focussing on services that are well defined
- adding additional services not captured in DEWHA (2008) or Ramsar (2009) where appropriate.

KEF and KEA were both considered in selecting the final list of ecosystem services.

KEA are defined by the *Water Act 2007* to include water dependent ecosystems, sites with ecological significance and ecosystem services[9]. The criteria used to identify KEA appear in Table 2.

Table 2: Criteria used to identify key environmental assets (MDBA 2010)

Criterion 1	The water-dependent ecosystem is formally recognised in, and/or is capable of supporting species listed in, international agreements and/or
Criterion 2	The water-dependent ecosystem is natural or near-natural, rare or unique and/or
Criterion 3	The water-dependent ecosystem provides vital habitat and/or
Criterion 4	The water-dependent ecosystem supports Commonwealth, State or Territory listed threatened species and/or ecological communities and/or
Criterion 5	The water-dependent ecosystem supports or is capable of supporting significant biodiversity.

[9] We noted earlier that for the purposes of testing the hypothesis offered in section 1, we treat ecosystem services separately from KEA in this report.

DEWHA (2008) define ecosystem functions as the dynamic forces within an ecosystem and include processes that occur between organisms, within and between populations and communities, and interactions with the abiotic environment that result in existing ecosystems and bring about changes in ecosystems over time (AHC 2002). Based on a set of three criteria, and using a geomorphic framework, three main groups of key ecosystem functions were identified (see Table 3). Groundwater related services are included in this classification.

The legislative requirement of the Basin Plan is to provide only for the management of the Basin water resources. Accordingly, in this report, analysis has been limited to a consideration of those ecosystem functions that only relate to hydrology (flow). This is also reflected in the formulation of KEF reported in Table 3.

Table 3: Key ecosystem functions (from MDBA 2009b)

Main grouping – large scale physical processes	Specific functions
1. Creation and maintenance of bed, bank and riparian habitat	1.1 Disturbance through cease to flow periods
	1.2 Disturbance and wetting through overbank flows
	1.3 Provide wetted habitat diversity in pool environments
	1.4 Provide wetted habitat in riffle and run environments
	1.5 Provide appropriate wetted habitats heterogeneity within a reach (creation of diverse hydraulic features/conditions)
	1.6 Provide in-channel habitat features within a reach (point bars and benches)
2. Sediment mobilisation, transport and dispersal	2.1 Organic and inorganic sediment delivery to downstream reaches (debris flows, scouring, flushing or fine sediments)
	2.2 Sediment delivery to and from floodplains
	2.3 Dilute carbon and nutrients from litter and soil on the floodplain that has been returned to the river systems
3. Lateral and longitudinal connectivity to maintain populations	3.1 Migration to fulfil requirements of life-history stages (drift, breeding, recolonisation, foraging)
	3.2 Instream primary production by periphyton, phytoplankton and biofilms.

Because of the complexities of classifying ecosystem services and the time and resource constraints circumscribing the development of the Plan, it has not been possible to comprehensively test the suitability of this classification. This will require greater attention as subsequent iterations of the Plan are developed. In essence, it is important to ensure all relevant ecosystem services are captured in the KEA and KEF approach[10].

[10] This is given closer attention later in the report.

Similarly, ensuring that all elements of the Productive Base are adequately met will require active monitoring and assessment, notwithstanding our earlier observation that these are essentially synonymous. The recommended classification of ecosystem services arising from this process is presented in Table 4.

Table 4: Classification of ecosystem services based on the benefits that people receive from the Key Environmental Assets and Key Ecosystem Functions identified by the MDBA. (Note the codes depicted in column 3 are employed throughout subsequent sections of this report)

	Category	**Ecosystem services**
Productive Base	Provisioning services	Drinking water for humans and/or livestock (P1) Water for irrigated agriculture (P2) Water for industry (P3) Food for humans (P4) Food for livestock (P5) Wood, reed, fibre and peat (P6) Medicinal products (P7) Other products and resources, including genetic material (P8)
	Regulating services	Groundwater replenishment (R1) Water purification/waste treatment or dilution (R2) Biological control agents for pests/disease (R3) Flood control, flood storage (R4) Coastal shoreline and river bank stabilisation and storm protection (R5) Other hydrological services (R6) Local climate regulations/buffering of change (R7) Carbon storage/sequestration (R8 Hydrological maintenance of biogeochemical processes (R9)
	Supporting services	Nutrient cycling (S1) Primary productivity (S2) Sediment trapping, stabilisation and soil formation (S3) Physical habitat (S4) Systemic consequence (ecological surprise); maintenance of desirable state (S5) Natural or near-natural wetland ecosystems (incorporates concept of resilience) (S6) Priority wetland species and ecosystems (S7) Ecological connectivity (S8) Threatened wetland species, habitats and ecosystems (S9)
	Cultural services	Science and education values (C1) Cultural heritage and identity (C2) Contemporary cultural significance (C3) Aesthetic and sense of place values (C4) Spiritual, inspirational and religious values (C5)

It has been possible to formulate an ecosystem services classification for the Basin Plan. The proposed classification makes use of the existing work in the field. There is insufficient scope to test all elements of this approach although it is possible to make some defensible qualitative judgements about the ecosystem services pertinent to the plan.

3.3 Ecosystem services within the MDB

This section contains a qualitative description of the Basin's ecosystem services, as broadly categorised in Table 4. The description focuses on industries and activities in the Murray-Darling Basin that benefit from ecosystem services.[11]

3.3.1 Ecosystem services by industry and activity

The work reported here was undertaken in three steps.

Step A: Industries and activities demonstrating a clear link between the consumptive or non-consumptive values of water were first grouped in a meaningful way that nonetheless acknowledges their diversity. These classifications followed trends in the literature and, of particular consideration, is the statistical report on water in the Murray-Darling Basin provided by Pink (2008). This step led to six main industry sectors being identified:

1. Irrigated agriculture – separated according to the type of commodity produced: dairy farming; pasture for other livestock; cotton; rice; cereals (excluding rice); vegetables; grapes; fruit (excluding grapes); and other agriculture.
2. Forestry – separated according to the type of forestry activity and setting: agroforestry; plantation forestry; intensively managed native forestry; less intensively managed native forestry; and conservation forestry.
3. Fisheries - separated according to the type of fishery activity and setting: commercial native fisheries (estuarine or oceanic); commercial native inland fisheries; aquaculture; and recreational fisheries.
4. Mining, energy, water industries, manufacturing and other industries
5. Tourism and Recreation – separated according to the degree of development required by the visitor.
6. Education and Residential development separated into consumptive and non-consumptive uses of water.

It is important to note four caveats at this point. Firstly, we recognise that accounting for things like the productive base and ecosystem services conforms to a world view of nature and the environment in modernised societies and one which is pervasive in government systems. However, it does not necessarily conform to the modern and traditional views held by Indigenous peoples and we recommend that the MDBA ensures that these views and perspectives are sought through proper channels, rather than run the risk of excluding important Indigenous viewpoints.

Secondly, non-irrigated agriculture is not considered in this report. The rationale for excluding this sector relates to the limited understanding of the sector's call on surface and groundwater, at least at a scale that is useful for the development of the plan (see, for example, Nordblom et al. 2010). But this does not mean that the sector is not relevant to the MDB, nor does it mean that the sector would not change or benefit from a redistribution of the 'take' of water. We recommend that this sector be considered in the future.

[11] This part specifically addresses Task C of the original Project Brief

Thirdly, Education and Residential Development are considered together in this instance, mainly because they are co-located and, at least in part, have the same ecosystem service considerations. These considerations also tend to be proportional to human population size. However, Education and Residential Development place different demands on the productive base and the degrees to which they draw on different ecosystem services will vary. Some attempt has been made here to highlight these differences.

Finally, one of the largest ‘consumers’ of water in the MDB is that which is unaccounted for during delivery – also termed ‘conveyance water’. By convention, this is included in industry sector 4 as ‘other industries’ although this is clearly an area for further work.

Step B: The ecosystem features desired for the operation of the separated industry, sector or activity types were then documented. This is based on the available literature for each industry/sector/activity. The desired ecosystem features represent those that are required for the industry/activity to continue to deliver its outputs.

Step C: The desirable water-dependent ecosystem features were then matched with ecosystem service requirements. These were organised under several headings: Water, Soils, Biodiversity and Industry Infrastructure and so on. The mechanisms by which a service might be compromised were developed largely on the basis of observation.

The industry/sector/activity analysis follows the order arising from Step A. A summary figure showing how the required ecosystem services are linked to the outputs that are produced is offered initially for each industry. Two tables for each industry/sector/activity follow and provide the substantive rationale behind Steps B and C respectively.

<u>Irrigated agriculture</u>

CULTURAL	
Science and education values	C1
Cultural heritage and identity	C2
Contemporary cultural significance	C3
Aesthetic and sense of place values	C4
Spiritual, inspirational and religious values	C5
PROVISIONING	
Water for domestic/human consumption	P1
Water for irrigated agriculture	P2
Water for industry	P3
Food for humans	P4
Food for livestock	P5
Wood, reed, fibre, and peat	P6
Medicinal products	P7
Other products and resources, including genetic material	P8
REGULATING	
Groundwater replenishment	R1
Water purification/waste treatment or dilution	R2
Biological control agents for pests/ disease	R3
Flood control, flood storage	R4
Coastal shoreline and river bank stabilisation and storm protection	R5
Other hydrological services (soil moisture, evaporation, surface runoff, infiltration etc)	R6
Local climate regulations/ buffering of change	R7
Carbon storage/ sequestration	R8
Hydrological maintenance of biogeochemical processes	R9
SUPPORTING	
Nutrient cycling	S1
Primary productivity	S2
Sediment trapping, stabilisation and soil formation	S3
Physical habitat	S4
Systemic consequence (ecological surprise); maintenance of desirable state	S5
Natural or near-natural wetland ecosystems (incorporates concept of resilience)	S6
Priority wetland species and ecosystems	S7
Ecological connectivity	S8
Threatened wetland species, habitats and ecosystems	S9

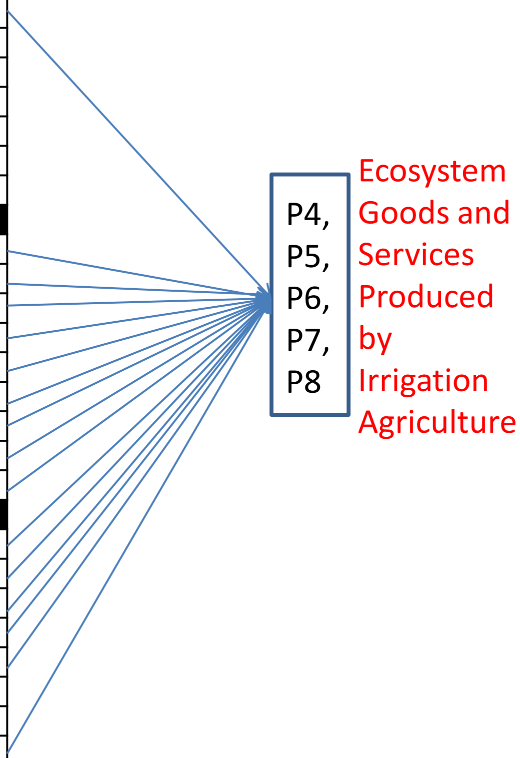

Figure 4: Ecosystem services required for Irrigated agriculture.

Table 5a: Irrigated Agriculture settings for aquatic ecosystem services.

