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Submission to the Inquiry into the Impact of the Murray-Darling Basin Plan in Regional Australia

Scrutinising the options – hydrological and ecological effects of proposed 'solutions'.

Prepared by Dr Rebecca E Lester & Professor Peter G Fairweather, Flinders University, Adelaide

In assessing the likely socioeconomic impacts of the proposed cuts outlined in the MDBA's Guide to the Basin Plan, it is important to consider whether the options will, in fact, achieve the ecological outcomes that have been suggested and what the environmental water requirements of key ecological assets are, such as the Coorong, Lower Lakes and Murray Mouth wetland of international importance. The link between healthy ecosystems and a good productive base through the provision of ecosystem services is well-established but easily over-looked, and so there will be substantial socio-economic benefits from having a healthy river ecosystem that have not yet been considered by the Guide to the Draft Murray-Darling Basin Plan. Without a healthy river ecosystem, it is questionable whether many of the current socioeconomic activities in the Basin could continue in the future without significant investment (e.g. to remove salt loads so water is of suitable quality for stock, irrigation and human use). Thus, a healthy river ecosystem has socioeconomic, as well as ecological benefits.

Key points:

- **Meeting the environmental water requirements of the region could be achieved by as little additional water as 410 GL per year on average, depending on how and when the water is delivered.**
- **The Coorong, Lower Lakes and Murray Mouth require an average barrage flow of at least 2000 GL per year to maintain good ecological condition.**
- **Even during very dry periods, the absolute minimum flow should be no less than 650 GL per year to prevent ecological damage from occurring.**
- **The timing of environmental water delivery, as much as the total volume, is of extreme importance in minimising ecological damage in the Coorong.**
- **Despite the recent drought, the Coorong remains one of the most important bird habitats in the Southern Hemisphere. Recent flows mean that the system is likely to have started recovering now. Protecting and restoring this wetland is of critical importance to worldwide populations of some bird species and is our international obligation.**
- **Estuaries require both fresh water and seawater, so options such as opening the barrages or using engineering to replace River Murray flows will not result in a healthy wetland.**

In anticipation of the preparation of the Murray-Darling Basin Plan, we, with a number of colleagues, undertook a large body of work to determine the minimum environmental water requirement for the Coorong, Lower Lakes and Murray Mouth Ramsar site. Determining an environmental water requirement for the region involved compiling all previous studies, report and data, hydrologic modelling of the Lakes and hydrodynamic and ecological modelling of the Coorong.

The environmental water requirement for the Coorong, Lower Lakes and Murray Mouth site is a minimum three-year rolling-average barrage flow of 2000 GL per year. This volume will maintain salinities within the Lower Lakes at their historical levels, flush salt from the Lower River Murray out to sea and maintain the ecological health of the Lower Lakes and the Coorong. Because the River Murray is a highly variable system, it is possible for the region to withstand occasional periods of flow below that volume. Significant ecological damage and a build-up of salt in the Lower River Murray are associated with flows of less than 650 GL, so this should be the absolute minimum in any one year. High flows are also important, and flows of between 6000 GL and 10 000 GL in a given year have been associated with healthy ecological conditions in the South Lagoon of the Coorong. These flows should be maintained at their current historical frequency of every three years on average for flows of 6000 GL and every seven years on average for flows over 10 000 GL (considering that both volumes are lower than the modelled average annual barrage flow without any water resource infrastructure and extractions in the basin, so 'naturally' these flows would have occurred every year, on average).

The total volumes of additional water required to meet this environmental water requirement are relatively small, compared with the volumes being considered by the MDBA. Meeting the minimum flow requirements, with occasional high-flow events, requires a long-term average of 5255 GL to pass through the barrages each year. While this is a large volume compared to recent drought years, the long-term average under current extraction levels is 4845 GL according to modelling done by the MDBA. This represents an increase of 410 GL each year, on average. In contrast, scenarios modelling possible flows if there were no extractions or water resource infrastructure in the Basin indicate that the average annual flow would have been 11 870 GL.

For the Coorong, in particular, the timing and pattern of flow delivery (i.e. the flow regime) is as important in minimising ecological damage as the average volume that passes through the barrages. Modelling has shown that long, slow releases of water are more effective at maintaining salinities and ecological condition in the Coorong than a faster release of the same volume of water. This means that optimising the delivery regime of environmental water can minimise the overall amount of water required to support the ecology of the region. This is especially so in drought conditions, but the environmental water requirements for the Coorong, Lower Lakes and Murray Mouth are achievable. Furthermore, environmental water delivered to the Coorong, Lower Lakes and Murray Mouth can also achieve other environmental benefits upstream, before it reaches the region as return flows, carrying upstream pollutants with it.

This work has been reviewed by an international expert who supports the methodology and conclusions of the work. These findings were also presented at the *14th International River Symposium* held in Perth in 2010 by Dr Lester and Mr Jason Higham from the South Australian Department of Environment and Natural Resources. Audio of those presentations is available on the symposium website (www.riversymposium.com). Copies of the accompanying slides are attached below for your information.

In recent years, a number of common questions have been asked and suggestions made relating to the management of the Coorong, Lower Lakes and Murray Mouth. Not all of the suggestions are likely to have the impact that is commonly expected, and some of the questions are based on misinterpretations of the science. Here, we present a list of the most common of those questions and misconceptions, to ensure that these are well understood and that any recommendations made by the Parliamentary Committee are not based on erroneous assumptions.

- Why does the Murray Mouth have to be open? Why do you need flow to do this – why not just keep dredging? Water flowing out the Mouth is simply a waste.

  It is important for the Murray Mouth to be open in order to allow seawater (and associated organisms) to enter the Coorong and for it to function as an estuary. An estuary is the mixing of seawater and fresh water, and will not be healthy without either. Dredging is only necessary in times of very low flow, like the recent few years. This means that there is not a balance between the fresh water and the seawater entering the system. Far from being wasted, water flowing out of the Mouth is critically important, for the River, the Lakes, the Coorong and for Encounter Bay and near-shore coastal processes. Water flowing from the Mouth transports salt and other pollutants from the River and the Lakes, keeping them healthy and ensuring that the water is suitable for drinking, irrigation and other uses. The Coorong requires freshwater to maintain low salinities, provide nutrients and create conditions that result in a healthy estuarine ecological character. Encounter Bay ecosystems, such as the Goolwa cockle fishery, rely on nutrient inputs from the River Murray as sources of food. Many fish species need to move between marine, estuarine and freshwater regions to successfully complete their lifecycles. These include commercially-fished and threatened species. Therefore, water used to keep the Mouth open maintains the balance of fresh water, seawater, salt concentrations and the health of many of the regions plants and animals.

- Why do the Lower Lakes need so much water?

The shape and size of the Lakes (i.e. large and shallow) increase the amount of water that tends to evaporate naturally. This is particularly true in the semi-arid South Australian climate, often with hot, dry summers. Approximately 800 GL is required each year to replace the water lost through evaporation, which is already incorporated into current South Australian entitlement flows. In addition, the water entering the Lakes is relatively salty, due to dryland salinity and other factors upstream. This means that, to keep them fresh, higher volumes are required than if the water was fresher to begin with. This transfer of salt through the system, out to Encounter Bay is a critical ecosystem service for the whole Lower Murray, and is necessary to maintain the quality of water for off-takes for metropolitan Adelaide. It should be noted that keeping the Lakes as a lower water level has little effect on the overall amount of water lost through evaporation each year and that modelling suggests that the removal of the barrages would actually decrease the amount of salt flushed from the system each year, creating a hypersaline lakes system.

- The barrages should simply be opened and the Lakes left as an estuarine environment
- Why not fill the Lakes with seawater?

It is a common misconception that opening the barrages would result in an estuarine environment in the Lakes. Unfortunately, estuaries require both fresh water and seawater to be healthy and simply allowing the Lakes to flood with seawater would not provide this. In addition, the topography of the region (specifically the Lake-Coorong connection) means that there would be very little water moving from the ocean into the Lakes, meaning that residence times for water in the Lakes would be very high. This would result in very high levels of evaporation and very high salinities, because there is limited flushing of hypersaline water, in the same way that has occurred in the South Lagoon of the Coorong. So, instead of a healthy estuarine Lakes ecosystem, opening the barrages is much more likely to result in a hypersaline environment more similar to the current degraded state of the South Lagoon.

- The Lakes were never a freshwater system

The available scientific evidence shows that this is not true. For a short period in the early 1900s, increasing levels of extraction upstream meant that low river flows increased the salinity in Lakes Alexandrina and Albert. It was during this time that sharks were recorded as far upstream as Mannum and the barrage were required to be built. However, this was the effect of human intervention, not a natural condition.

With this exception (and a couple of other short periods), the lakes have been a freshwater system. This is demonstrated independently via numerous different types of research, including measurements and modelling of the amount of water flowing in the River Murray, salinities in the Lakes, the salinity tolerances of the biota that live there (and have done for recorded history) and the diatoms (microscopic plants and animals) buried in sediments that can be dated through time. All these different pieces of evidence clearly show that the Lakes have been an almost-exclusively freshwater system in the recent past (~7000 years).

- The system is in decline – why waste water on a degraded system?

The Lakes and Coorong have been in decline for the last 5 years, in particular. However, they are still currently capable of being rehabilitated and much of their ecological value can, we believe, be restored (although good flows are now needed to improve the ecosystem's capacity to recover from any further dry periods). Indeed, recent flows into both the Lakes appear to have made a good start to that process (as evidenced by water quality improvements based on information available online) and monitoring and research throughout this year will indicate how much improvement has already been made.

It is important to consider, however, that, even during the recent decline, the Coorong was one of the most significant waterbird breeding sites in the Southern Hemisphere. When it is in good ecological condition, it has the potential to support hundreds of thousands of birds for feeding and/or breeding each year. Australia has signed multiple international treaties that oblige us to maintain the ecological character of the region. Therefore, it is our international responsibility, as well as our ethical duty to protect the system and to restore the damage that has occurred in recent years. In addition, the Lakes and Coorong also perform a range of vital services that are worth using environmental water to protect. They assist in the export of a vast amount of salt from the River Murray, ensuring that the water upstream is suitable for drinking and for irrigation; they support both commercial and recreational fishing, as well as sizeable tourism industries and recent CSIRO research shows that there is a willingness within the community to pay for the maintenance of the ecosystem.

The traditional owners, the Ngarrindjeri, have expressed a deep spiritual connection to the land and the organisms that live there, and are unlikely to consider that water used to rehabilitate the system would be wasted. In short, there are many reasons why water used to restore this unique system would not be wasted, despite the current degraded status.

