

1 Lakes

The primary valleys of the Avon River basin's Central, Eastern and Southern sub-regions and the GWW are dominated by extremely low flow gradients (between 0.01% and 0.07%) and are home to extensive lake chains.

The ARB has 11,530 wetlands that cover 2.8% of its land area (refer Table 1). Ninety per cent of the 11,530 wetlands of the region are less than 25 ha in size, but the east and south of the region are characterised by massive lakes: 38 lakes within the region are more than 1,000 ha in size. Figure 1 (overleaf) depicts the lakes of the ARB.

Table 1. Area of Lakes by ARB Sub-Region

	<i>Count</i>	<i>Total Area (ha)</i>	<i>Area of Lakes (ha)</i>	<i>% Area</i>
<i>Avon Arc</i>	460	1,378,420	5,163	0.4%
<i>Central</i>	3399	2,706,558	59,945	2.2%
<i>Eastern</i>	1564	1,726,773	33,393	1.9%
<i>GWW</i>	2,662	3,424,616	119,961	3.5%
<i>Lockhart</i>	3444	2,478,364	112,284	4.5%
<i>Total</i>	11,529	11,714,731	330,746	2.8%

Sometimes described as river systems, the Yilgarn, Lockhart, Cam and Pingrup systems are lake chains representing massive floodplain storage, only filling and flowing downstream in extreme rainfall events or as a result of exceptionally wet winters. These lake chains form extremely complex flow patterns, with many basins isolated from the main flow path or terminal, in that they receive flow but rarely if ever actually overflow into the primary flow paths. In fact, 30% of the region's lakes are described as terminal and a further 51% are either isolated or partially isolated from the primary flow path (Jones et al. 2009).

Table 2. ARB Lake Connectivity (Adapted from Jones et al 2009).

	Area (ha)	Number	%
Headwater	12,081	344	3
Isolated	62,713	5928	51
Terminal	129,973	3447	30
Through-flow	125,956	1803	16
	330,722	11,522	

Figure 1. Lakes of the Avon River Basin



The lakes of the region are important in managing water quality, settling out suspended sediment within flow discharge and facilitating nutrient uptake through aquatic plants into extensive food webs.

The ARB's lakes undergo seasonal wetting and drying and seasonal variations in salinity. Lakes may remain dry for long periods of time, with aquatic biota remaining dormant awaiting significant rainfall. Lakes initially fill with relatively fresh water, but as rainfall decreases and evaporation increases during the onset of summer the salinity of most lakes increases dramatically (Jones et al. 2009).

The lake system of the region is unique and fascinating. The underlying ecological values of the lake systems within the Wheatbelt are largely unknown and for the most part undervalued. The complexity of the region's lake systems is illustrated by the Yenyening Lake system, located at the confluence of the Salt and Avon Rivers. Here, relatively fresh water pools fed by fresh groundwater discharge from adjacent sandy slope, exist immediately adjacent to the hyper-saline channel lakes system; two completely different but adjacent wetlands provide for a huge diversity of habitat.

1.1 State and Transitions

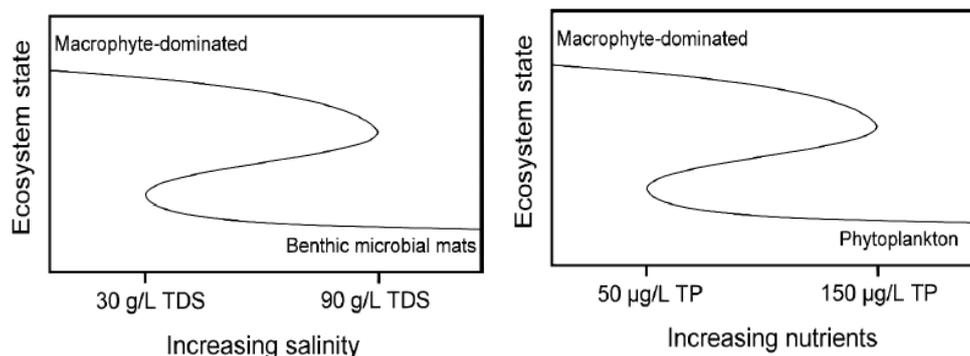
Wheatbelt lakes have four alternate stable states:

1. *Clear aquatic plant (macrophyte) dominated systems*
2. *Clear, benthic microbial or benthic-mat dominated systems (containing multi-layer sheets of micro-organisms (bacteria and aecheae) on the the lake bed)*
3. *Turbid phytoplankton (algal) dominated systems*
4. *Turbid, sediment-dominated systems.*

1.1.1 Salinity and Nutrients

As a general rule aquatic ecosystems range from more diverse to less diverse as they proceed from 1 to 4 in the above list of states. Increasing salinity is typically the trigger to transition from the macrophyte-dominant to microbial mat-dominated state, and excess nutrients is the trigger for transitioning from macrophyte microbial mat-dominated to a phytoplankton-dominated aquatic system. A simple state and transition model (Figure 2) illustrates the salinity and nutrient triggers for a change in ecosystem dominance.

Figure 2. Simple state and transition models for wheatbelt lakes systems (DoW 2005)



Sim (2001) found that successful germination of most aquatic plant species within the region occurs only up to salinity of 45,000 mg/L, but once germinated plants can tolerate salinity of approximately 90,000 mg/L. If these thresholds are exceeded, then aquatic systems will change from vegetated benthic aquatic ecosystems to algal-dominant systems.