Irrigated Agricultural Commodity	Dairy farming -a	Pasture for other livestock -b	Cotton	Rice	Cereals (excl rice)	Vegetables	Grapes	Fruit (excl grapes)	Other agriculture -c
**Ecosystem service derived	P4, P5	P5	P6	P4	P4, P5	P4	P4	P4	P4, P5, P6, P7, P8
Drivers	Climate and rainfall variability								
*Volume of water consumed 2005-2006 (GL)	1287	1284	1574	1252	782	152	515	413	461
Growth and seasonality	Annual pastures mainly	Annual pastures mainly	Annual	Annual (Oct – Mar)	Annual	Annual but all year	Perennial	Perennial	Annual and perennial
*Predominant State/Region (%water consumed for MDB)	NSW/ACT (13%) VIC (82%)	NSW/ACT (53%), VIC (41%)	NSW/ACT (72%) QLD (28%)	NSW/ACT (99)	NSW/ACT (79%) VIC (11%) QLD (10%)	NSW/ACT (39%) VIC (24%) SA (30%)	NSW/ACT (35%) VIC (35%) SA (30%)	NSW/ACT (30%) VIC (40%) SA (28%)	NSW/ACT (64%) VIC (17%) QLD (14%)
Coarse physiography	Uplands and slopes, lowlands	Uplands and slopes, lowlands	Inland, flatter alluvial areas	Lowlands and floodplains	Floodplains	Mainly floodplains; Variable	Slopes	Flood-plains	Variable
Main desired ecosystem features for growth, production and harvest	Conditions suitable for (maximising) primary production: Biologically functional soils Fertile soils Nutrient retention Water supply Fresh clean water for drinking and washing Absence of weeds Absence of competing grazers Availability of genetic resources (local and introduced for biological functioning; usually introduced for stock and pasture) Cool temperatures (dairy) (Natural) infrastructure capability for water channels		Conditions suitable for (maximising) primary production: Long frost–free period (cotton) Sunshine (cotton) Mainly fertile deep alluvial dark clay soils (cotton) Heavy clay soils that minimise seepage into water tables (rice) Fertile soils Soil nutrients Biologically functional soils Absence of weeds, pests and diseases Presence of pollinators Availability of genetic resources (local and introduced for biological functioning; usually introduced for crops) Water 'fit for purpose' as required by activity Moderate rainfall or diverted water supply (Natural) infrastructure capability for water channels			Conditions suitable for (maximising) primary production: Biologically functional soils Well-drained soils Absence of weeds, pests and diseases Availability of genetic resources (local and introduced for biological functioning; usually introduced for crops) Presence of pollinators Water supply Various requirements depending on commodity			

*Statistics taken from Water and the Murray Darling Basin Statistical Profile 2000-2001 to 2005-2006 (Pink 2008)
a – irrigated pasture for grazing, hay and seed production; livestock drinking and shed washdown
b – irrigated pasture for grazing, hay and seed
c - broadacre crops, nurseries, livestock (other than dairy), drinking

Table 5b: Features associated with water and wetland ecosystems of relevance for IRRIGATED AGRICULTURE, showing the ecosystem services that support, provide or emanate from them and the processes that compromise them. Desirable aquatic ecosystem features from Table 1. Ecosystem services are those adopted for this report.

Desirable/required aquatic ecosystem features for Irrigated Agriculture	Ecosystem service(s) required for Irrigated Agriculture	Processes that change the feature (i.e. compromise the ecosystem service)
CLIMATE		
Long frost–free period	**R7**	Global climate changes are projected to shift temperature, evaporation and rainfall patterns from those historically experienced, and which directly affects the agriculture already established locally). These conditions may have been enhanced, or perhaps caused (via a feedback loop), by changes in land use.
Sunshine	**R7**	
Cool temperatures	**R7, R8, S5**	
Rainfall (seasonal)	**R7, R8, S5**	
WATER		
Water supply (volume appropriate for commodity) surface water – runoff and storage	**P2, R4**	Overallocation and overextraction.
Water supply (volume appropriate for commodity) groundwater	**P2, R1**	Overallocation and overextraction.
Water supply (timing appropriate for commodity)	**P2, R4**	Overallocation and overextraction.
Water quality (appropriate for commodity)	**P2, R2**	Eutrophication leading to blue green algal blooms, mobilisation of toxic materials used in industry, sedimentation, (also as for salt and acidity below). Over application of pesticides and herbicides.
Soil moisture	**R6, R8**	Drought, compaction of soil, loss of organics, inappropriate mechanical disturbance
Absence of excess salts	**R9, S5**	Clearing of native vegetation (dryland salinity), irrigation (evaporation)
Absence of excess acidity	**R9, S5**	For acidity, oxidised sulphidic sediments by drought, exacerbated by salinisation and/or mechanical disturbance of acid sulphate soils or elevated nitrates.
SOIL		
Fertile deep alluvial dark clay soils	**S1, S3,**	Soil erosion
Fertile soils	**S1, S3, R8**	Soil erosion
Nutrient retention	**S1, R9**	Soil erosion. Over application of rapid release fertilisers.
Well-drained soils	**R6, S3**	Soil compaction (cattle, tilling, other mechanical)
BIODIVERSITY		
Absence of weeds, pests and diseases	**S8, R3, S6**	Poor land management practices
Biologically functional soils	**R9, S3, R3, S6**	Over application of pesticides and herbicides. Soil compaction
Absence of competing grazers	**S5, R3**	Disrupted trophic systems (overabundance of herbivores – vertebrate or invertebrate); introduced feral herbivores
Availability of genetic resources	**P7**	Loss of habitat
Presence of pollinators	**Sx, S4, S8**	Loss of habitat
IRRIGATION FACILITIES and INFRASTRUCTURE		
(Natural) infrastructure capability for water channels, dam wall locations etc	**R5, R6, S4**	Land subsidence

Forestry

CULTURAL	
Science and education values	C1
Cultural heritage and identity	C2
Contemporary cultural significance	C3
Aesthetic and sense of place values	C4
Spiritual, inspirational and religious values	C5
PROVISIONING	
Drinking water for humans and or livestock	P1
Water for irrigated agriculture	P2
Water for industry	P3
Food for humans	P4
Food for livestock	P5
Wood, reed, fibre, and peat	P6
Medicinal products	P7
Other products and resources, including genetic material	P8
REGULATING	
Groundwater replenishment	R1
Water purification/waste treatment or dilution	R2
Biological control agents for pests/ disease	R3
Flood control, flood storage	R4
Coastal shoreline and river bank stabilisation and storm protection	R5
Other hydrological services (soil moisture, evaporation, surface runoff, infiltration etc)	R6
Local climate regulations/ buffering of change	R7
Carbon storage/ sequestration	R8
Hydrological maintenance of biogeochemical processes	R9
SUPPORTING	
Nutrient cycling	S1
Primary productivity	S2
Sediment trapping, stabilisation and soil formation	S3
Physical habitat	S4
Systemic consequence (ecological surprise); maintenance of desirable state	S5
Natural or near-natural wetland ecosystems (incorporates concept of resilience)	S6
Priority wetland species and ecosystems	S7
Ecological connectivity	S8
Threatened wetland species, habitats and ecosystems	S9

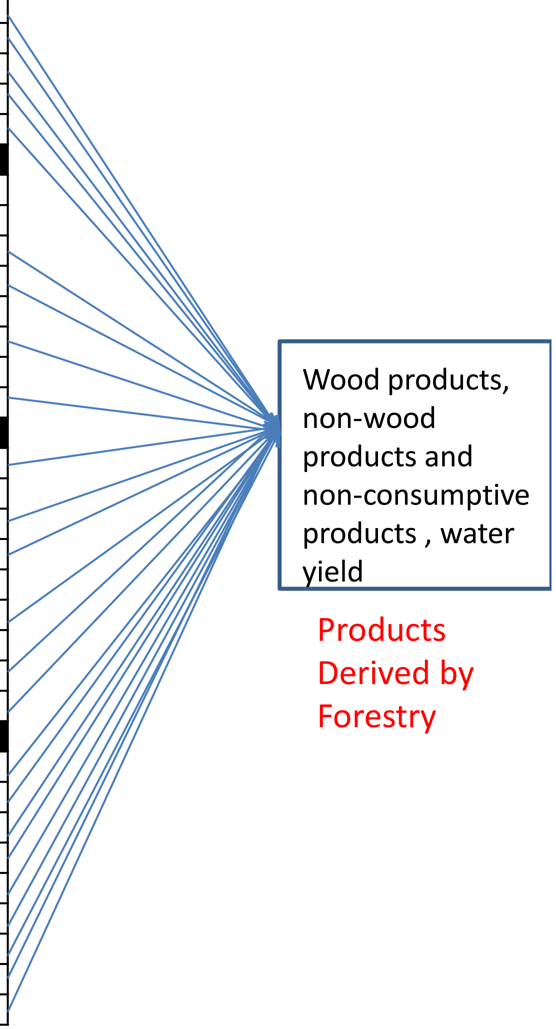

Figure 5: Ecosystem services required for Forestry products.

Table 6a: Forestry as settings for ecosystem services.

Activity/Industry Setting	Agroforestry	Plantation forestry	Intensively managed native forestry	Less intensively managed native forestry	Conservation forestry
Ecosystem service derived*	Wood products (hardwood and softwood sawlog and pulpwood)	Wood products (hardwood and softwood sawlog and pulpwood)	Hardwood sawlog and pulpwood Other non-wood products	Water for harvesting/consumption Other non-wood products Hardwood sawlog	Mainly supporting services
Land use/ownership	Mainly private land	Mainly public land	State forests (or private land)	State forests (or private land)	State forests
Access infrastructure	Access for mechanical harvesting, roads	Access for mechanical harvesting, roads	Access for harvesting, snig tracks, roads	Access for harvesting, snig tracks, tracks, roads	
Ecosystem features desired to deliver products (terrestrial: not necessarily Water and Aquatic ecosystem features)	Capacity to deliver wood products Adequate conditions for growth: Soil moisture (and appropriately drained soils) Soil fertility Nutrient retention Soil micronutrients Seed and seedling supply (appropriate genetic stock) Absence of fire Absence of weeds, pests and disease		Capacity to deliver water and wood products Capacity to deliver non-wood products Capacity to provide non-consumptive uses Adequate conditions for growth: Soil moisture (and appropriately drained soils) Soil fertility Nutrient cycling Soil micronutrients Seed and seedling supply (appropriate genetic stock) Appropriate fire regimes Absence or suppression of diseases, pests and other introduced organisms Decomposition of organic matter		Capacity to provide non-consumptive uses (scientific, educational, cultural, spiritual, etc. values) Capacity to provide for the perpetuation of biodiversity values All ecosystem processes: Competition Predation Nutrient cycling Water cycling Decomposition of organic matter Photosynthesis Pollination Parasitism Fire Suppression of diseases, pests and other introduced organisms

Table 6b: Features associated with water and wetland ecosystems noticeably relevant to forestry and fisheries, showing the ecosystem services that support, provide or emanate from them and the processes that compromise them. Ecosystem services are those adopted for this report.

Desirable ecosystem features for Forestry	**Ecosystem service(s) relevant for industrial activities**	**Processes that change the feature (i.e. compromise the service)**
WATER		
Sufficient water – runoff, groundwater, storage	**P2, P3, R1, R4**	Drought, overextraction, overallocation
BIODIVERSITY		
Absence or suppression of diseases, pests and other introduced organisms	**R3**	Over application of pesticides and herbicides
Plant (tree) growth	**S2, P5**	Fire, poor drainage, diseases
Seed and seedling supply (appropriate genetic stock)	**P8**	
Non-wood products	**S2**	Overharvesting
Capacity to provide for the perpetuation of biodiversity values	**S4, S6, S7, S8, S9**	Overharvesting, poor forest practices, clear-felling
Ecosystem processes: Competition, predation, photosynthesis, pollination, parasitism etc.	**Supporting services**	Failure to provide for the perpetuation of biodiversity
SOILS		
Decomposition of organic matter	**R8**	Features that degrade soil health: soil compaction, overuse of fire, soil erosion etc.
Soil moisture (and appropriately drained soils)	**R6, R9**	
Soil micronutrients	**S1, R9**	
Nutrient cycling, nutrient retention	**S1**	
Soil fertility	**S1, S3**	
OTHER FACILITIES and INFRASTRUCTURE for FORESTRY		
Materials suitable for roading, landings etc.		
Capacity to provide for non-consumptive uses (different forms of access for different uses)	**C1, C2, C3, C4, C5**	Conversion to production forestry

Green text: those ecosystem services which are exclusive to conservation forests (where production forestry does not play a role)