- Much larger volumes of water used to flow from the South East of South Australia into the Coorong. Couldn't we restore that system and then use less water from the River Murray?

Despite many anecdotal accounts of large volumes of water flowing into the Coorong from the South East via Salt Creek, there is no data to support this claim (or otherwise). All flow data that are available for that system were collected after the extensive drainage systems in the South East had been put in place. We have, however, explored options suggested for extending the current drainage system to increase flow volumes to the South Lagoon of the Coorong. Our work suggested that, in very dry years, volumes of more than 60 GL of water from Salt Creek can have an impact on salinity levels and ecological condition in the South Lagoon. However, it is relatively unlikely that volumes of this magnitude will be able to be delivered during those very dry years (because it may or may not rain in south-east catchments when it isn't raining in the Murray-Darling Basin) and there is currently no mechanism for storing water within that system so that it can be applied when it is needed. In addition, the effect of that water, if it could be delivered when needed is was to mitigate very high salinities in the South Lagoon only but not to maintain water levels or to affect the North Lagoon. Thus, it will mitigate some of the worst effects of the very dry conditions, but, in itself, cannot maintain the system in acceptable ecological condition and will not, and could not, replace the River Murray as a major source of fresh water for the Coorong. Instead, it could be a useful insurance policy against severe ecological degradation during extended droughts.

- Many other engineering options have been proposed to maintain the ecological condition of the Coorong in very dry times. Couldn't one of those options be used to cut the amount of water needed from the River Murray?

Our work investigating the best management options to maintain the ecological condition of the Coorong during dry times has involved us running nearly 500 modelling scenarios, including many options relating to pumping of hypersaline water from the Coorong, channel works at Parnka Point, increased dredging at the Murray Mouth and additional water from the South East. Out of all those options and combinations of options, no engineering solutions came close to replicating the effect of fresh water on the Coorong. The Coorong is an estuary and therefore requires sources of both fresh water and seawater. The organisms that live in the region have evolved to be suited to those conditions and none of the engineering solutions that we have investigated provided an appropriate substitute. Some engineering solutions can play a role in optimising social, economic and ecological outcomes for the region, such as providing additional water from the South East of SA through Salt Creek to provide benefits not only to the Coorong but also arguably the SE, for example. In particular, engineering solutions can be very important in times of extreme drought (e.g. dredging of the Murray Mouth) to prevent severe ecological degradation and could be used in this way. However, none of the solutions we have investigated are able to maintain or restore good ecological condition to the region without freshwater flows, so cannot be used as a substitute for water from the River Murray. Instead, careful management, through the use of targeted engineering solutions and other interventions, should aim to increase the ability of the Coorong, Lower Lakes and Murray Mouth ecosystems to withstand occasional dry periods, while seeking to minimise those dry periods through a secure environmental water allocation.

13th International Riversymposium

Perth - Australia 11 - 14 October 2010

How much Environmental Water is enough for the Lower River Murray Wetlands? - Part I

Jason HIGHAM,

DENR, Australia

RIVERSYMPOSIUM

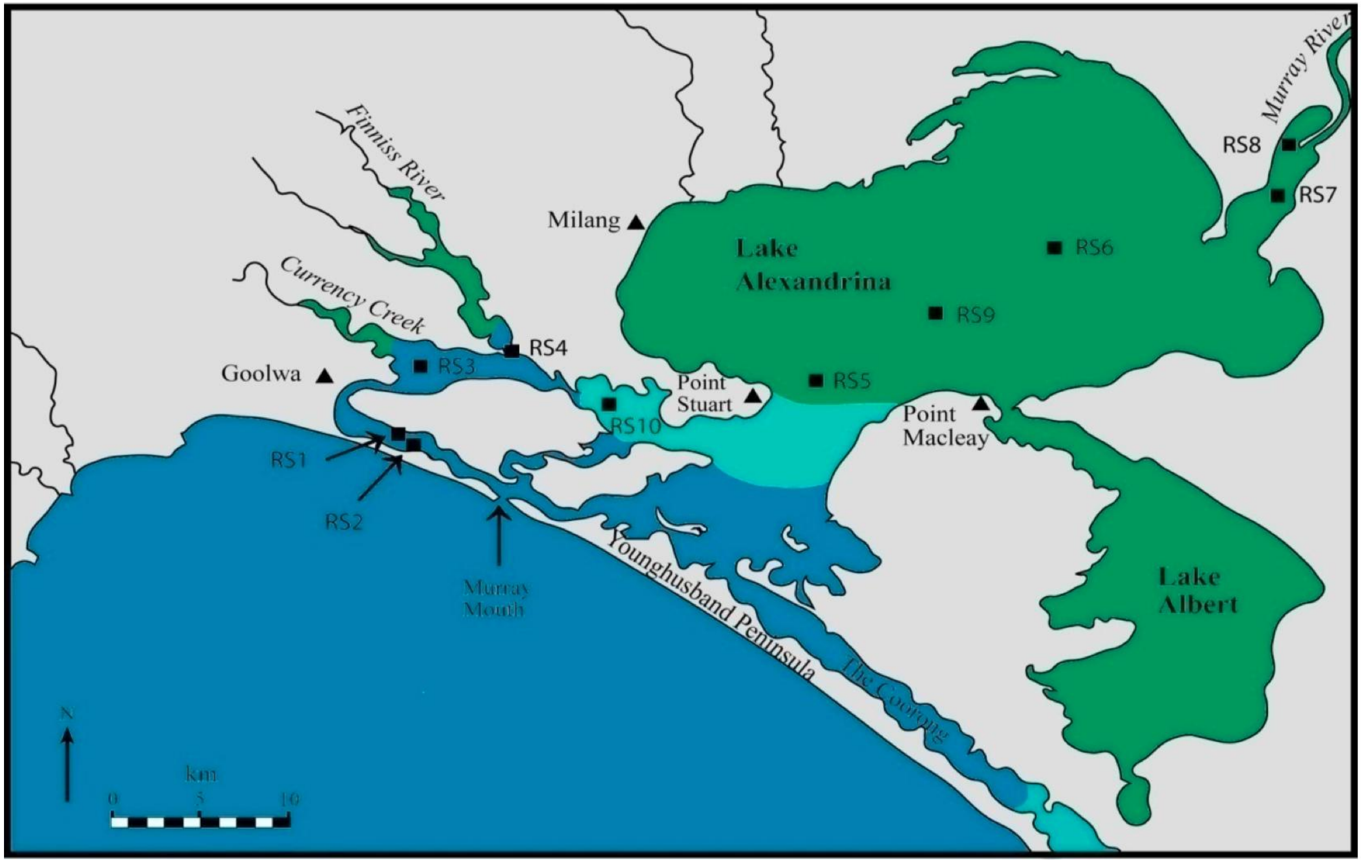
Flow requirements for CLLMM

- Sufficient flow from the MDB to ensure:
  - Lake Levels vary seasonally,
  - Barrage outflows maintain salinity in Lakes below 1000 EC 95% of the time,
  - The river flows to the sea annually
  - Higher flows as frequent as historically.
- **Average** annual outflow of **5,255 GL** /yr
- **Median** annual outflow of **3,214 GL**, /yr.

The CLLMM site

- Declared Ramsar Wetland in 1985
  - 8 of 9 Ramsar criteria
- Series of freshwater, estuarine, marine & hyper-marine habitats
- over 200,000 visitors/yr
- traditional owners are the Ngarrindjeri people

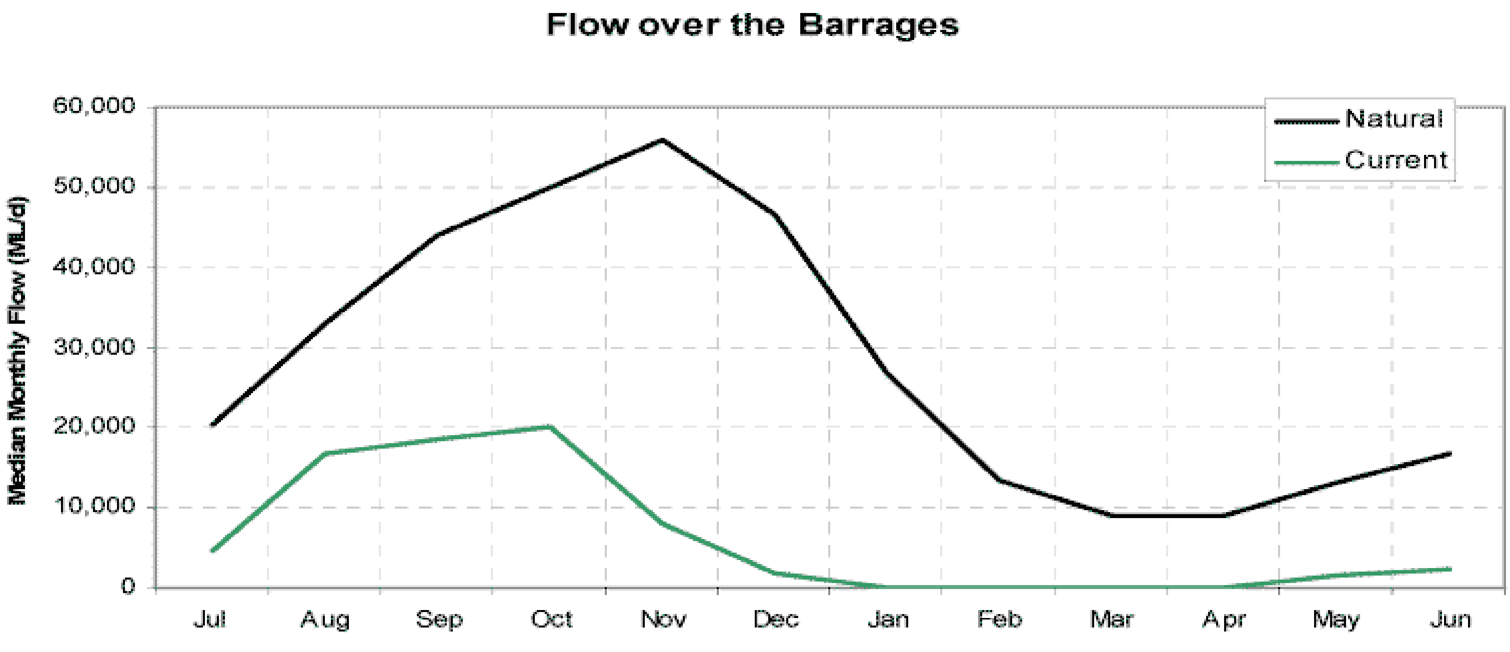
Pre-European Mixing zones based on diatom analysis