When salinity remains below 90,000 mg/L (90 g/L), then wetlands tend to remain in a clear macrophyte-dominated state characterised by *Ruppia*, *Lepilaena* and *Lamprothamnium* species. As salinity increases over 90,000 mg/L, the aquatic system shifts to a clear benthic microbial community, dominated by benthic mats composed predominantly of cyanobacteria (blue-green algae) and halophilic bacteria. Peak microbial communities or lake bed mats are often pink and purple in colour.

Turbid phytoplankton-dominated systems can occur in both freshwater and saline wetlands due to an excess of nutrients. If phosphorus levels exceed 0.15 mg/L, algal blooms are likely to occur, resulting in either anoxic (oxygen-deprived) or toxic conditions.

The fourth state occurs when large sediment load contained within a wetland in flow reduces light penetration to the extent that the proliferation of algae and aquatic plants cannot occur. This is rare in the ARB, but farm dams essentially replicate this state.

1.1.2 Acidity

pH is another water quality parameter governing the structure and function of aquatic ecosystems within the Wheatbelt. Groundwater in some parts of the ARB is very acidic (pH 3 – 4), and contains high concentrations of dissolved aluminium, iron and trace elements such as lead, nickel, copper, zinc, cadmium and (in some cases) uranium. These trace elements have been leached from local bedrock materials by acid groundwater. It is generally accepted that large areas of the broad valleys of the Central and Eastern Subregions, have acidic groundwater (interspersed with pockets of alkaline groundwater), and more than 50% of the groundwater bores of the Avon Region are acidic (Degans & Shand 2009).

Generally accepted thresholds at which pH begins to negatively impact aquatic life are <6.5 and >8.0 (ANZECC 2000).

If acid waters are neutralised by alkaline waters or materials, dissolved material such as iron, aluminium and a range of toxic heavy metals can precipitate into underlying sediments, presenting a range of environmental hazards, including the potential for remobilisation during subsequent acidic flows.

Acid groundwaters can acidify lakes, creeks and river systems if groundwater discharges to natural pathways. Acidification of valley floor systems, including lakes and rivers, may entail a secondary risk of trace element mobilisation. This hazard includes the potential accumulation of metals including lead, cadmium, uranium, arsenic and selenium in surface environments. Accumulation of heavy metals in wetlands and river sediments may result in toxic impacts on wildlife and longer-term bioaccumulation through aquatic food chains (Degans & Shand 2009).

Some lakes and waterways within the Avon region are becoming acidic due to groundwater discharge resulting from profile saturation. Pumping of groundwater and construction of deep drains is a primary mechanism for the mobilisation of acid groundwater within the region presenting an increasing threat to the natural environment. Poorly planned disposal of groundwater from farm drains to lakes, creeks and floodplains presents a significant threat to natural aquatic environments. Additional information on drainage and salinity are presented in the Landscape Water chapter, [section XX](#).

Given the inherent complexity of the drainage systems within the region and the interactions that occur between natural floodwaters and accumulated groundwater discharge, it is difficult, if not impossible, to predict where dangerous and toxic elements will precipitate and accumulate, potentially subsequently redissolving and accumulating downstream.

1.2 Stressors

The key stressors influencing wetland health within the region are summarised in Table 3.

Table 3. Primary Stress Factors Influencing Wetlands

Stress Factors	Measure / Parameter
Increased landscape salinity	Salinity
Agricultural drainage	Salinity, pH, nutrients, metals
Agricultural practice	Salinity, pH, nutrients, metals, sediments, channel stability, reduced flow, weed invasion, fire
Increased storm intensity	Sediment, channel structure, nutrient transport
Increased aridity	Salinity, nutrients, sediment interactions
Increased temperature	Water temperature

Increasing landscape salinity, exacerbated by agricultural drainage, represents a significant risk to wetland environments within the region. Changes in run-off patterns, increasing aridity and increasing temperature due to projected climate change will also become significant stress factors for aquatic environments.

Salinity and climate change impacts are whole-of-landscape scale responses to regional clearing of native vegetation and changing global weather patterns. As a result, there are scale-related barriers in managing the underlying cause of the stressor.

Goals for wetland management:

- *Better understand potential climate change impacts on development of salinity within the region*
- *Revegetation to control local aquifer-related expressions of salinity*
- *Surface water management*
- *Better planning, environmental management and strategic assessment of the cumulative impacts of deep drainage on the receiving environment*
- *Improved soil testing and fertiliser management to reduce leaching of nutrients to the natural environment*
- *Improved understanding and awareness of potential negative environmental impacts associated with the drainage within the region.*

1.3 References

ANZECC and ARMCANZ. (2000). *'Australian and New Zealand guidelines for fresh and drinking water quality'*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. October 2000

Shand, P & Degens, B 2008, Avon catchment acid ground-water: geochemical risk assessment, CRC-LEME Open File Report 191, CSIRO Exploration and Mining, Bentley, WA, accessible at <http://crclme.org.au/>.

Degens, B & Shand, P 2009, Introduction to acidic saline groundwater in the WA Wheatbelt – characteristics, distribution, risks and management, Department of Water.

Jones S, Frances C, Halliday D, Leung A 2009 *The potential effects of groundwater disposal on biota of wetlands in the Wheatbelt, Western Australia*. Science Division, Department of Environment and Conservation, WA.