<u>Fisheries</u>

CULTURAL	
Science and education values	C1
Cultural heritage and identity	C2
Contemporary cultural significance	C3
Aesthetic and sense of place values	C4
Spiritual, inspirational and religious values	C5
PROVISIONING	
Drinking water for humans and or livestock	P1
Water for irrigated agriculture	P2
Water for industry	P3
Food for humans	P4
Food for livestock	P5
Wood, reed, fibre, and peat	P6
Medicinal products	P7
Other products and resources, including genetic material	P8
REGULATING	
Groundwater replenishment	R1
Water purification/waste treatment or dilution	R2
Biological control agents for pests/ disease	R3
Flood control, flood storage	R4
Coastal shoreline and river bank stabilisation and storm protection	R5
Other hydrological services (soil moisture, evaporation, surface runoff, infiltration etc)	R6
Local climate regulations/ buffering of change	R7
Carbon storage/ sequestration	R8
Hydrological maintenance of biogeochemical processes	R9
SUPPORTING	
Nutrient cycling	S1
Primary productivity	S2
Sediment trapping, stabilisation and soil formation	S3
Physical habitat	S4
Systemic consequence (ecological surprise); maintenance of desirable state	S5
Natural or near-natural wetland ecosystems (incorporates concept of resilience)	S6
Priority wetland species and ecosystems	S7
Ecological connectivity	S8
Threatened wetland species, habitats and ecosystems	S9

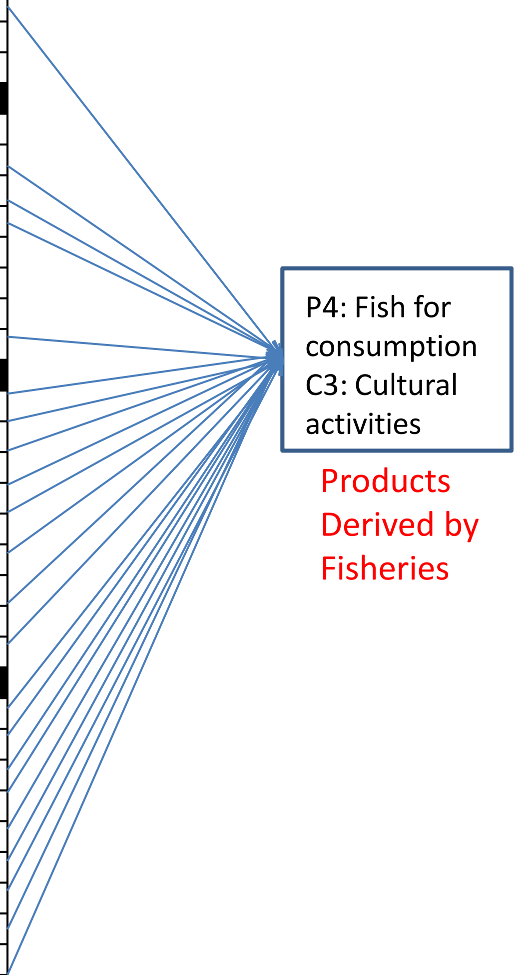

Figure 6: Ecosystem services required for fisheries products.

Table 7a: Fisheries as settings for ecosystem services.

Activity/ Industry Setting	Commercial native fisheries (estuarine or oceanic)	Commercial native inland fisheries	Aquaculture	Recreational fisheries
Ecosystem service derived*	Food for humans	Food for humans, other animals and other uses	Food for humans	Food for humans Cultural - recreation
Location in the MDB	Estuarine, saltwater and freshwater species are harvested from the Wellington ferry to the waters of Lakes Alexandrina and Albert, the Coorong lagoons and estuary, and coastal waters from the Murray Mouth to Kingston.	Commercial fishing for carp in Murray River channels and backwaters e.g. Murrum	Some limited aquaculture in Lake Alexandrina and Lake Albert. Elsewhere in the basin – fish farms are extensively operated. Trout in highland areas of the Basin (mostly Victoria and NSW). Saline trials in irrigation regions (northern Victoria and Southern NSW)	Any significant water body, usually permanent – as for commercial native inland fisheries.
Main species	mulloway, flounder, yellow-eye mullet, cockles, black bream, bony bream, redfin perch, golden perch, European carp, yabbies	Historically Murray cod and golden Perch but now almost exclusively restricted to harvests of carp, with a few licences for redfin perch.	Silver perch (fingerlings for stocking and grow-out). Barcoo grunter (jade perch; native to neighbouring basins/catchments). Murray cod, golden perch and catfish also in farm production. Brown and rainbow trout (and much smaller numbers of Atlantic salmon, brook trout, chinook salmon). Other fish such as barramundi, grown within closed recirculating systems. Saline fish and prawns being trialled. Yabbies are increasingly being produced on a number of fish farms throughout the Basin	European carp (*Cyprinus carpio*), redfin (*Perca*), trout/salmon dominate the recreational harvest. Golden perch, Murray cod and other species including silver perch, freshwater catfish, spangled perch, river blackfish and two-spined blackfish. Also yabbie and River Murray crayfish
Drivers	Climate and rainfall variability	Climate and rainfall variability	Financial overheads Climate and rainfall variability Geology for water delivery	Climate and rainfall variability Human attitudes and behaviour
Water and Aquatic ecosystem features desired to deliver products	Sufficient flows of water into lower lakes and outflow to ocean, including flood waters Appropriate water quality for native species Adequate passage for native fish Adequate stocks of fish species Genetic stocks Appropriate aquatic and riparian habitat for breeding, sheltering, feeding Natural functioning of wetlands and floodplain habitats For native species - control and manage alien fish species Absence of diseases	Sufficient water, sufficient flows Floods Adequate stocks of fish species Genetic stocks Adequate passage for native fish For native species - control and manage alien fish species Appropriate aquatic and riparian habitat for breeding, sheltering, feeding Natural functioning of wetlands and floodplain habitats	Sufficient water Food for fish Adequate stocks of fish species Genetic stocks Clean water (absence of toxicants) Sufficiently oxygenated water Adequate passage for native fish Assimilatory capacity of facilities and infrastructure to assist reduction of nutrient levels in effluent. Absence of diseases Natural infrastructure to deliver water (storage, channels)	Sufficient water, sufficient flows (modification of flow regulation practices) Capacity to deliver sufficient water of the appropriate quality for native species Adequate stocks of fish species Genetic stocks Adequate passage for native fish Appropriate aquatic and riparian habitat for breeding, sheltering, feeding Natural functioning of wetlands and floodplain habitats For native species - control and manage alien fish species Absence of diseases Absence of weeds and pests Access to water bodies

Information sourced from:

http://www.pir.sa.gov.au/fisheries/commercial_fishing/lakes__and__coorong_fishery http://www2.mdbc.gov.au/subs/eResource_book/chapter4/p4.htm

Table 7b: Features associated with water and wetland ecosystems noticeably to be of relevance for fisheries, showing the ecosystem services that support, provide or emanate from them and the processes that compromise them. Ecosystem services are those adopted for this report.

Desirable Aquatic ecosystem features for Fisheries	Ecosystem service(s) relevant for fishing	Processes that change the feature (i.e. compromise the service)
WATER		
Sufficient water – runoff, groundwater, storage	**P3, R1, R4**	Drought, overextraction, overallocation
Environmental flows, including floods	**R4, R6**	Various water flow management measures and water extraction systems have collectively served to modify the structure, productivity and function of the entire ecosystem
Clean water (absence of toxicants, absence of elevated salt concentrations, absence of severe acidity)	**P3, R2, R9, S5**	Eutrophication leading to blue green algal blooms. Mobilisation of toxic materials used in industry. Sedimentation. Over application of pesticides and herbicides. Clearing of native vegetation (dryland salinity); irrigation (evaporation) For acidity, oxidised sulfidic sediments by drought, exacerbated by salinisation, and/or mechanical disturbance of acid sulphate soils, or elevated nitrates
Sufficiently oxygenated water	**R6, R9**	Elevated quantities of organic pollution in low flow situations
BIODIVERSITY		
Adequate stocks of fish species	**P8**	Overharvesting of stock, barriers to migration, barriers to breeding habitat (water regulation to eliminate a type of flood)
Food for fish	**P5, S2, S3, S6**	Trophic alteration due to presence of exotics, poor water quality (including turbidity or presence of an algal bloom)
Genetic stocks	**P8, S9**	Extinction of local populations reduces genetic variability
Appropriate aquatic and riparian habitat for breeding, sheltering, feeding	**S4**	Livestock access to river channels and billabongs, removal of riparian vegetation
Natural functioning of wetlands and floodplain habitats	**S1, S2, S3, S5, S6, S7, S9**	Physical disturbance of habitats, increasing occurrence of alien species
For native species - control and manage alien fish species	**R3, S4, S6**	Alteration of flows and water quality to favour alien species
Absence of diseases	**R3**	Overuse of pesticides, herbicides and other antibiotics
Absence of weeds and pests	**R3**	Destruction of physical habitat
SOILS		
Nutrient release from flood plain sediments and soils (includes decomposition of organic material)	**R8, S3, R6**	Reduction of flows or elimination of particular types of floods. Clearing of floodplain vegetation removes leaf litter and organic supply
FISHING FACILITIES and INFRASTRUCTURE		
Adequate passage for native fish (absence, or infrastructure to move around, barriers to flow and migration)	**S8**	Construction of weirs, locks, dam walls etc.
Natural infrastructure to deliver water (storage, channels)	**R5**	Erosion of river banks
Assimilatory capacity of facilities and infrastructure to assist reduction of nutrient levels in effluent	**R2**	Excessive pollution exceeds assimilatory capacity; biological dysfunction
Access to water bodies	**S4**	Overgrowth of vegetation, including introduced species

Mining, energy, water industry and manufacturing and other industries

CULTURAL	
Science and education values	C1
Cultural heritage and identity	C2
Contemporary cultural significance	C3
Aesthetic and sense of place values	C4
Spiritual, inspirational and religious values	C5
PROVISIONING	
Drinking water for humans and or livestock	P1
Water for irrigated agriculture	P1
Water for industry	P2
Food for humans	P3
Food for livestock	P4
Wood, reed, fibre, and peat	P5
Medicinal products	P6
Other products and resources, including genetic material	P7
REGULATING	
Groundwater replenishment	R1
Water purification/waste treatment or dilution	R2
Biological control agents for pests/ disease	R3
Flood control, flood storage	R4
Coastal shoreline and river bank stabilisation and storm protection	R5
Other hydrological services (soil moisture, evaporation, surface runoff, infiltration etc)	R6
Local climate regulations/ buffering of change	R7
Carbon storage/ sequestration	R8
Hydrological maintenance of biogeochemical processes	R9
SUPPORTING	
Nutrient cycling	S1
Primary productivity	S2
Sediment trapping, stabilisation and soil formation	S3
Physical habitat	S4
Systemic consequence (ecological surprise); maintenance of desirable state	S5
Natural or near-natural wetland ecosystems (incorporates concept of resilience)	S6
Priority wetland species and ecosystems	S7
Ecological connectivity	S8
Threatened wetland species, habitats and ecosystems	S9

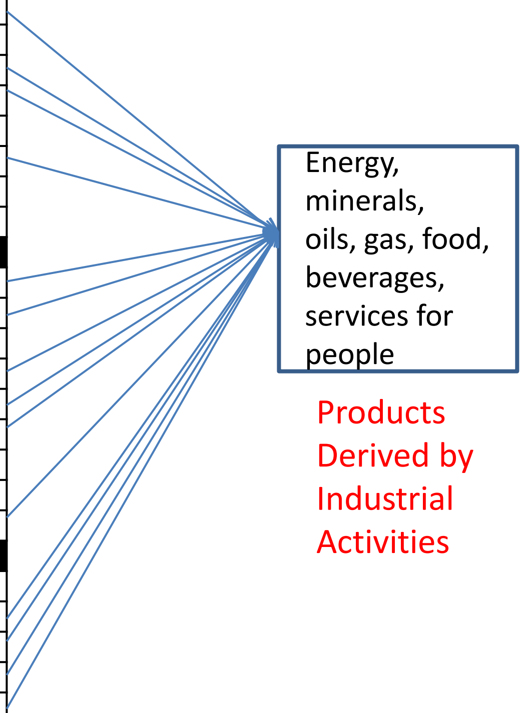

Figure 7: Ecosystem services required for Industrial products.

Table 8a: Mining, energy, water industry and manufacturing and other industries as settings for water and aquatic ecosystem services.