Freshwater

Estuarine/Marine mixing zone

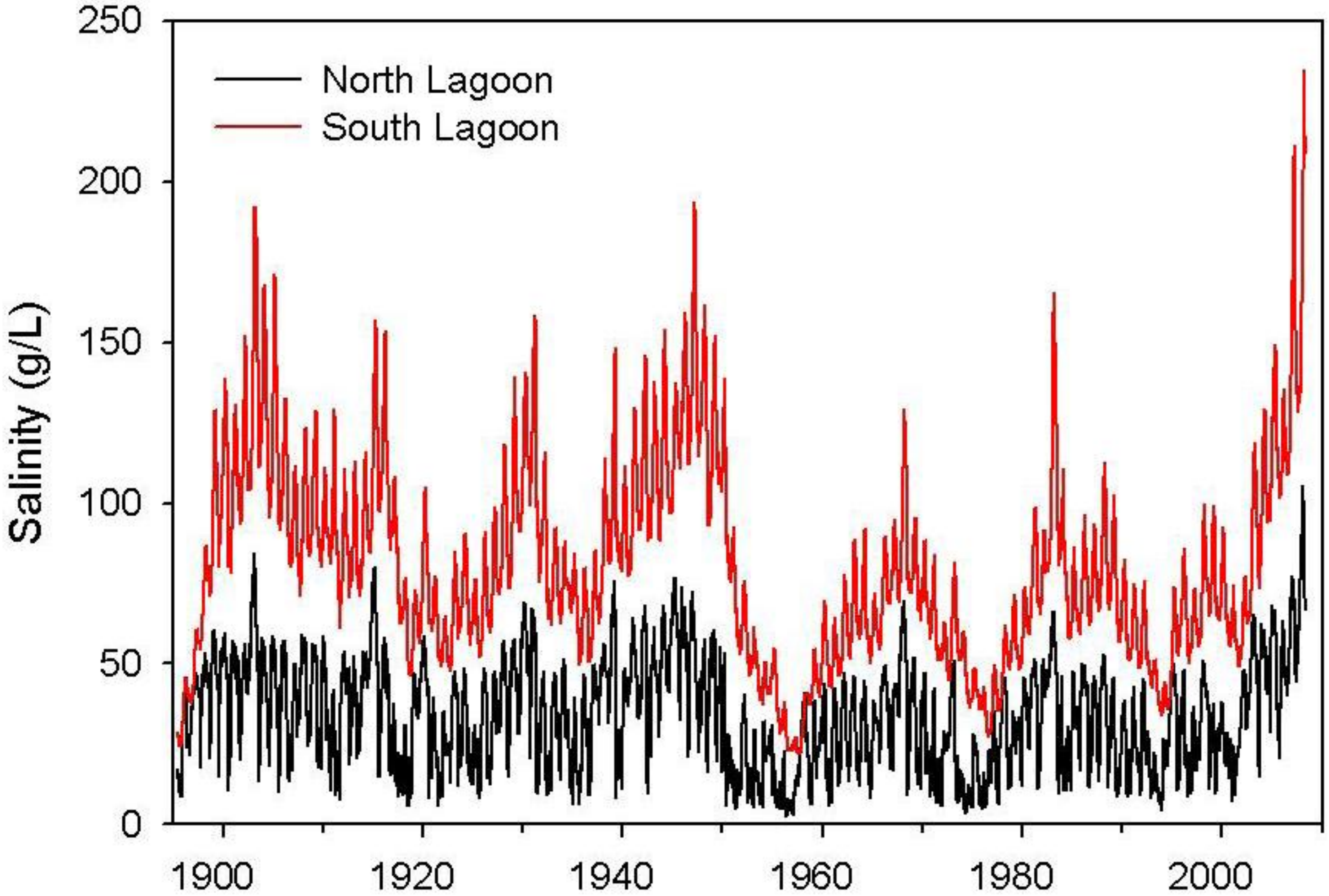
Taken from: Fluin, J, Haynes, D. and J. Tibby (2009). An environmental history of the Lower Lakes and the Coorong. The University of Adelaide, South Australia. September, 2009.



Variable	Mean	Median (50th percentile)	80th percentile	90th percentile	95th percentile
Without development	11,597	10,764	6,566	5,179	3,259
Current	4,734	3,075	690	358	138
Current/Without development	41%	29%	11%	7%	4%

Kingsford et al 2009

Coorong salinity



Context to CLLMM EWR work

- Recent drought exacerbating existing over-allocation - Significant implications for site
- Murray futures program created
- SA Government developing long term plan for site:
  – How much water is needed in the future?
  – Is the water needed available under climate change?
  – Will it go below sea level in the future?

Historical site/Basin EWR work

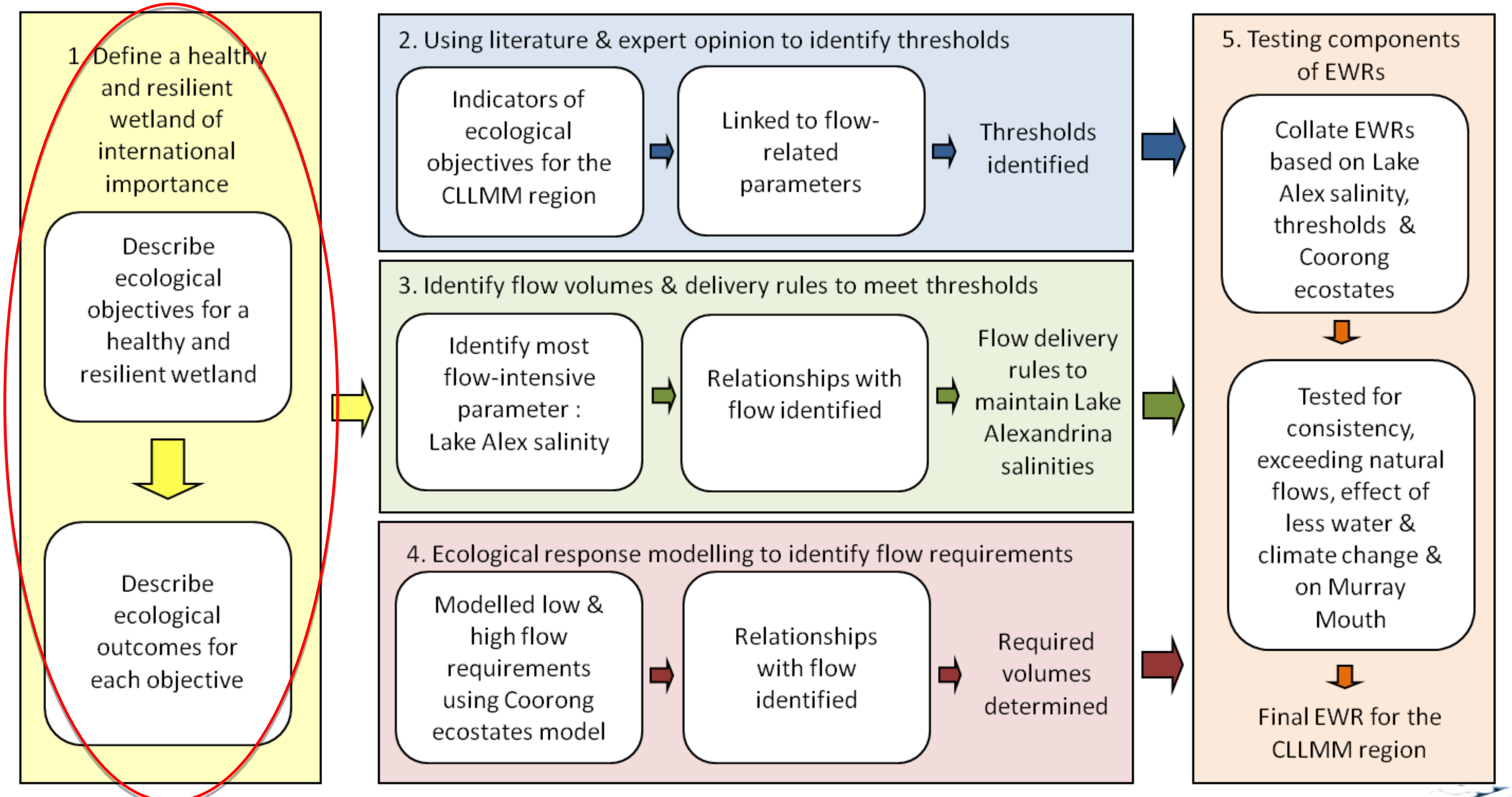
- Jones *et al* (2002) – 3250GL/yr LCE?
- End of system / barrage flows
  - Kingsford *et al* (2009) median 3800GL/yr
  - Icon site (2006) regime ave of 3953GL/yr
- Present work builds on TLM attempts
  - greater degree of documentation
  - remove constraints intrinsic under TLM

Present Project Background

- Project undertaken by
  - Dr Rebecca Lester (Flinders Uni),
  - Dr Kerri Muller from (Kerri Muller NRM)
  - Dr Theresa Heneker of (DfW)
  - J Higham (DENR)
  - Prof. Peter Fairweather (Flinders Uni),

- Presentations to be elements of this work

Methodology used



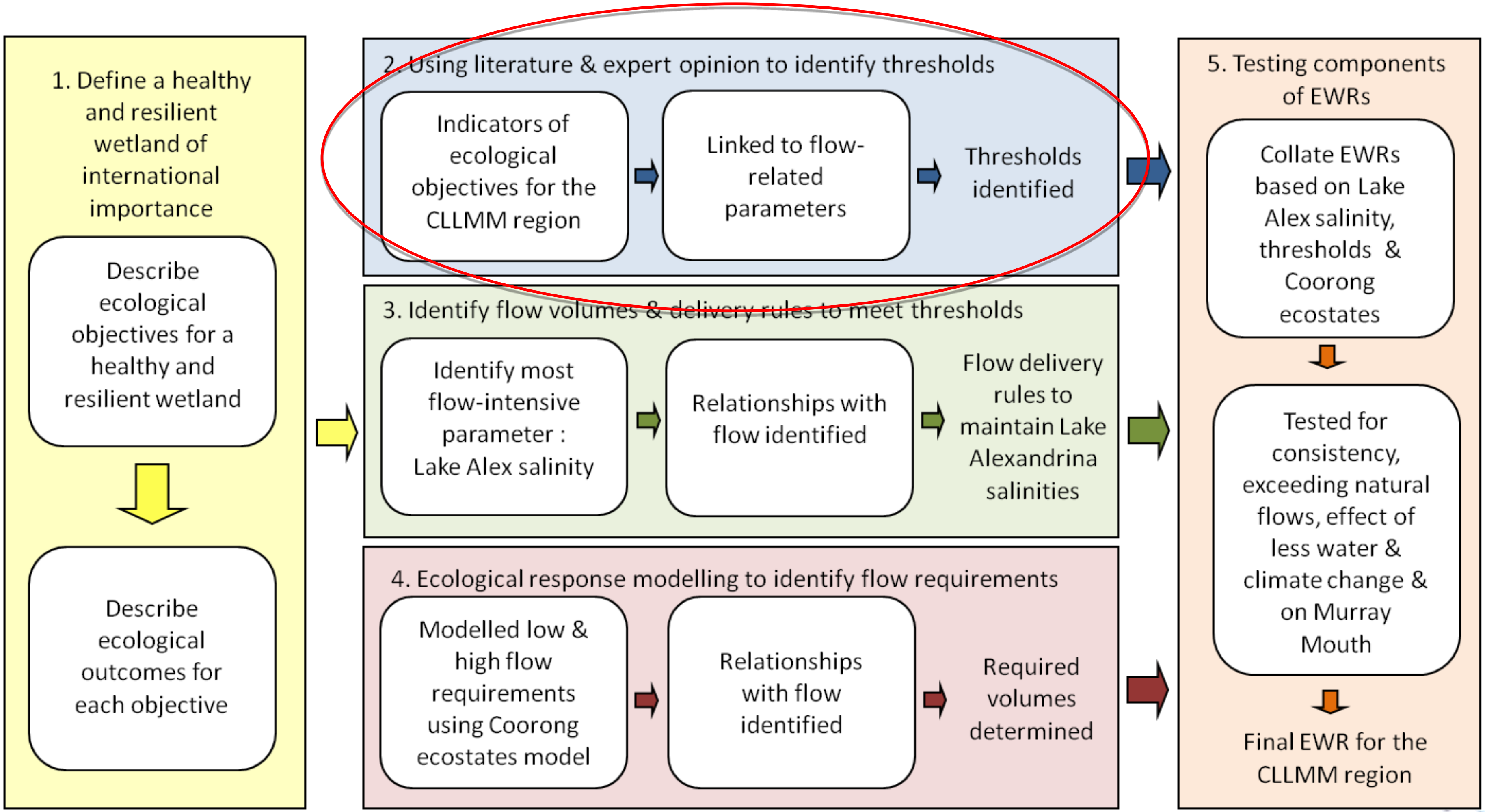
Ecological Objectives for CLLMM

- Expansion on management objective to maintain the CLLMM site as

  "a healthy & resilient wetland of international importance"

- 8 high level objectives
- 33 outcomes linked to the 8 ecological objectives
- achievement would indicate management objective achieved

Methodology used



Linking objectives & ECD

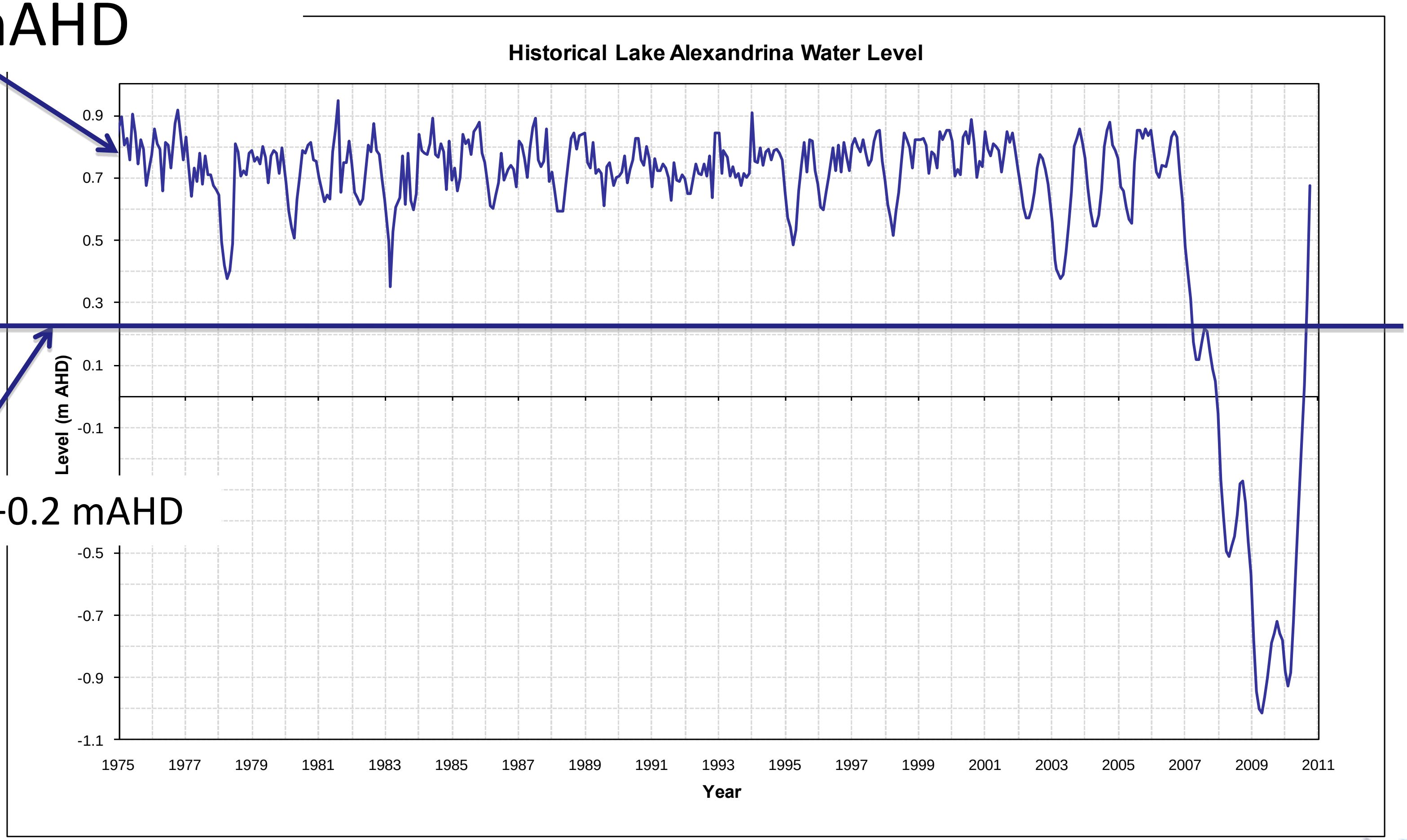
- Indicators
  - needed to provide explicit link to ecological objectives thru outcomes
- Selection based on
  - Ramsar ECD
  - key taxa & assemblages
  - ‘canary’ taxa
  - invasive taxa
  - ecological processes

Chosen indicators

- 13 vegetation species/assemblages
  - including phytoplankton assemblage
- 17 fish species
- 19 macroinvertebrate taxa
- 12 ecological processes
- No frogs, birds or reptiles included
  - Resource & information limitations
  - respond indirectly to flow

Regulated water regime: static

+0.75 mAHD



Sea level ~ +0.2 mAHD

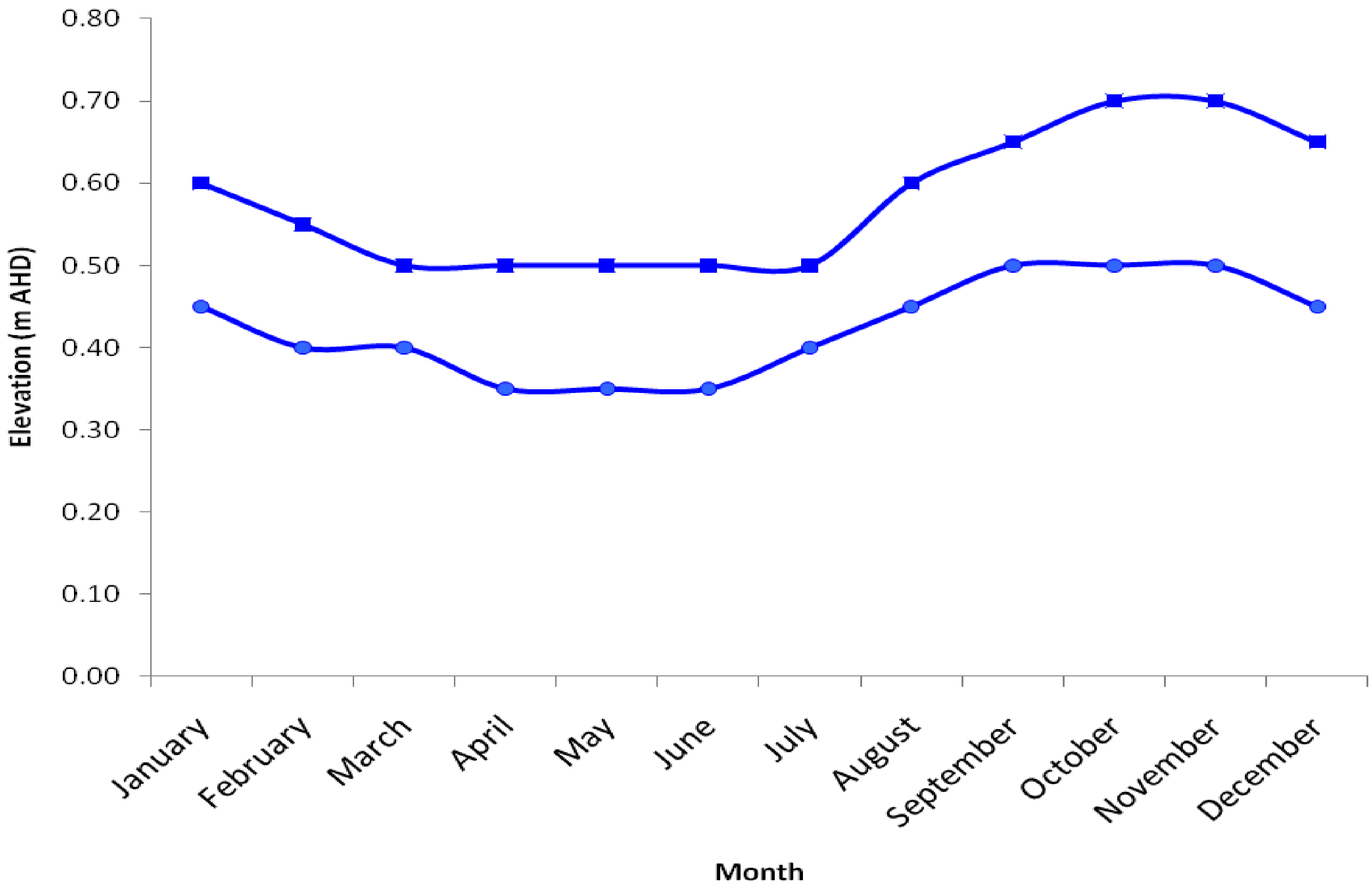
Implications of static lake levels

- Contraction of variability reduces plant diversity
  - Narrow band of vegetation (< 25 m) dominated by *Phragmites* & *Typha*
- Little or no recruitment of floodplain vegetation
- Reduces available habitat at interface
- Simplification of ECD as a whole