INDUSTRY Setting	Hydro-electricity generation	Water supply industry (irrigation and urban aggregated)	Mining (predominantly metal ore mining)	Manufacturing (predominantly pulp and paper mills, abattoirs and other food manufacturing, dairy factories and breweries)	Other industries (local, state and commonwealth governments, service industries, restaurants, motels, schools and hospitals)
Ecosystem service derived*	NA	(P2 lost not gained)	NA	NA	NA
Proportion of water consumed in the MDB 2004-2005 GL (or % of total)**	15 582	1 246 (13%)	Up to 20 (0.2%)	Up to 53 (0.6%)	(1.6%)
Facilities and expectations of industry with respect to the water/industry setting relationship**	Non-consumptive use, although this usually requires construction of water storage facilities (dams) as well as infrastructure like channels tunnels, dams and generating stations	Water is lost from circulation back to the ecosystem or to another part of the hydrological cycle	Water to facilitate the transport, flotation, grinding and separation of minerals, as well as dust suppression	Water for cooling, cleaning, as a solvent, and as a food or beverage constituent	Water is used for activities such as irrigating parks, gardens and sporting fields, for fire fighting, filling swimming pools and laundry operation
Aquatic ecosystem features desired to deliver water	Sufficient water (principally surface water runoff, plus contribution of groundwater to baseflows)	(Best seen as the features of the ecosystem desired to reduce amount lost): (Reduced) soil porosity and permeability (Reduced) evaporation Increased shade (? from riparian vegetation)	Sufficient water Appropriate water quality Features intrinsic to water itself (wetting capabilities, capacity to dissolve substances, water density, lubrication)	Sufficient water Clean water Ecosystem products needed for manufacturing	Capacity to deliver sufficient water Capacity to deliver clean water

*NA = Not applicable because the product of the industry cannot be interpreted as an ecosystem service or is converted to a form of capital (social, infrastructure or financial) other than natural capital.
**Statistics taken from Water and the Murray Darling Basin Statistical Profile 2000-2001 to 2005-2006 (Pink 2008).
Note: Apart from Agriculture, the largest source of industry and household water consumption in the MDB was water lost or unaccounted for during delivery from water supply sources to end-users (accounting for 13% of total water consumption in the MDB). Water losses can result from evaporation, channel seepage, pipe leakage or bursts, mains flushing and water meter errors. The standard water accounting convention, according to the System of Environmental and Economic Accounting for Water (UN 2007), is to attribute this consumption to the water supply industry. This industry includes both urban and irrigation water suppliers (Pink 2008).

Table 8b: Features associated with water and wetland ecosystems noticeably to be of relevance for industrial activities, showing the ecosystem services that support, provide or emanate from them, the processes that compromise them and the way industrial activities might react to that compromise. Ecosystem services are those adopted for this report.

Desirable aquatic ecosystem features for industrial activities	Ecosystem service(s) relevant for industrial activities	Processes that change the feature (i.e. compromise the service)
WATER		
Sufficient water – runoff, groundwater, storage	**P3, R1, R4**	Drought, overextraction, overallocation
Clean water (absence of toxicants, absence of elevated salt concentrations, absence of severe acidity)	**P3, R2, R9, S5**	Eutrophication leading to blue green algal blooms Mobilisation of toxic materials used in industry Sedimentation Over application of pesticides and herbicides Clearing of native vegetation (dryland salinity), irrigation (evaporation) For acidity, oxidised sulfidic sediments by drought, exacerbated by salinisation, and/or mechanical disturbance of acid sulphate soils or elevated nitrates
Features intrinsic to water itself (wetting capabilities, capacity to dissolve substances, water density, lubrication)	**R6**	Any activity that diminishes the capacity of water to deliver these features, principally pollution
BIODIVERSITY		
Riparian vegetation	**S2, S4**	Removal of shade increases evaporative water losses
Ecosystem products needed for manufacturing	**P4, P6**	
SOILS		
(Reduced) soil porosity and permeability	**S3, R6**	Increased soil porosity and increased soil permeability increases water losses from channels and storages
INDUSTRIAL FACILITIES and INFRASTRUCTURE		
(Natural) infrastructure capability for water channels, dam wall locations, surface water storages etc.	**R5, R6, S4**	Degradation to channel banks increases water loss

Tourism and recreation

CULTURAL	
Science and education values	C1
Cultural heritage and identity	C2
Contemporary cultural significance	C3
Aesthetic and sense of place values	C4
Spiritual, inspirational and religious values	C5
PROVISIONING	
Drinking water for humans and or livestock	P1
Water for irrigated agriculture	P2
Water for industry	P3
Food for humans	P4
Food for livestock	P5
Wood, reed, fibre, and peat	P6
Medicinal products	P7
Other products and resources, including genetic material	P8
REGULATING	
Groundwater replenishment	R1
Water purification/waste treatment or dilution	R2
Biological control agents for pests/ disease	R3
Flood control, flood storage	R4
Coastal shoreline and river bank stabilisation and storm protection	R5
Other hydrological services (soil moisture, evaporation, surface runoff, infiltration etc)	R6
Local climate regulations/ buffering of change	R7
Carbon storage/ sequestration	R8
Hydrological maintenance of biogeochemical processes	R9
SUPPORTING	
Nutrient cycling	S1
Primary productivity	S2
Sediment trapping, stabilisation and soil formation	S3
Physical habitat	S4
Systemic consequence (ecological surprise); maintenance of desirable state	S5
Natural or near-natural wetland ecosystems (incorporates concept of resilience)	S6
Priority wetland species and ecosystems	S7
Ecological connectivity	S8
Threatened wetland species, habitats and ecosystems	S9

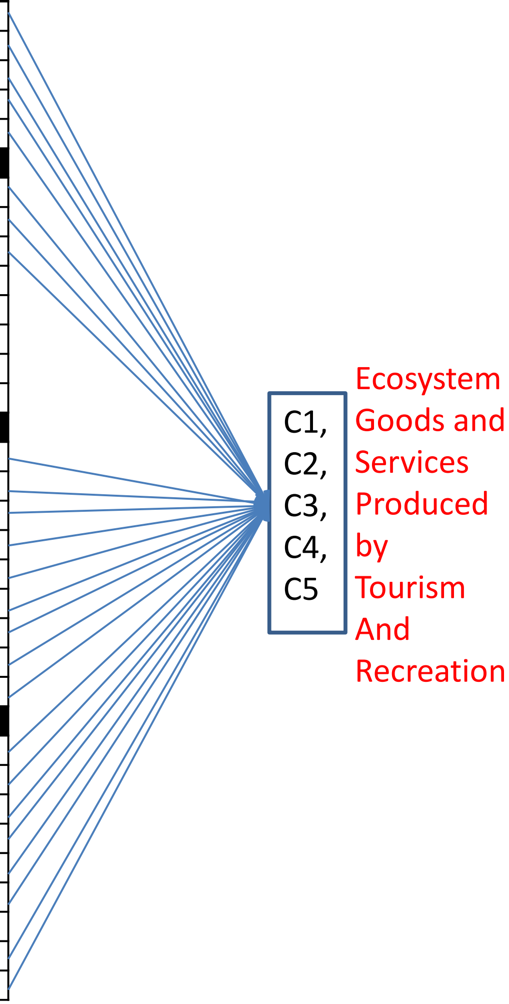

Figure 8: Ecosystem services required for tourism and recreation to derive cultural services.

Table 9a: Visitation for tourism and recreation: industry settings for aquatic ecosystem services adapted from Queensland Outdoor Recreation Foundation: Recreation Setting Classification System.

Degree of development	**Undeveloped**								**Developed**
Industry Setting	Wild and remote places	Limited access, few trails	Rough trails, remote camping and walking	Places usually accessible by vehicle. Tracks are main facility	Formed tracks with cleared areas	Developed camp grounds Or boat homes	Parks, picnic shelters Or ferry/boat cruises	Highly modified agricultural or urban with visitor amenities	Urban, commercial, industrial, without amenities
Visitor activities	Wilderness hiking and camping, swimming, rafting and paddling, convening with nature			Bushwalking, 4WD, fishing, paddling, some small craft boating and fishing, some overnight camping		Overnight and extended camping, boating and fishing	Walking, relaxing, mountain biking, picnicking, sight seeing	Various recreation and/or cultural attractions	Special interest
Visitor type	International and regional, long stays			International, regional, local, long or short stay - including day trips					
Visitor facilities and social expectation	Limited access Sense of isolation Expect few facilities or amenities			Vehicle access Expect to see other visitors Limited facilities and amenities		Easy access Expect to see many other visitors Infrastructure to support recreational activity		Easy access Many visitors Well developed facilities	Few facilities or expectations
Aquatic ecosystem features that are desired or have appeal for visitors (see Table 2)	<u>High appeal:</u> Water quantity (availability of water - consumptive) Water clarity (clear water) Water temperature (seasonal relevance) Water views High (fresh) water quality Absence of toxicants, vector borne and water borne pathogens (and signs of human defecation) Riparian vegetation Locally characteristic plants and animals <u>Desirable but not essential</u> Recreational fishing (native species)			<u>High appeal</u> Water quantity (availability of water - consumptive) Water clarity (clear water) Water temperature (seasonal relevance) Water views Water quality (absence of odours) Absence of toxicants, vector borne and water borne pathogens Emergent plants in water, over-hanging vegetation, riparian shade Absence of tree stumps in water Locally characteristic plants and animals Recreational fishing (native species) <u>Desirable but not essential</u> Absence of toxicants Absence of vector borne pathogens Introduced fish Accessibility to water bodies (short and safe when desired)		<u>High appeal</u> Sufficient water depth Water temperature (seasonal/aseasonal relevance) Water views Water quality (absence of odours) Absence of toxicants, vector borne and water borne pathogens (Absence of) tree stumps in water Recreational fishing (native or introduced) Accessibility to water bodies (short and safe when desired) Other visitors Land-based infrastructure (water, toilets, shelters) <u>Desirable but not essential</u> Water clarity (clear water) Locally characteristic plants and animals Water quantity (availability of water - consumptive) Emergent plants in water, over-hanging vegetation, riparian shade		<u>High appeal</u> Water clarity (clear water) Water views Water quality (absence of odours) Absence of toxicants, vector borne and water borne pathogens (Absence of) tree stumps in water Accessibility to water bodies (short and safe when desired) Other visitors Land-based infrastructure (water, toilets, shelters)	

Table 9b: Features associated with water and wetland ecosystems perceptibly relevant to for tourism and recreation, showing the ecosystem services that support, provide or emanate from them and the processes that compromise them. Parts of the table (processes that change the feature and visitor relationships) have been adapted from Hadwen et al. (2008). Ecosystem services are those used in this report.

Aquatic ecosystem features (that have appeal for visitors)	Ecosystem service(s) relevant for visitation	Processes that change the feature (i.e. compromise the service)
WATER		
Water quantity (availability of water)	**P3, R1**	Drought, overextraction
Sufficient water depth	**P3, R1, R4**	Drought, overextraction
Water clarity (clear water)	**R2, R5, R9**	Sediment delivery – erosion from access points and trails. Catchment disturbance can increase Dissolved Organic Carbon (DOC), nutrients
Water temperature (seasonal/aseasonal relevance)	**R7, R8**	Drought (loss of volume), removal of riparian vegetation Removal of shade
Water views	**P3, R1, R4, R6, C4**	Not enough water from drought and overextraction Too much water from upstream (where flood control/storage compromised)
Water quality (absence of odours)	**R2, S1, S3**	Drought, exposure of previously anaerobic sediments. Eutrophication (nutrient delivery) Shoreline deposition of decaying algae/macrophytes
Absence of toxicants	**R2, R9**	Discharge that over-rides assimilatory and regulatory capacities. Change to biogeochemical processes that results in mobilisation of toxicants
BIODIVERSITY		
Absence of vector borne pathogens	**R2, R3, S3, R4, R6**	Trophic disruption (S): disruption or imbalance resulting in an upsurge of vector numbers (including human or animal exposure). Emergent phenomenon - possibly due to new biological relationships, including new or chance human exposures
Absence of waterborne pathogens	**R3, S3, R9**	Discharge that over-rides assimilatory and regulatory capacities and results in a biological response (including human or animal exposure)
Emergent plants in water, over-hanging vegetation, riparian shade	**S2, S3, R5, C4**	Increased nutrient loads, changed flow regimes influence aquatic macrophyte growth and abundance
Tree stumps in water (absence of)	**S2, R5, C3, C4**	Changes in riparian zone structure and function (and delivery of LWD). De-snagging activities by visitors or resource managers
Locally characteristic plants and animals	**S2, S1, S4, R3, C4, C3, C2, C1**	Disturbances associated with overuse – too many visitors - can reduce species diversity. Disturbances can adversely influence the behaviour of animals or result in the introduction of weeds or other non-natives species
Recreational fishing (native species)	**C2, C3, C4, S2, S4, S6, S7, S8 , S9**	Overfishing, altered reproductive productivity, species interactions (predation, competition, diseases) and changed aspects of dispersal
Recreational fishing (introduced fish)	**S2, S4, C3**	Fishing opportunities may increase in some areas in response to fish stocking
VISITOR FACILITIES		
Accessibility to water bodies (short and safe when desired)	**R5, S3**	Access can be facilitated through geomorphological modifications (rock, sediment, water and infrastructure like jetties, boardwalks). These disturbances change water sediment interactions and provide for intrusions of other organisms. Access point modifications and changing facilities can influence the use and loads at key sites
Other visitors	**C3, C5**	Antisocial behaviours can be created by the nature of surroundings and facilities, the clientele encouraged to the site and/or lack of respect for other aquatic features
Land-based infrastructure	**R5, S3**	Landform features prone to erosion

Education and residential development

CULTURAL	
Science and education values	C1
Cultural heritage and identity	C2
Contemporary cultural significance	C3
Aesthetic and sense of place values	C4
Spiritual, inspirational and religious values	C5
PROVISIONING	
Drinking water for humans and or livestock	P1
Water for irrigated agriculture	P2
Water for industry	P3
Food for humans	P4
Food for livestock	P5
Wood, reed, fibre, and peat	P6
Medicinal products	P7
Other products and resources, including genetic material	P8
Groundwater replenishment	R1
Water purification/waste treatment or dilution	R2
Biological control agents for pests/ disease	R3
Flood control, flood storage	R4
Coastal shoreline and river bank stabilisation and storm protection	R5
Other hydrological services (soil moisture, evaporation, surface runoff, infiltration etc)	R6
Local climate regulations/ buffering of change	R7
Carbon storage/ sequestration	R8
Hydrological maintenance of biogeochemical processes	R9
SUPPORTING	
Nutrient cycling	S1
Primary productivity	S2
Sediment trapping, stabilisation and soil formation	S3
Physical habitat	S4
Systemic consequence (ecological surprise); maintenance of desirable state	S5
Natural or near-natural wetland ecosystems (incorporates concept of resilience)	S6
Priority wetland species and ecosystems	S7
Ecological connectivity	S8
Threatened wetland species, habitats and ecosystems	S9

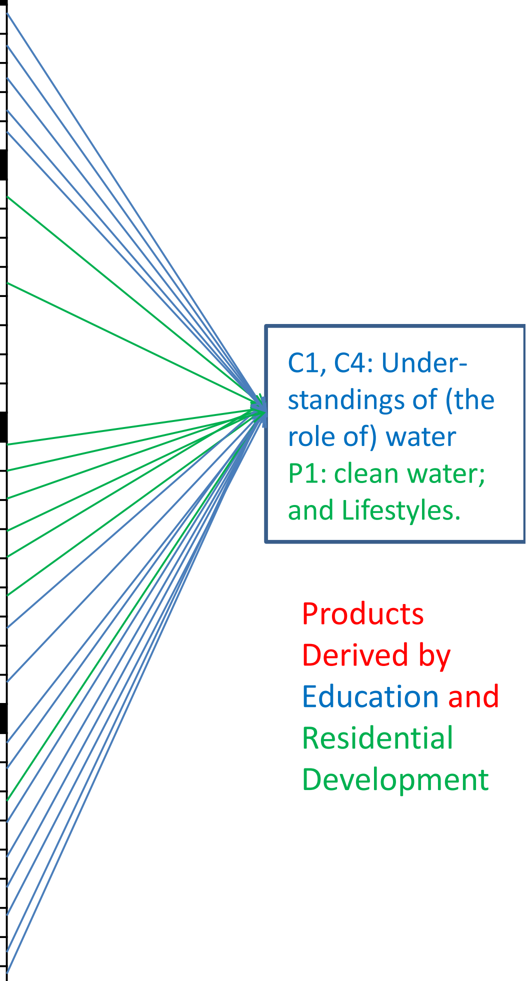

Figure 10: Ecosystem services required for education and residential development to derive cultural and other services.

Table 11a: Education and residential development as settings for water use and aquatic ecosystem services.

Education Setting	Preschool and Family-based education	Primary	Secondary	Tertiary
Consumptive use of water	Household: water required to maintain households (not dealt with here – see Residential)	Institutional service: Water is used for activities such as irrigating parks, gardens and sporting fields, for fire fighting, filling swimming pools, washing, drinking, cooking, laundry, operation (not dealt with here – see Other Industries)		
Non-consumptive use of water	Early childhood experiences with water. Awareness of behaviour of water locally. Understandings of intrinsic characteristics of water.	Requirements for a water literacy*: Awareness of behaviour of water locally and in the landscape at different seasons and inter-annual events, and extreme (flood and drought). Understandings of intrinsic characteristics of water.		Understandings of water in the landscape (geomorphological, chemical and biological role), the central roles of water in societies, role of water in cultural and spiritual enrichment, attitudes to water, societal interventions concerning water for all these.
Desirable aquatic ecosystem features for education	Access for experiences and exposure to water in a variety of its forms: soil moisture, surface water, groundwater, wetlands, aquatic biodiversity. Land-based infrastructure (water, toilets, shelters).	Exposure to the multiple and diverse uses and values of water. Exposure to seasonal and inter-annual variation in the occurrence of water.		Need aquatic ecosystems that can yield rich and diverse understandings of the centrality of water (from human modified systems to where the human handprint is much less evident).

*as in the role of water in an ecological literacy: '*an ecologically literate citizen in a bioregional sense is defined as someone who knows about, cares for, and acts on behalf of the cultural and ecological integrity of their home-place. Ecological literacy has no endpoint. Rather, it is an active engagement with place, an ongoing dialogue with place, and it is nurtured through celebration of place*' [Curthoys, L. and Cuthbertson, B. (2002). Listening to the Landscape: Interpretive Planning for Ecological Literacy. *Canadian Journal of Environmental Education* 7(2): 224-240.]

Residential development setting	Houses, residences	Water treatment facilities	Housing construction	Urban infrastructure
Consumptive uses of water	Water required to maintain households: inside domestic (washing, cleaning, cooking, drinking), outside domestic (home-grown irrigated agricultural produce, gardens, lawns, swimming pools).	Water required to transport settled and filtered materials and treatment by-products. Water losses.	Water for construction (i.e. cement mixing, washing materials).	Pipes, water storages, losses from these (not dealt with here – see Other Industries) Use of water to divert it away from urban infrastructure.
Non-consumptive uses of water	Water views, recreation (location dependent) (not dealt with here – see Tourism and Recreation)	Intrinsic characteristics of water	Location - dependent on where water lies or accumulates	Intrinsic characteristics of water.
Desirable aquatic ecosystem features for residential development	Water quantity (availability of water - consumptive) Water clarity (clear water) Water temperature (seasonal relevance) Water views Water quality (absence of odours) Absence of vector borne pathogens Accessibility to water bodies (short and safe when desired).	Water quantity (availability) Water of sufficient quality to treat without extra energy or expense.	Landscape features that can be used or modified to allow water to be diverted. Geomorphological features that will prevent flooding of housing, or allow construction of flood proof houses.	

Table 11b: Features associated with water and wetland ecosystems perceptibly relevant to education and residential development, showing the ecosystem services that support, provide or emanate from them and the processes that compromise them.

Desirable aquatic ecosystem features for education and residential development	Ecosystem service(s) relevant for education and residential development	Processes that change the feature (i.e. compromise the service) (partial exploration only, not a comprehensive analysis)
Education		
Need aquatic ecosystems that can yield rich and diverse understandings of the centrality of water (from human modified systems to where the human handprint is much less evident).	**C1, C2, C3, C4, C5, S5, S6, S7, S8, S9**	Homogenisation of the landscape and the elimination or reversal of the seasonality of flows through modifications to the flow of the water, clearing of native vegetation, construction of water channels and drains, reservoirs etc.
Access for experiences and exposure to water in a variety of its forms: soil moisture, surface water, groundwater, wetlands, aquatic biodiversity.	**S1, S2, S3, S4, S5, S6, S7, S8, S9**	Increasingly digital and virtual world; perceptions of water in the landscape as dangerous.
Exposure to the multiple and diverse uses and values of water.	**C1, C2, C3, C4, C5**	Elevation of one worldview to marginalise the way another sees the uses or values water.
Exposure to seasonal and inter-annual variation in the occurrence of water.	**R7, S5, S6, S8**	Homogenisation of the landscape and the elimination or reversal of the seasonality of flows through modifications to the flow of the water, clearing of native vegetation, construction of water channels and drains, reservoirs etc.
Land-based infrastructure (water, toilets, shelters).	**R5, S8**	Lack of resources, perceptions of water in the landscape as dangerous.
Residential Development		
Water quantity (availability of water - consumptive)	**R1, R4, R6**	Drought, overextraction.
Water clarity (clear water)	**R2**	
Water temperature (seasonal relevance)	**R2**	Reversal of seasonal flows.
Water quality (absence of odours; and of sufficient quality to treat without extra energy or expense)	**P1, R2**	Drought, exposure of previously anaerobic sediments. Eutrophication (nutrient delivery) and shoreline deposition of decaying algae/macrophytes. Discharge that over-rides assimilatory and regulatory capacities; change to biogeochemical processes that results in mobilisation of toxicants.
Water views	**R1, R6**	Drought, overextraction.
Absence of vector borne pathogens	**R3**	Trophic disruption (S): disruption or imbalance resulting in an upsurge of vector numbers (including human or animal exposure). Emergent phenomenon possible due to new biological relationships, including new or chance human exposures.
Accessibility to water bodies (short and safe when desired)	**R5, S3**	Perceptions of water in the landscape as dangerous.
Landscape features that can be used or modified to allow water to be diverted	**S3, R4, R5, R6**	Landscape features that have already be modified or destroyed.
Geomorphological features that will prevent flooding of housing, or allow construction of flood proof houses	**S3, R4, R5, R6**	Landscape features that have already be modified or destroyed.

3.3.2 Summary of ecosystem services in the Murray-Darling Basin

Table 12 is a summary of ecosystem services for the Basin by industry/sector/activity.

When interpreting the table it is important to note that:

- Required ecosystem services for specific industries/activities are indicated with an ‘X’.
- Specific goods or services that are produced as a function of the ecosystem service category are indicated with highlighted cells.

For some activities (e.g. mining, energy, water industries, manufacturing) it is not feasible to comprehensively categorise all dimensions of ecosystem services.

Table 12: Ecosystem services (C, P, R, S) for the MDB by industry/activity.
(where 1= Irrigated agriculture, 2=Forestry, 3=Fisheries, 4=Mining, Energy, Service Industries and Other Industries, 5=Tourism and recreation, and 6=Education and Residential development).

INDUSTRY/ACTIVITY		1	2	3	4	5	6
CULTURAL							
Science and education values	C1		X			X	X
Cultural heritage and identity	C2		X			X	X
Contemporary cultural significance	C3		X	X		X	X
Aesthetic and sense of place values	C4		X			X	X
Spiritual, inspirational and religious values	C5		X			X	X
PROVISIONING							
Water for drinking (humans or livestock)	P1	X	X			X	X
Water for irrigated agriculture	P2	X					
Water for industry	P3		X	X	X		
Food for humans	P4		X	X	X		X
Food for livestock	P5			X			
Wood, reed, fibre and peat	P6		X		X		
Medicinal products	P7						
Other products and resources, including genetic material	P8		X	X			
REGULATING							
Groundwater replenishment	R1	X	X	X	X	X	X
Water purification/waste treatment or dilution	R2	X		X	X	X	X
Biological control agents for pests/disease	R3	X	X	X		X	X
Flood control, flood storage	R4	X	X	X	X	X	X
Coastal shoreline and river bank stabilisation and storm protection	R5	X		X	X	X	X
Other hydrological services	R6	X	X	X	X	X	X
Local climate regulations/buffering of change	R7	X				X	X
Carbon storage/sequestration	R8	X	X	X		X	
Hydrological maintenance of biogeochemical processes	R9	X	X	X	X	X	X
SUPPORTING							
Nutrient cycling	S1	X	X	X		X	X
Primary productivity	S2	X	X	X	X	X	X
Sediment trapping, stabilisation and soil formation	S3	X	X	X	X	X	X
Physical habitat	S4	X	X	X	X	X	X
Systemic consequence (ecological surprise); maintenance of desirable state	S5	X	X	X	X	X	X
Natural or near-natural wetland ecosystems (incorporates concept of resilience)	S6		X	X	X	X	X
Priority wetland species and ecosystems	S7		X	X			X
Ecological connectivity	S8	X	X	X		X	X
Threatened wetland species, habitats and ecosystems	S9		X	X			X

The project brief required that the framework classification of ecosystem services be deployed to analyse ecosystem services by industry, sector or activity in the Basin. This approach has allowed for the unbundling of services, albeit on the basis of qualitative assessments and the use of the available literature. This approach has set aside some cultural ecosystem services, particularly those relating to Indigenous communities. These should be considered in other forums by the MDBA. Nevertheless, the outcome is a useful tool for future monitoring of the Plan's deliverables, especially the requirement that ecosystem services not be compromised.