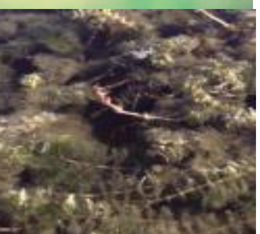
Water levels determine ECD

- Variability structures plant community
- Enable access to or disconnect habitats
  - determine habitats & trophic interactions
- Lake Alex level determines level of Lake Albert & capacity to release water
- Varying levels drives 70% of Outcomes sought
- Inundate or expose acid sulfate soils

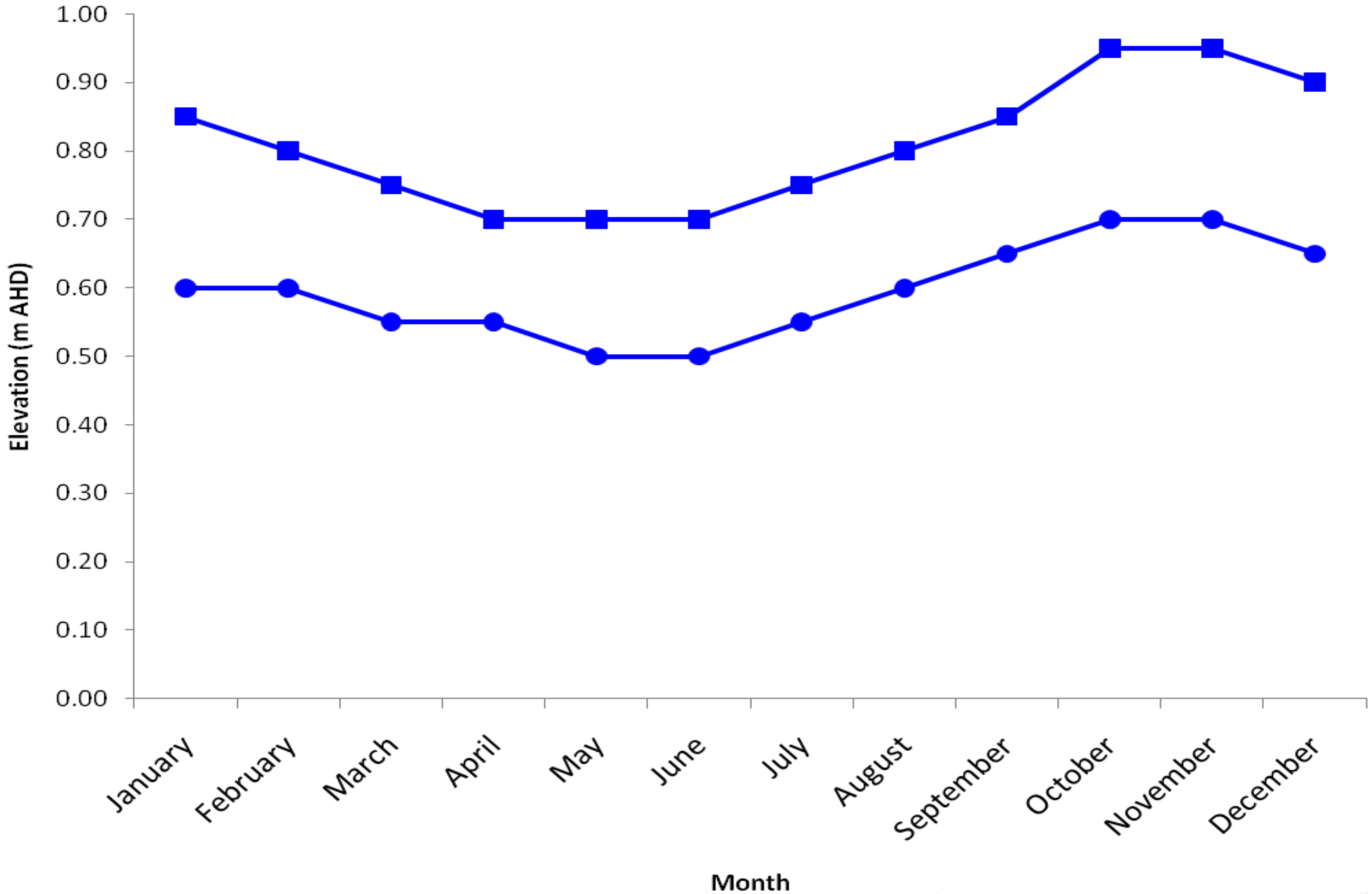
Proposed Lake regime: ARI=1





Proposed Lake regime: ARI=3



Expected ecological outcomes

- Wide, diverse littoral zone & reed beds
- Recruitment of long-lived floodplain veg
- Spatio-temporal variability of habitat & food resources for different life stages of higher trophic levels
- Continuous connection to islands
- Facilitates hydro connection to estuary
- Minimise lakeshore erosion

Flow-related sensitivities

- Known thresholds for each indicator
  - salinity ← Most information available
  - water level
  - turbidity
  - intervals between barrage flows
  - intervals between flooding
  - connectivity
  - timing of flows & water levels

Indicator species Common name	Scientific name	Functional Group	Life span	Flow-related requirements Salinity (g/L)	Connectivity	Water level	Timing
				ates … nate … o … y of … nt up to			
Freshwater Crayfish (Yabbie)	*Cherax destructor*		approx. 4 years[5]	Adults more tolerant than juveniles; normal behavioural responses (loss of activity) affected at range of 12 - 18 g/L[3]; number of freshwater	Able to burrow & survive in ephemera aquatic habitats; ca survive several years between floods	Prefer to be under water, are able to survive drought[2]	Spawning period noted to be between July & January in WA[4]
Mayfly larvae	Ephemeroptera		most adults are short lived, lasting only a matter of days or even hours[1]; larval life 40-110 days[6]	… 5.399 g/L; non-baetid >8.568 - 10.2 g/L[7]			
Stonefly larvae	Plecoptera		adults can live up to a month[1]	10.2 - 13.6 g/L[7]			Most adults emerge around spring or autumn
Caddisfly larvae	Trichoptera		examples of very short-lived & adults that live for many months (e.g. *Odontocerum albicorneand Glyphotaelius pellucidus*, respectively)[8]	6.12 - 26.15 g/L[7]			

Indicator names

Sources referenced

Life history characteristics

Quantitative thresholds

Qualitative information

Salinity & Sub-lethal impacts

- Persistence not always best measure
  - Especially for long-lived organisms
- Sub-lethal impacts
  - Δ in condition without mortality ie prevalence of disease, Δ growth rates, no recruitment
  - can influence population viability over time
- Thresholds mostly poorly understood

Sub-lethal impacts cont...

- Vegetation thought to be more sensitive
  - Lethal thresholds 3-4 g L^{-1} for FW taxa
  - Documented effects 1 g L^{-1} (~1500 EC)
    - e.g. stunted growth, delayed germination, no flower development
- Macroinvertebrates also affected
  - Also affected at ~ 1 g L^{-1}
    - lower microcrustacean diversity, ↓egg survival, delayed emergence

Conclusions & thresholds

- Salinity target most robust & appropriate
  - Incorporates many other requirements
  - Most literature & info on tolerances
- BUT, **conservative approach warranted**
  - unknown influences & interaction of stressors
  - Lake Albert/Alex salinity relationship

Conclusions & thresholds

- **Lake levels vary seasonally** between:
  - 0.35m & 0.75m AHD 2 yrs in 3,
  - 0.5m & 0.83m AHD every third year.
- Water quality target:
  - a long-term average of 700 µS cm^{-1} EC
  - **below 1000 µS cm^{-1} EC 95% of the time**
  - **always below 1500 µS cm^{-1} EC.**
- CLLAMMEcology: Coorong salinity & water level thresholds & targets

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KERRI MULLER NRM
WATER • LAND • LIFE

Australian Government

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  Chris Bice,
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- Refer to reports for all references when released later this year

Key Points & concepts

- The Lakes have always been a freshwater environment - barrages just artificially maintained this in spite of development
- The environment requires a range of flows rather than a fixed volume year in, year out (**environmental water requirements should be expressed as an average for planning purposes only**)
- Water level is a key environmental attribute that determines the availability of physical habitat for fish, birds plants and other aquatic life
- Salinity levels, their degree of variation and rate of change, affect the aquatic species present and their "health"
- Barrage outflows control the water level and salinity of Lakes Alexandrina and Albert and provide connectivity to the Coorong
- Barrage outflows major "driver" of Murray Mouth openness & these in combination affect water levels & water quality of the **entire** Coorong
- Flows from the SE of the state are complementary to Barrage outflows (and are **much** smaller volumes)
  - **CAN only moderate degradation in southern Coorong CAN NOT prevent it.**

CLLMM EWR Summary

- Work undertaken is robust and links ecological outcomes to water quality and volumes through MDBA approved models
- Possible to demonstrate the impacts of insufficient flow on the site and risks posed
- Work to date indicates water required for the site and regime can be provided for even under climate change
- Volumes determined in line with other studies
- More work required to complete and refine EWR now underway
  - International peer review of existing work

Flow objectives for CLLMM

- Lake levels vary seasonally & inter-annually
- The river flows to sea annually – higher security to low flow regime
- Barrage outflows to maintain salinity
  - total outflow 6,000 & 12,000GL per 3-yr rolling period
  - not less than 650GL in any 1 of the 3-yrs
- higher barrage flows of between 6,000GL & 10,000GL as frequent as historically the case

Flow objectives for CLLMM

- Sufficient environmental flow from the MDB to ensure:
  - **Lake levels vary seasonally** between 0.35 metres and 0.75 metres above sea level annually, with higher lake levels of between 0.5 metres and 0.83 metres above sea level every third year.
  - **Barrage outflows sufficient to maintain salinity in Lake Alexandrina below 1000 EC 95% of the time***,
    - a total barrage outflow of between 6,000 and 12,000GL per three year rolling period and not less than 650GL in any one of the three years
  - **The river flows to the sea annually** – higher security to low flow regime
  - **higher barrage flows of between 6,000 GL and 10,000 GL every three and seven years respectively** to supplement the flows needed to maintain the lake's water quality and **keep the Southern Coorong 'healthy' as frequently as was historically the case** .