The classification and the subsequent unbundling add further weight to the argument that ecosystem services and the productive base are synonymous.

4. Suitability of using a KEA and KEF approach to not compromising ecosystem services and the productive base

It was noted in section 1 that the main task of this work is to test the hypotheses about the relationship between important concepts that attend the Basin Plan. More specifically, this report is seeking to test the expectation that an ESLT that does not compromise key ecosystem functions, key water dependent ecosystems and key sites with ecological significance of a water resource will not compromise ecosystem services and the productive base of a water resource.

To reiterate, ecosystem services are considered separately to the KEA of water dependent ecosystems and sites with ecological significance for the purpose of this report to allow us to test these hypothetical relationships.

To progress our understanding of the comprehensiveness of the current ESLT approach to meet the requirements to not compromise ecosystem services and the productive base, a qualitative assessment of the ESLT approach was undertaken. In addition, a qualitative assessment of processes relating to the Water Quality and Salinity Management Plan was undertaken since water quality (a Key Environmental Outcome, one element of the ESLT) is related to ecosystem services (see Figure 1).

For the purposes of this report it is assumed that enough water is set aside under the ESLT, for water quality outcomes specified in the Water Quality and Salinity Management Plan (reference WQ&SP). To reiterate, water quality is one of the key environmental outcomes that can not be compromised under an ESLT.

Sustainable Diversion Limits and ESLT
The environmentally sustainable level of take (ESLT) for the water resources of the Murray-Darling Basin has been established according to a methodology presented in MDBA (2010). ESLT's are levels which, if exceeded, would compromise the Key Environmental Assets (KEA), Key Ecosystems Functions (KEF), productive base and Key Environmental Outcomes (KEO) of a water resource. Long-term average sustainable diversion limits (SDLs) will be set to reflect the ESLT's.

KEA in this case relate to all the environmental assets and largely site-specific water dependent ecosystems, determined as being 'key' by using one or more of five criteria (given in Table 3 of this report). KEF are 14 specific functions in three broad classes, these are locationally non-specific and are applicable to the entire Basin.

Water Quality and Salinity Management Plan

Building on existing water quality and salinity frameworks and management approaches, this plan identifies water quality and salinity objectives and establishes targets at appropriate scales. These scales range from Basin, to regional water resource planning areas, to individual sites. A risk assessment methodology is used to identify and prioritise risks to water quality, including salinity. The plan then identifies a management framework to meet targets and achieve objectives to improve water quality.

Qualitative mapping of ecosystem services
By reflecting on what is intended to be achieved by the ESLT approach and water quality as a key environmental outcome, it then becomes possible to examine whether ecosystem services and the productive base will be compromised by the ESLT if the water requirements for KEA, KEF and water quality KEO are met.

As we have already established that ecosystem services and the productive base are synonymous, our efforts have focussed on mapping ecosystem services against the processes designed to not compromise KEA and KEF and water quality KEO. The results of this mapping are reported in Table 14.

Of the 31 discrete ecosystem services, 23 are directly attended to by one or more of these three approaches and are therefore unlikely to be compromised, provided the KEA, KEF and water quality approaches are implemented appropriately.

However, eight of the ecosystem services are only indirectly (at best) attended to by these approaches. Five of these are provisioning ecosystem services (five types of products or goods derived by humans from ecosystems). The eight ecosystem services indirectly accounted for are listed below:

- Food for humans (P4)
- Food for livestock (P5)
- Wood, reed, fibre and peat (P6)
- Medicinal products (P7)
- Other products and resources, including genetic material (P8)
- Groundwater replenishment (R1)
- Biological control agents for pests/disease (R3)
- Local climate regulations/buffering of change (R7)

It is important to note that there are no EWR for provisioning services (since they do not equate to the recognised criteria for KEA nor the 14 specific KEF). So in the context of the first two ecosystems services (P4 and P5 above), the ESLT is not explicitly designed to avoid compromising of these two services. P4 and P5 are reliant on water extraction (take), where elements of both water quality and water quantity are considered. However, EWR are not conclusively determined for the water extractions of these two. Similarly, a plan seeking to deal with water quality and salinity management will indirectly avoid compromising P4 and P5.

Services P6-8 are indirectly attended to by a plan that provides sufficient water for biodiversity, one of the key environmental outcomes of the Plan. Services R1, R3 and R7 are regulating ecosystem services; and service R3 in particular, appears likely to be attended to by a plan that provides sufficient water for biodiversity. The final two ecosystem services (R3 & R7) will need to be addressed by refinements to the ESLT approach, perhaps by broadening the concept of Key Ecosystem Functions and then modifying EWR to account for this breadth.

Table 13: Qualitative assessment of whether the ESLT method developed by the MDBA as part of the Basin Plan can prevent the compromise of ecosystem services and the productive base.

Note: For Key Environmental Assets (KEA), determination of an environmentally sustainable level of take based on established Environmental Water Requirements (EWR) to protect and restore water dependent ecosystems and sites with ecological significance (one or more of five criteria from Table 3). For Key Ecosystem Functions (KEF) implementation of an environmentally sustainable level of take based on environmental water requirements to protect and restore one or more of three main groups of functions (FGs 1, 2 and/or 3; Table 4). For Key Environmental Outcomes (KEO) only water quality (WQ) is considered here, and whether the Water Quality and Salinity Management Plan explicitly seeks to address (Direct), implicitly covers (Indirect), or does not appear to be relevant (not deemed relevant) for ecosystem services.

Also note: Colour code: Light green – yes; if applied appropriately, the approach taken here is presumed to prevent this ecosystem service from being compromised. Orange – maybe; the approach taken here might be able to prevent this ecosystem service from being compromised, and/or is indirect or spatially limited at best. Blue – The approach taken here does not consider the prevention of the ecosystem service from being compromised. Red – The approach is should prevent the ecosystem service being compromised

Ecosystem Service				
CULTURAL		**EWR for KEA**	**EWR for KEF**	**KEO – WQ**
Science and education values	C1	Yes where it coincides with sites and species (Criteria 1-5)	Yes, FGs1-3	Indirect
Cultural heritage and identity	C2	Yes where it coincides with sites and species (Criteria 1-5)	Indirectly, perhaps	Indirect
Contemporary cultural significance	C3	Yes where it coincides with sites and species (Criteria 1-5)	Indirectly, perhaps	Indirect
Aesthetic and sense of place values	C4	Indirect at best	Indirectly	Yes, Direct
Spiritual, inspirational and religious values	C5	Indirect at best	Indirectly	Yes, Direct
PROVISIONING				
Water for drinking (humans or livestock)	P1	Does not seek to prevent this from being compromised	Yes, FGs1-3	Yes, Direct
Water for irrigated agriculture	P2	Does not seek to prevent this from being compromised	Yes, FGs1-3	Yes, Direct
Water for industry	P3	Does not seek to prevent this from being compromised	Yes, FGs1-3	Yes, Direct
Food for humans	P4	Does not seek to prevent this from being compromised	Indirectly	Indirect
Food for livestock	P5	Does not seek to prevent this from being compromised	Indirectly	Indirect
Wood, reed, fibre and peat	P6	Indirectly	Indirectly	Not deemed relevant
Medicinal products	P7	Can be direct if sites are known (criterion 5)	No	Not deemed relevant
Other products and resources, including genetic material	P8	Can be direct if sites are known (criterion 5)	Indirectly	Indirect
REGULATING				
Groundwater replenishment	R1	Indirectly, limited to relevant local sites	No, not addressed	Not deemed relevant
Water purification/waste treatment or dilution	R2	Indirectly, limited to relevant local sites	Yes, FGs1-3	Yes, Direct
Biological control agents for pests/disease	R3	Can be direct if species are known (criteria 3 or 5)	No	Indirect
Flood control, flood storage	R4	Can be direct (criteria 1-3) or indirect (criteria 4-5)	Yes, FG2	Indirect
Coastal shoreline and river bank stabilisation and storm protection	R5	Yes where it coincides with species sites	Yes, FG1	Not deemed relevant
Other hydrological services	R6	Yes where it coincides with sites, species, communities, habitats or ecosystems of interest	Yes, FGs1-3	Indirect

Local climate regulations/buffering of change	R7	Indirect at best	Indirectly, perhaps	Not deemed relevant
Carbon storage/sequestration	R8	Spatially limited i.e. limited to local sites	Yes, FG2	Not deemed relevant
Hydrological maintenance of biogeochemical processes	R9	Yes where it coincides with species sites of interest	Yes, FG1	Direct
SUPPORTING				
Nutrient cycling	S1	Spatially limited – see above	Yes, FGs 2-3	Direct
Primary productivity	S2	Spatially limited	Yes, FG3	Direct
Sediment trapping, stabilisation and soil formation	S3	Spatially limited	Yes, FG2	Direct
Physical habitat	S4	Yes where it coincides with sites, habitats of interest (criterion 3 in particular)	Yes, FG3	Direct
Systemic consequence (ecological surprise); maintenance of desirable state	S5	Indirect only	Yes, FGs1-3	Direct
Natural or near-natural wetland ecosystems (incorporates concept of resilience)	S6	Yes, directly applicable (criterion 2)	Yes, FGs1-3	Direct
Priority wetland species and ecosystems	S7	Yes, directly applicable (criterion 4)	Indirectly	Direct
Ecological connectivity	S8	Yes where it coincides with sites, species, communities, habitats or ecosystems of interest	Yes, FG1	Indirect
Threatened wetland species, habitats and ecosystems	S9	Yes, directly applicable (criterion 4)	Indirectly	Direct

An environmentally sustainable level of take that does not compromise KEA (water dependent ecosystems and sites with ecological significance), KEF and the water quality KEO, appears to directly address the environmental water requirements of 23 of the 31 identified ecosystem services/productive base. It is anticipated that the environmental water requirements of the remaining 8 ecosystem services will be either; a) addressed indirectly through this ESLT approach and/or b) attended to by other mechanisms that aim to maintain key environmental outcomes such as managing for biodiversity, water resource health and ecosystem function.

5. Gaps, risks and challenges

This report has already identified a number of gaps, risks and challenges that attend the objectives of not compromising ecosystem services and the productive base.

Some of the risks and challenges relate specifically to the formulation of the first ESLT. Others relate to the broader difficulties of employing ecosystem services as a water planning framework. Each of these is addressed separately in this section.

5.1 Risks and gaps attending the first ESLT

From the perspective of the topic addressed in this report there are three main risks and gaps that attend the immediate progress of the first Basin Plan.

Overlap of the productive base and ecosystem services and the wider community understanding of nomenclature

The analysis offered in this report suggests that there are no defensible grounds for separately accounting for ecosystem services and the productive base. We have also emphasised throughout this report that ecosystem services is a useful conceptual tool but the construct is rarely employed in everyday parlance.

There are at least some grounds for believing that sections of the community might confuse some of these terms and not clearly understand the role of ESLT. For instance, it is possible that individuals might equate 'maintenance of the productive base' with 'maintenance of historical extractions for productive pursuits'. There is also scope for confusion around the notion of maintaining a productive base of water resources which is distinguishable from quantities of water provided for what are conventionally regarded as productive pursuits (see, for example, Horticultural Water Initiative 2009).

This represents a risk to the deployment of the plan and the MDBA should endeavour to provide clear communication around the establishment of meaningful ESLT.

Comprehensiveness of the ecosystem classification

It was noted in section 3 that there is insufficient time to test the comprehensiveness of the ecosystem service classification framework offered as Table 4.

The authors of this report are hopeful that future iterations of the Basin Plan, allow for adequate time and resourcing to ensure a more thorough assessment of the classification framework is undertaken. It is acknowledged that currently, this process has been as constrained by timeframe, similarly to other activities for the development of the Basin Plan, however it has been no less severe a process.

One area requiring attention in the short term is improved understanding of cultural ecosystem services, particularly those that attend Indigenous communities.

Indirect accounting of ecosystem services via the KEA/KEF approach including Water Quality

The final risk relating to the first plan is illustrated in Table 14. Approximately two thirds of the identified ecosystem services' environmental water requirements will be accounted for by an adequate response to determining the environmental water requirements for KEA, KEF and water quality.

The remaining third appear partially accounted for or attended to by other mechanisms that aim to maintain key environmental outcomes. It would appear prudent to continue to monitor these ecosystem services closely to ensure that our assessment holds.

There are three immediate risks relating to the development of the Plan. These comprise:

- Potential for confusion amongst the community around the definition of the productive base and its overlap with ecosystem services.
- Possible gaps in the ecosystem classification.
- Inability to address the environmental water requirements of all ecosystem services directly via the provision of environmental water to KEA, KEF and water quality.

The view of the authors is that none of these risks is so severe as to prevent immediate progress of the Plan along KEA and KEF lines. Moreover, sensible strategies can be easily developed to monitor and control these risks.

5.2 The longer term challenges of employing ecosystem services as a planning tool12

To date we have argued that ecosystem services represent a useful conceptual tool but their measurement and thus deployment as a planning mechanism is not yet fully developed. We have also argued that there will be an inevitable correlation between protecting and restoring the productive base and protecting and restoring ecosystem services.

[12] A more detailed analysis of issues raised in this section forms part of later stages of the project.

We have further noted that it is possible to develop a classification of ecosystem services and apply this at a basin scale in relation to industry sectors. This was illustrated in the preceding sections. However, the practical application of these frameworks is no simple task. There are also concerns about the measurement of ecosystem services. In simple terms, it will be difficult to determine and validate if an ecosystem service is being undermined if it is not feasible to measure it.

We now return specifically to the conceptual and practical challenges embodied in ecosystem services. These are medium and longer term risks rather than immediate concerns around the current plan. Nevertheless, this section serves to reemphasise the unavoidable nexus between ecosystem services, ecosystem functions and processes. It also illustrates why the first Basin Plan might best be served if MDBA's resources are devoted to improving the understanding of KEA and KEF, at least in the immediate term.

The MA (2005) framework, which is now widely regarded as offering the seminal definition of ecosystem services, was subject to review by the International Council for Science (ICSU), the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the United Nations University (UNU). The report titled *Ecosystem Change and Human Well-Being* (ICSU-UNESCO-UNU 2008) provides some salient insights into the practical dilemmas of operationalising ecosystem services.

On a positive note, ICSU-UNESCO-UNU (2008, p. 11) credit the framework with:

- building a connection between ecological and human systems
- as 'offering a useful typology
- embedding the effects of ecosystem services on human well-being within a feedback loop; and
- encouraging the conceptualisation of systems rather than just ecosystems.

The less successful elements of the framework were fourfold:

- The relationship between biodiversity and ecosystem services was never sufficiently developed. As a result, establishing this link was only weakly achieved[13]
- The assumption that the MA conceptual framework was identical at all scales" was a weakness[14]
- The failure to explicitly acknowledge that human well-being has determinants other than ecosystem services (but this still requires more work), and
- The relationship between regulating and supporting services and human well-being was poorly conceived, and this had consequences for attempts to value services (ICSU-UNESCO-UNU 2008, p. 11).

Notwithstanding that these constitute relatively high-level criticisms; we use these elements as a vehicle for contemplating the links between ecosystem service measurement and the proposed approach for formulating future Basin Plans.

[13] Arguably, the approach from Ramsar offers more promise in this context.
[14] Rodriguez et al. (2006) question the seriousness of this flaw.

5.2.1 Biodiversity and ecosystem services

The relationship between biodiversity and ecosystem services comes via the effect it has on ecosystem processes. One of the accomplishments of the MA (2005b) was that it showed that the functional composition of the ecosystem (identity, abundance and range of species traits) explained the majority of the effects on most ecosystem services (ICSU-UNESCO-UNU 2008, p. 15). Put differently, measures of biodiversity may act as a starting point for contemplating the ecosystem functioning and ecosystem services[15]. Regrettably, in the context of making specific use of the ecosystem services concept to inform the Basin Plan, and more broadly in its application, ICSU-UNESCO-UNU (2008) note that there are a number of conceptual and empirical gaps to be filled (p. 15).

Listed amongst these are:

- The need for more studies on species richness and biomass production "at the broader spatial and temporal scale";
- Much of the evidence relating the positive effects of biodiversity to ecosystem processes deals only with species richness and "very little is known about the role of diversity at finer or courser levels"[16];
- There is only limited work on the "comparative roles of genetic versus species richness in ecosystem processes and services … [so it is not feasible] to give priority to one of these levels over the other to maximise the provision of certain ecosystem services";
- "Critical scales [in terms of time and space] at which different components of biodiversity become important to ecosystem processes and services are not fully understood" and
- "There is a need to develop theoretical and methodological tools to deal with … intrinsically non-linear processes" (ICSU-UNESCO-UNU 2008, pp. 15-16)[17].

5.2.3 Scale and ecosystem services

Biodiversity and ecosystem services usually reside at the local level of the spatial scale. In contrast, human well-being is most commonly expressed at the local and regional scale (ICSU-UNESCO-UNU 2008, p. 11). In the context of the formulation of the Plan for instance, the well-being of agriculturalists as a result of access to water for irrigation will usually be depicted in terms of the number of jobs in a government jurisdiction or the dollar value of regional agricultural output (see, for example, RMCG 2009). These conflicting scales seriously complicate the task of aligning ecosystem services and the beneficiaries of those services with the ecosystem processes and conditions.

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[15] A cautionary note on this matter is offered in the final section of the report. At this stage it is worth noting that biodiversity can act as surrogate, but as shown in Ramsar's approach, components (genes, populations, species etc in this sense) are acquitted separately to processes (functions; supporting services) and other ecosystem services (Provisioning, Regulating and Cultural services).

[16] If there was a simple positive relationship between biodiversity and ecosystem services then much of human kind would still be hunter-gatherers. Humans tend to reduce diversity to have the ecosystem produce more of at least some services. The same can be observed in natural systems. If a reliable correlation exists between biodiversity and ecosystem services then it must be at very large time/space scales. This makes it hard to incorporate in planning at site or regional scale within 'water-years' for instance. It also means caution needs to be taken if crude measures of biodiversity are passed off as acceptable measures of ecosystem performance.

[17] The Resilience Alliance makes some progress on defining this.

The upshot is that important questions like 'how widely or narrowly do we measure beneficiaries to set the benchmark for ecosystem services' have not been adequately answered. Moreover, in the time available to develop the Basin Plan it would appear unwise to devote resources to resolving this question although understanding the trade-offs between ecosystem services is a theme worthy of further work in the medium to long term.

5.2.4 Other sources of well-being besides ecosystem services

As discussed previously, ecosystem services relate specifically to the benefits that humans derive from ecosystems. Put differently, this relates to the stream of benefits that come from a level of 'natural capital'. However, there is a range of other types of capital covering manufactured and social forms. Of itself, this should not impede the concept of ecosystem services but it does create a series of measurement dilemmas when applying the concept. The overriding strength of the notion of ecosystem services is that it overtly acknowledges the pivotal consideration of human well-being when resource management decisions are made. Given current knowledge and expertise, ecosystem services can become a vehicle by which the wider impacts and implications of a resource use decision, or a change in use, can be considered.

However, disaggregating the welfare change that arises from a modification to natural capital versus that related to the circumscribing social and manufactured capitals is highly implausible. There is a complicating factor as some of these forms of capital may be substitutable. Thus, to assume that a reduction in natural capital of itself results in a deterioration in human well-being runs the risk of overestimating ecosystem services. There is also a body of work that shows the complementary nature of some forms of capital (see, for example, Herath 2009). Ironically, this hardly simplifies the measurement task and there is a potential for double counting and/or an underestimation of ecosystem services.

5.2.5 Values and ecosystem services

The final broad concern expressed by ICSU-UNESCO-UNU (2008) relates to the conceptualisation of regulating and supporting services and the measurement challenges that attend these services in particular. Regulating and supporting services are not directly consumed but nevertheless underpin provisioning and cultural services. The fact that such services are not directly consumed means that it is difficult to find market prices that adequately reflect their value. Moreover, it is worth noting that valuation in this field remains a developing research field (see, for example, Cooper & Crase in press). This is addressed in greater detail in the following section.

Ecosystem services is a useful conceptual tool but relatively immature to be used solely as a basis for water resource planning at this stage. The relationship between biodiversity and ecosystem services is not sufficiently understood; scale inconsistencies remain unresolved; and establishing robust measures for calculating human value and then disaggregating it to the ecosystem service level is a developing field. These are medium and longer term tasks that should be undertaken to make for better future planning.

5.3 Price, willingness to pay, value and ecosystem services

Ecosystem services are unequivocally utilitarian in nature and this has led to criticism from some quarters (McCauley 2006). However, this needs to be set against the advantage gained by switching attention from ecosystem processes and functioning alone to the economics of ecosystem change. This is especially the case in those settings where development goals are seriously challenging the short-term viability and resilience of ecosystems. In the context of developing future water plans for the Basin this is also important. To reiterate, to be confident that ecosystem services are not being compromised it will be necessary to measure them. With that in mind, this section is used to address some specific measurement challenges that the MDBA will need to address as part of the formulation of future plans.

5.3.1 Provisioning services

The most commonly (mis)conceived measure of value is the price paid for services and goods in a market setting. Whilst this approach might offer some scope for valuing provisioning services, even this is no straightforward task. Market prices do not adequately reflect total value, even under the fanciful conditions of perfect competition invoked in neoclassical economics. Rather, value (or benefit) relates to the aggregation of an individuals willingness to pay for a good or service. In this context, Dobes and Bennett (2009, p. 9) note that:

> 'An individual's willingness to pay for water, for example, may be several thousands of dollars a year. But the price actually paid for that water by an individual may be far less (perhaps just several dollars per year). The difference between the individual's willingness to pay and the price they pay is defined as the benefit generated from the consumption of water. Thus price alone does not define the benefit.'

The upshot is that establishing a measure of value from market information involves more than simply gathering price data. This data then needs to be converted to establish the reservation prices to which individuals would go to avoid foregoing the good or service altogether. Economists describe this as estimating the demand function but even this is disputed territory. Some advocate the use of Hicksian compensating demand functions whilst others argue that standard Marshallian demand functions offer an adequate proxy. There is also confusion between estimating the demand function versus movements in the demand function. Nevertheless, once a demand function is established the 'surplus' (i.e. the integral of the demand curve) then purports to represent the total value of the good or service.

Clearly, provisioning services are most likely to be considered through this approach but care needs to be taken; after all, ecosystem services constitute intermediate inputs into the production of goods for which there is a demand. Thus, whilst market data can provide a starting point for assessing the value of goods that rely on ecosystem services, considerable amounts of additional information are required before the marginal impact of an ecosystem service can be traced to the values expressed in markets.

There are several options for accomplishing this task, depending in large part on data availability and the likely underlying relationships in the data. For instance, where a provisioning service feeds directly into production, modifications to those services might be estimated using shadow prices (i.e. an estimate of the opportunity cost of providing or eliminating an additional unit of the service). Examples include the use of fertilizer prices (i.e. the next best alternative) as a proxy for nature's provision of fertile soils for cropping.

Alternatively, an estimate of value can be developed using related-market techniques, such as the 'travel cost method' or 'hedonic pricing'. Here the aim is to unbundle existing market prices to estimate the contribution of the ecosystem service to that price. The fact that so few Australian studies of this type are reported in the literature is testament to the difficulty of accessing good data sets for this work. For example, Crase and Gillespie (2008) endeavoured to estimate the value of having a view of clean water, as embodied in house prices overlooking Lake Hume. This was largely thwarted by an absence of adequate data and the travel cost method was ultimately invoked. More recently, CSIRO has undertaken hedonic pricing studies but these are focussed on a narrow set of studies where data is plentiful and unlikely to serve any useful purpose in formulating a Basin Plan[18].