EWR Findings or Simple numbers…

- **Coorong, Lower Lakes & Murray Mouth require*:**
  - **Average** annual outflow of **5,255 GL** per year.
  - **Median** annual outflow of **3,214 GL**, per year.

Comparisons:

- The historical baseline scenario used by the MDBA
  - average annual outflow of **4,845 GL**, per year
  - median annual outflow of **2,958 GL** per year
- Modelled historical (pre-development) scenario
  - average annual outflow of **11,660 GL** per year
  - median annual outflow of **10,870 GL** per year.

*Lake Alex WQ <1000 EC 95% of time & not seeking Coorong to be 'healthier' than in the past

13th International Riversymposium

Perth - Australia 11 - 14 October 2010

How much environmental water is enough for the Lower River Murray wetlands? Part II

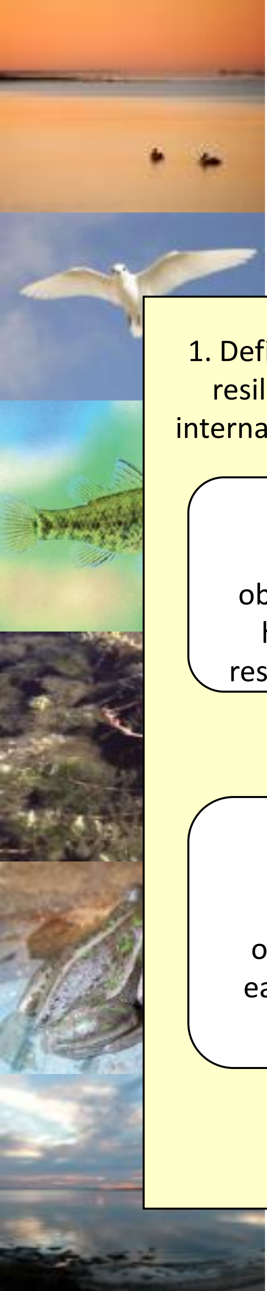
Rebecca Lester, Peter Fairweather, Theresa Heneker, Jason Higham & Kerri Muller

Flinders University, Australia

RIVERSYMPOSIUM

An environmental water requirement for the Coorong, Lower Lakes & Murray Mouth

- Ramsar-listed Murray-Darling Basin wetland
  - Including the estuary
- Recent drought & over-allocation led to severe ecological decline
- How much water is needed?



EWR modelling methods

1. Define a healthy and resilient wetland of international importance

- Describe ecological objectives for a healthy and resilient wetland
- Describe ecological outcomes for each objective

2. Using literature & expert opinion to identify thresholds

Indicators of ecological objectives for the CLLMM region → Linked to flow-related parameters → Thresholds identified

3. Identify flow volumes & delivery rules to meet thresholds

Identify most flow-intensive parameter
• Lake Alex salinity
→ Relationships with flow identified → Flow delivery rules to maintain Lake Alexandrina salinities

4. Ecological response modelling to identify flow requirements

Modelled low & high flow requirements using Coorong ecostates model → Relationships with flow identified → Required volumes determined

5. Testing components of EWRs

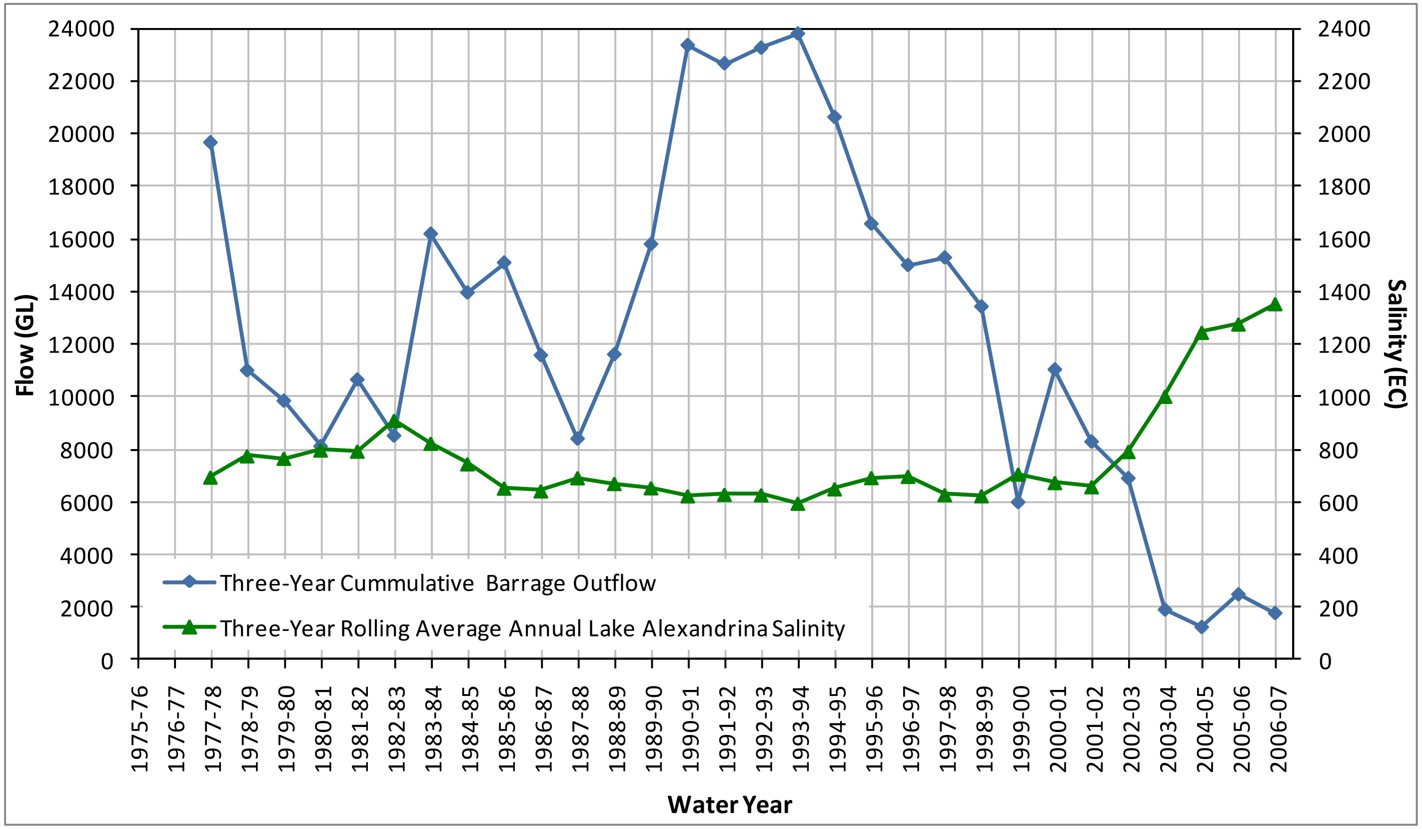
- Collate EWRs based on Lake Alex salinity, thresholds & Coorong ecostates
- Tested for consistency, exceeding natural flows, effect of less water & climate change & on Murray Mouth
- Final EWR for the CLLMM region

Targets for the region

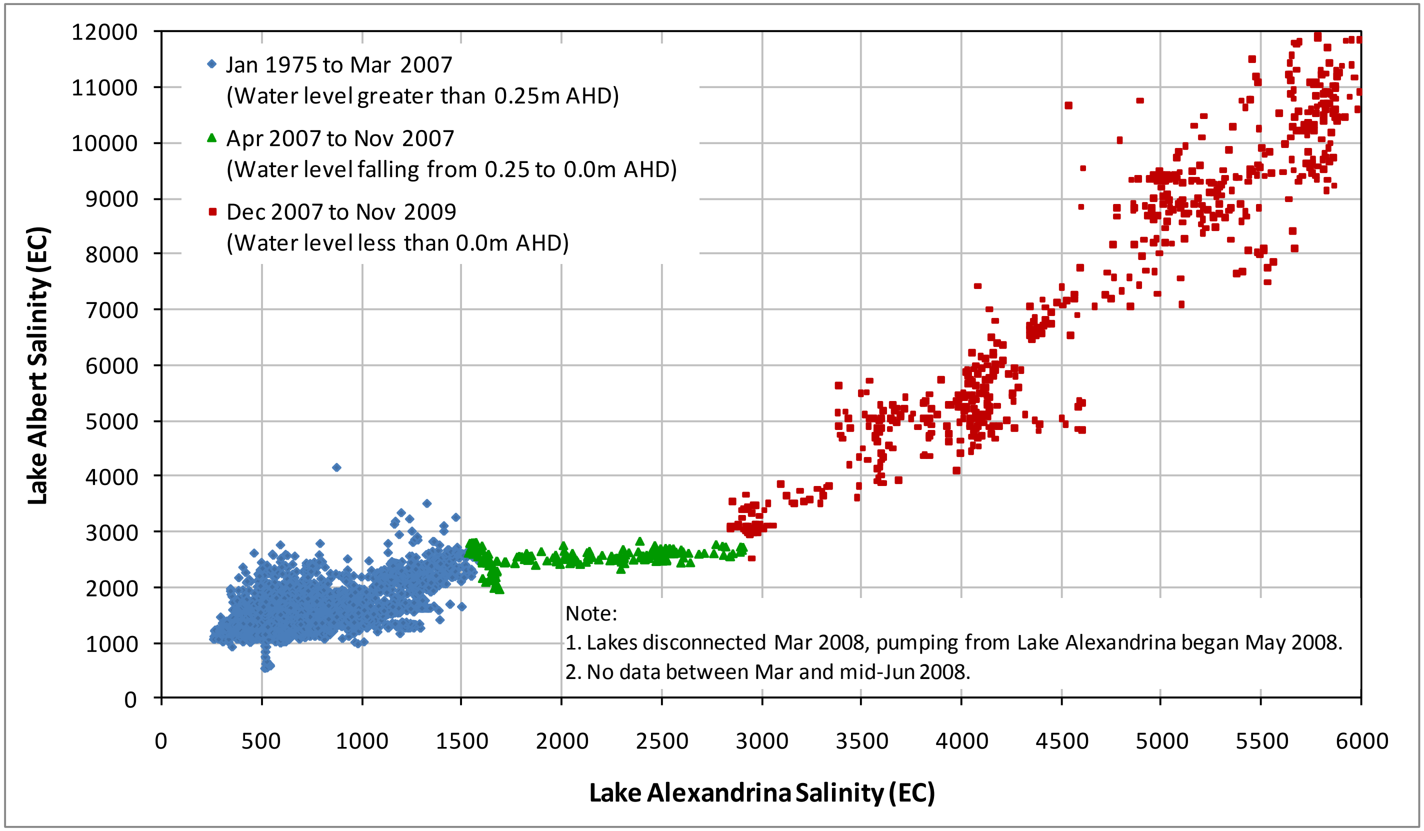
- Water levels to mimic natural variability
  - To support floodplain vegetation
- Salinities in Lake Alexandrina of 700-1000 µS cm^{-1} EC, always less than 1500 µS cm^{-1}
  - Salinity in Lake Alex linked to Lake Albert & Coorong
- Based on assessment of flow-related requirements indicators
  - Using literature reviews & expert opinion
  - Species, assemblages & ecological processes
  - Based on Ramsar-listed ecological character