In general, it is feasible to develop some estimates of provisioning services but this is a time-consuming and data-hungry activity. This says nothing of the formidable challenges that attend tracing the link between changes in ecosystem components and processes to the ecosystem service that is ultimately consumed.

Whilst the challenge of measuring ecosystem provisioning services is non-trivial, it is plausible to undertake such a task given sufficient time, at least for a limited set of activities. The extent to which such estimates are accurate, will obviously depend on the validity of the underlying data about ecosystem functioning and condition; without good data on these fronts any estimate of marginal impacts on human welfare would be meaningless from a planning perspective.

5.3.2 Regulating and supporting services

Regulating and supporting services are only indirectly related to provisioning services where human valuation is arguably most overt. This does not imply that such services are not important or that economists have nothing to say about their value or estimation. Rather, what is required is a different set of tools for analysis.

In the absence of any market information at all, economists have developed a range of non-market valuation techniques. The two most common approaches in this genre are Contingent Valuation and Choice Modelling. Both of these techniques are termed 'stated-preference' which, as implied by their description, solicits estimates of individual willingness to pay by survey. In its simplest form participants in the survey are asked 'how much would you pay to achieve X?' Non-market valuation is not without its critics or controversies (Chee 2004) and there continues to be debate about the reliability of value estimates obtained using this approach.

[18] Benefit transfer techniques are on hand to give some guide to the plausible range of values when a limited number of studies are on hand. We argue that such techniques need to be viewed cautiously.

Refinements to improve the reliability of results have progressively emerged in the literature and there is some legal precedent to support non-market techniques. However, in the context of regulating and supporting services and the development of the Basin Plan several cautionary observations can be made.

Firstly, the widely accepted approach employed for such studies is to use willingness to pay estimates rather than willingness to accept. In part, this has been a pragmatic choice since economic theory suggests that willingness to pay and willingness to accept should deliver similar outcomes. However, in practice, estimates derived from willingness to pay studies usually fall well short of those emanating from willingness to accept (Knetsch & Synden 1984). This has significant implications for policy choices and planning. More specifically, if these estimates are to be believed, then the welfare enhancements gained by adding an additional unit of regulating or supporting services would appear to be less than if that same unit was removed. Thus, if the usual approach recommended by the economic literature is applied, the value assigned to such services will invariably be on the low side. Accordingly, enhancements in ecosystem services will not appear as valuable to humans simply because of this measurement nuance, even though improved regulating and supporting services may substantially add to well-being.

Secondly, most stated preference models struggle to disaggregate specific ecosystem services, although it is not impossible (Loomis et al. 1996; Brown et al. 2007). Admittedly, choice modelling allows for part-worth measurement of some aspects of ecosystems (e.g. the value of an extra fish species; additional breeding sites) but this often requires a level of abstraction that grossly masks the underlying ecological complexity. A choice model usually has to limit the number of attributes because the cognitive burdens on survey participants need to be constrained. The upshot is that 'super-attributes' or assumptions of linearity among the attributes become the norm for many of these studies. So having knowledge of the 'value' that humans place on inaccurately specified ecosystem services would appear to add little to the formulation of a robust Basin Plan. Rather, additional and more sophisticated measures of the ecosystem features and processes and adequately set targets in this context would appear to be the first sensible step.

In any case, given the propensity for willingness to pay to downplay such values, sensible targets grounded on sound ecological principles would more than adequately meet targets or management activities based on improving ecosystem services.

5.3.3 Cultural services

Cultural services include, but is not limited to, the spiritual and other non-material benefits enjoyed by humans and supplied by ecosystems. Like regulating and supporting services, cultural ecosystem services are seldom exchanged in a market, leaving economists with few choices to ascertain their value. The consequence is deference to non-market valuation techniques, as described above.

Obviously the limitations described above must also be borne in mind when valuing cultural services. However there are other specific challenges that warrant consideration. These are particularly pertinent in the case of the Basin Plan as Indigenous cultural values will require careful treatment.

Adamowicz et al. (1998) lists a number of failings or likely failings in the application of non-market techniques when valuing Indigenous cultural services. Venn and Quiggin (2007) subsequently refine this list to those most pertinent to Australian Indigenous cultural heritage. These are:

- Unfamiliarity with the purchasing power of money and the absence of an alternative numeraire
- Poor English and numeracy skills
- The low level of knowledge and understanding that Indigenous people have about non-Indigenous forms of natural resource management
- Problems of interviewer and compliance bias
- The tendency for Indigenous people to accumulate and share wealth among larger groupings of individuals rather than households
- Cultural diversity among traditional owner groups in artificial Indigenous communities that are situated on former Aboriginal Reserves, where residents do not share common heritage, values, beliefs and interests
- The need to distinguish between traditional owner groups and the local Indigenous community (p. 336).

In addition, the Indigenous perception of relationships and responsibilities to the environment, including concepts of *belonging* to the land, may test the comprehension of the investigator and/or defy realistic quantification.

Venn and Quiggin (2007) subsequently recommend modifications to the valuation process, although few Australian examples are presently available to test this approach.

Measurement of the cultural values that derive from ecosystem services is attended by unique challenges. There is inadequate empirical work at this stage to produce robust estimates of such values, notwithstanding their importance. Their inclusion as part of a basin-wide water planning exercise needs to be dealt with cautiously until more reliable and tested valuation mechanisms are on hand. Care needs to be taken to avoid defining cultural ecosystem services as a simple subset of other services. The problems associated with tracing the relationship between ecosystem condition/functioning and marginal changes in cultural services are significant. It is unlikely that there is sufficient overlap between the understanding of Indigenous cultural values and the knowledge base of natural resource management (NRM) planning to resolve these issues within the time scale of the Basin Plan program.

In the longer term it will be necessary to improve the measurement of ecosystem services in order to validate that they are not being compromised. If ecosystem services are to be seriously deployed as a planning tool the MDBA will need to actively address this challenge. This is a significant task, particularly in the context of valuing cultural services.

6. Immediate response to risks

In the previous section we highlighted three immediate risks to the Basin Plan in the context of the project brief. This short section offers the MDBA a series of immediate responses for its consideration.

6.1 Misinterpretations of the productive base and its overlap with ecosystem services

This report is heavily premised on an understanding of the definition of ecosystem services. There is at least some evidence (see for example responses to SDL Issues Paper) that the intention of the Act is not fully understood or appreciated by all sectors of the community. More specifically, there is a risk that the notion of ‘maintaining the productive base’ is interpreted by some as analogous to the preservation of the existing level of extractions. Whilst it is beyond the scope of this report to deal with this issue in detail, the MDBA needs to be cognisant of this risk.

It is recommended that the MDBA continue to reiterate the underlying intentions of the Act and to position the notion of productive base in a manner consistent with the argument present in this report, i.e. it is largely synonymous with ecosystem services. The productive base should be clearly articulated as encapsulating a range of ecosystem services that extend beyond provisioning services.

6.2 Gaps in the ecosystem classification

We noted in section 3 that there is insufficient time to test the classification of ecosystems services. In this context there is a risk that some services are overlooked and thus not captured in subsequent mapping exercise (see section 4).

This risk is not adjudged to be severe although it warrants some attention. It is recommended that the MDBA maintain a watching brief to ensure that new literature and scientific knowledge/evidence arising after the 2010 Basin Plan is produced, is incorporated into the next iteration of the plan, and uses adaptively in supporting management actions and/or policies derived thereof.

6.3 Inability to address all ecosystem services adequately via a KEA and KEF approach to planning

It is not possible to predict with certainty whether the environmental water requirements of all ecosystem services will avoid compromise of water resources ecosystem services as a result of providing environmental water for KEA and KEF. In part, this arises because it is not yet clear how the MDBA will manage what amounts to a series of challenging decisions. For example, the SDL Issues Paper points to an ‘iterative process’ which may (or may not) improve the matching of SDLs with an ESLT. The requirement to include socio-economic inputs in the analysis is also not clear to the authors and may have implications for SDLs. The authors are unable to advocate anything more than a watching brief on this front.

The immediate risks to the planning process appear manageable with a combination of articulate communication (in particularly reference to the definition of the productive base) and resources devoted to scanning for inconsistencies between emerging data and the rationale presented in this report.

7. Enduring approaches for including Ecosystem Services and the Productive Base in the Basin Plan

We noted earlier in this report that the understanding of ecosystem performance is not yet fully developed and that there was a need for caution when adopting proxy measures such as KEA and KEF. Some long term responses to these limitations are addressed here.

7.1 Best practice?

As discussed previously, ecosystem services and the concept of the productive base are complex and the current status of knowledge and information is not adequately progressed to make full use of them as an operational framework. Moreover, there is a risk that, if invoked, such a framework would result in seriously simplified and mis-specified objectives.

As with many regulated catchments worldwide, large-scale technical infrastructure is used in the MDB to shield human activities from the variability of water. Reservoirs, water diversions and artificial storages are used to enhance the resource availability, particularly in case of droughts. Water can be pooled ‘unnaturally’ in dams & weirs to control flow amounts and timing. Levees are built to protect settlements from floods in case of excess precipitation but hinder larger-scale flooding - important for long-term catchment productivity and viability.

By way of contrast, environmental flows are presented as environmental best practice, not only to provide a pool of water for ecological purposes, but to address the spatio-temporal distribution of quantity and quality of water (Pahl-Wostl 2007b). Again, as a ‘best practice’ method, this is done to maintain the integrity of riverine ecosystems and preserve their ability to provide services valuable to humans (Dyson et al. 2003). Nevertheless, there are some doubts as to whether selecting location-specific key assets (as in the development of KEA) will adequately meet all ecosystem services catchment-wide. Notwithstanding the intention to incorporate wide-scale KEF this concern is particularly pressing for the more subtle regulating and supporting services.

One of the measures of ESTL is biodiversity. In many cases this is a pragmatic decision to use this as a measure, often forced by the gaps in scientific knowledge and the limitations of time in producing and implementing planning frameworks. Currently, biodiversity defined, does not stipulate whether species are ‘native’, endemic’ or otherwise, and whether this matters anyway.

Other problems with using biodiversity as an outcome (criterion 5, p. 24) is centred around several questions:

- Do we have enough knowledge and data to support which species are 'key', so that we can use them to measure success?
- Do we understand their habitat requirements, life history traits, their resilience and their evolutionary potential?
- What is the 'benchmark' to strive for, in terms of biodiversity measures? Knowledge of distribution and abundances (historically and currently) are lacking.

Best practice would advocate that it should be the processes and their interactions underpinning the survival of species that must be managed and not the number of species. This is important as, if we are to set aside the measurement of ecosystem services for the time being due to the complexities that attend this approach, there needs to be an adequate proxy in its place.

To simplify the criteria of deciding on what constitutes KEA, invariably makes management and decision-making processes easier. However, this approach needs to be considered against the risk that more accurately specified complex ecological and social relationships are overlooked (Nicholson et al. 2009).

Having only those functions that can be described at the basin-scale considered as KEA (MDBA 2009b) may also result in serious flaws in the specification of management actions. Complex system dynamics might be ignored, knowledge gaps assumed away, uncertainty passed off as risk and feedback largely dismissed.

7.2 Future approach and adaptive management

Clearly, this report shows limitations are not only associated with the ecological sciences but there are also important challenges that require iterative improvement in the social sciences. To have adaptive capacity implies having the potential or capability to adjust to better cope with existing and future stresses (Pahl-Wostl 2007a). More specifically, adaptive capacity refers to 'the ability of a socio-ecological system to cope with novelty without losing options for the future' (Folke et al. 2005) and 'that reflects learning, flexibility to experiment and adopt novel solutions, and development of generalised responses to broad classes of challenges' (Walker et al. 2002). In this context the calibre of adaptive management becomes an important caveat to this report. Without adequate and systematic improvements in science, including social science, the longer term goal of not compromising ecosystem services and the productive base will be undermined.

The current, overall assessment is that there is already considerable investment in the KEA/KEF approach to managing water resources. What is lacking is knowledge that traces the intricacies of this approach to the desired ecosystem service and productive base outcomes. We strongly recommend that the MDBA continue to invest in research to refine and better understand these linkages, to increase its knowledge on the functioning of the Murray-Darling, and to concurrently increase its capacity to make informed management decisions regarding the water resources.

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