Lake Alexandrina salinity & barrage outflows

Relationship between annual outflow sequences & average salinity



Relationship between Lake Alexandrina & Lake Albert salinity

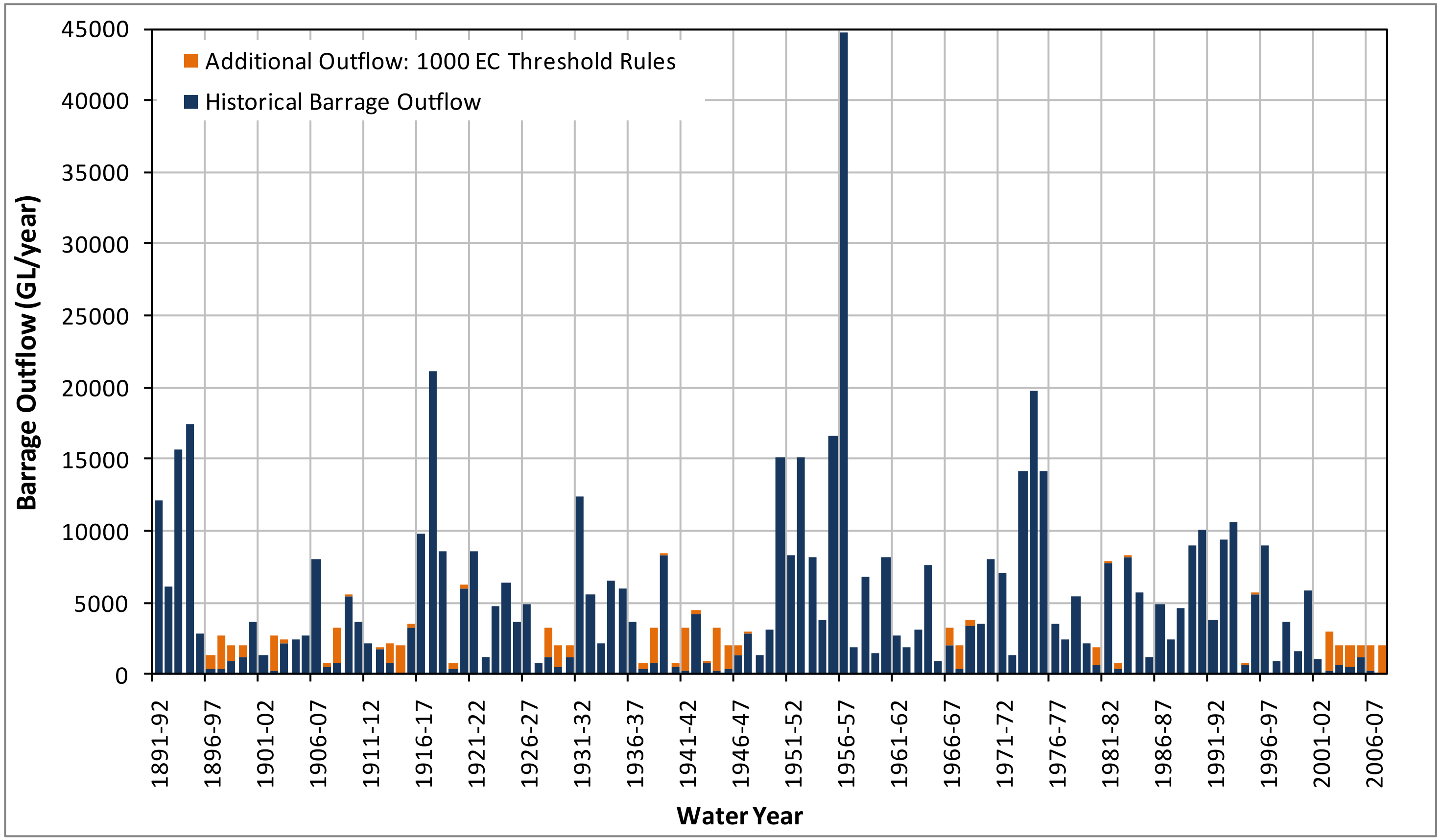


Minimum flow regime to meet 1000 EC threshold

- Barrage outflow is calculated as the greater of:
  1. 650 GL
  2. 4000 GL – F_{X-1} (where FX-1 = flow from previous year)
  3. 6000 GL – F_{X-1} – F^{*}_{X-2} (where F^{*}_{X-2} = minimum of flow from two years ago and 2000 GL)
- Accommodate low water availability
  - a 650 GL absolute minimum outflow
  - less than the required outflow of 2000+ GL yr^{-1} required

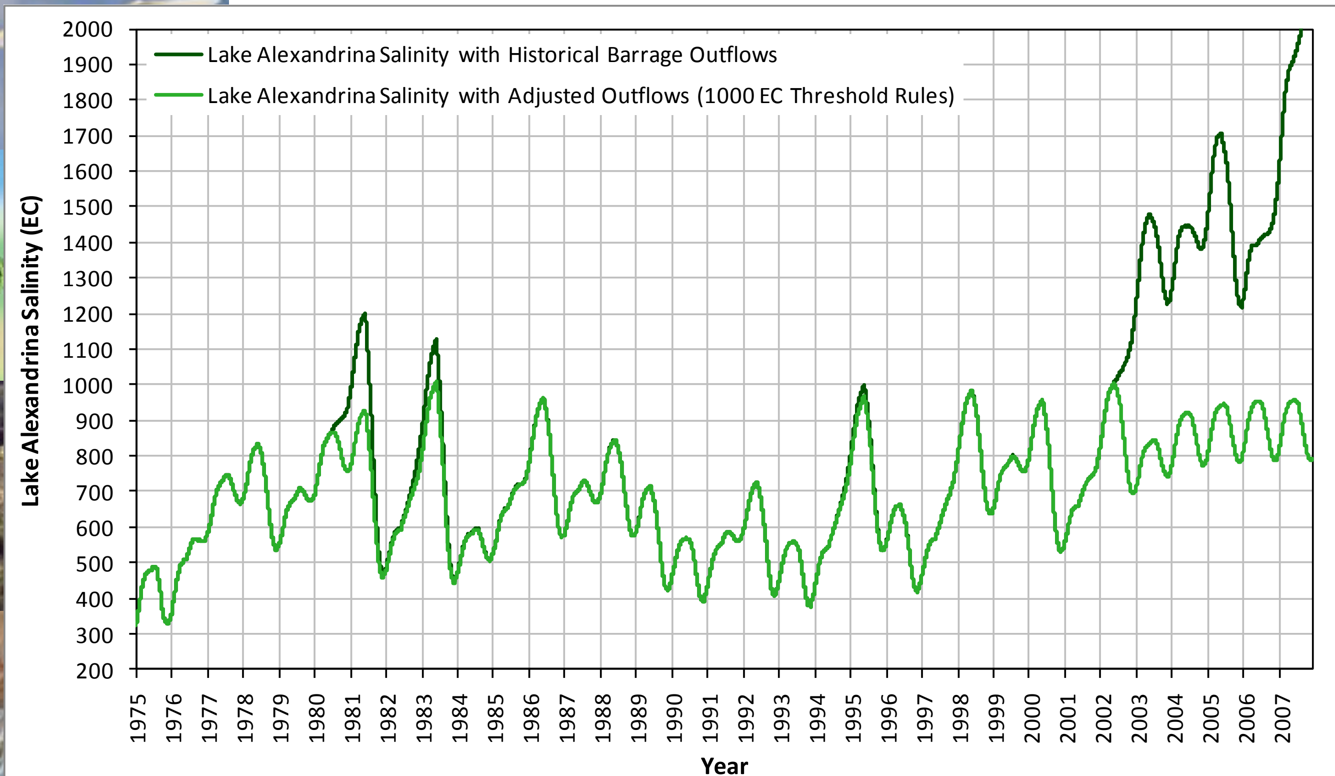
Adjusted historical barrage outflows

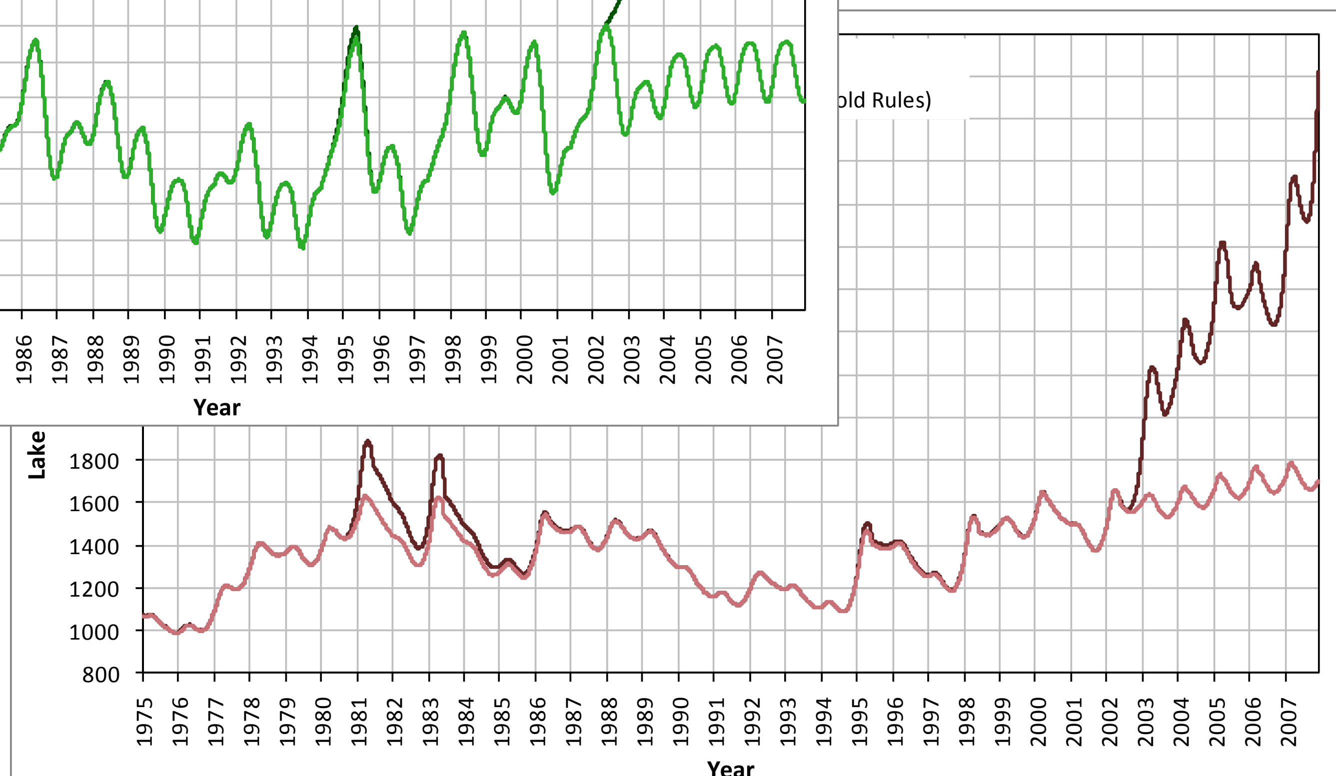
Adjustments required over 114 years of modelled historical climate



Lakes salinity with adjusted barrage outflows

- Maximum Salinity < 1000 EC
- Average Salinity ~ 700 EC



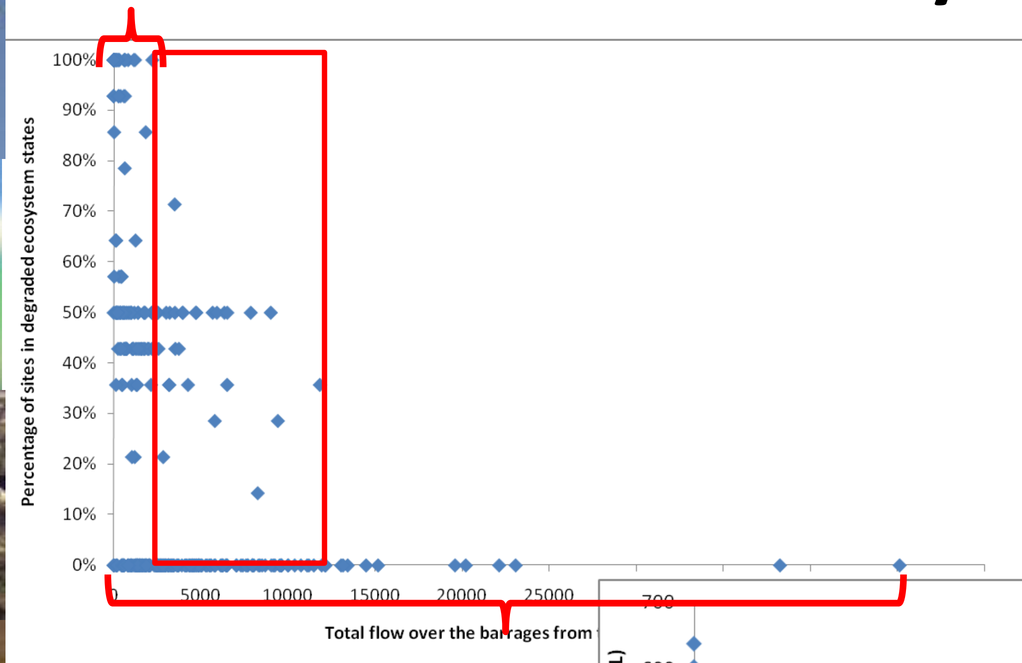


- Maximum Salinity < 1800 EC
- Average Salinity ~ 1400 EC

Developing a Coorong EWR

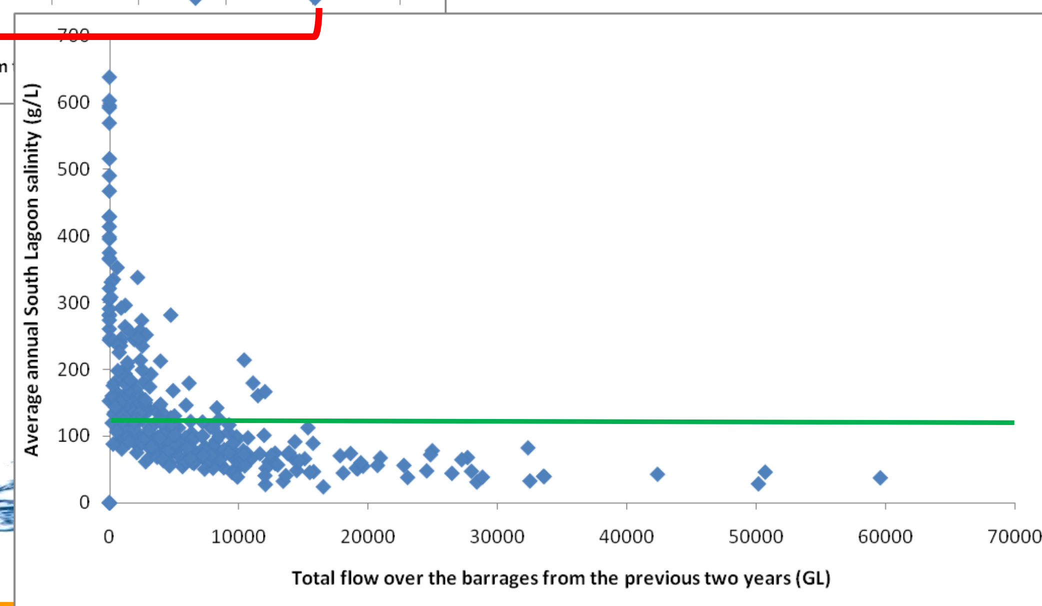
- In addition to indicator assessments
  - parallel process, multiple lines of evidence
- Targets based on existing Coorong models
  - % degraded ecosystem states
  - % time Sth Lagoon salinity >117 g L^{-1}
    - Shown to predict future degraded ecosystem states
  - % Healthy Hypersaline site-years
    - Thought to be correlated with high flow events

Relating flow, degraded ecosystem states & salinity



Relating flow from previous year to % degraded ecostates

Relating flow from previous 2 yrs to average Sth Lagoon salinity (green line = 117 g L^{-1} threshold)



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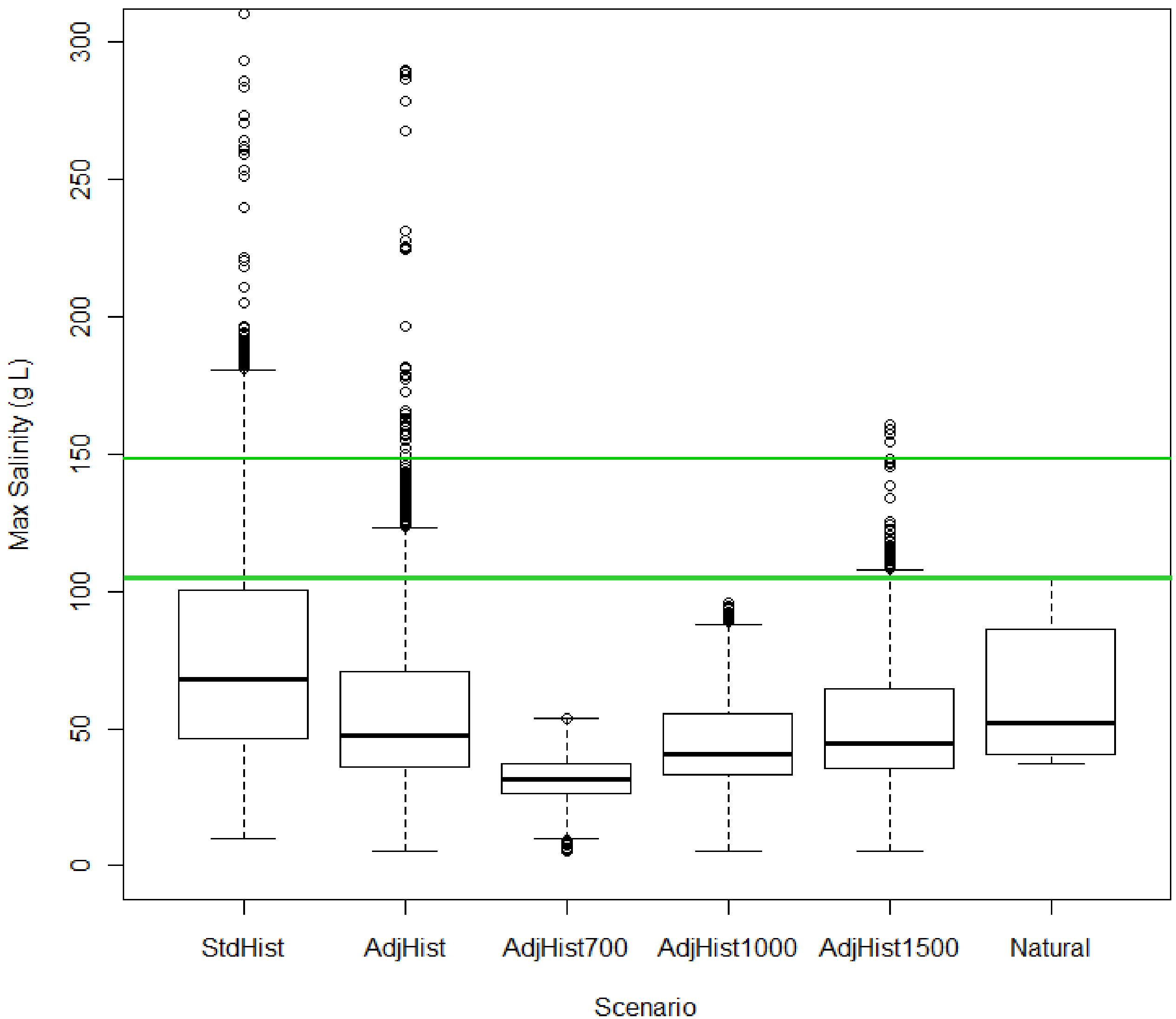
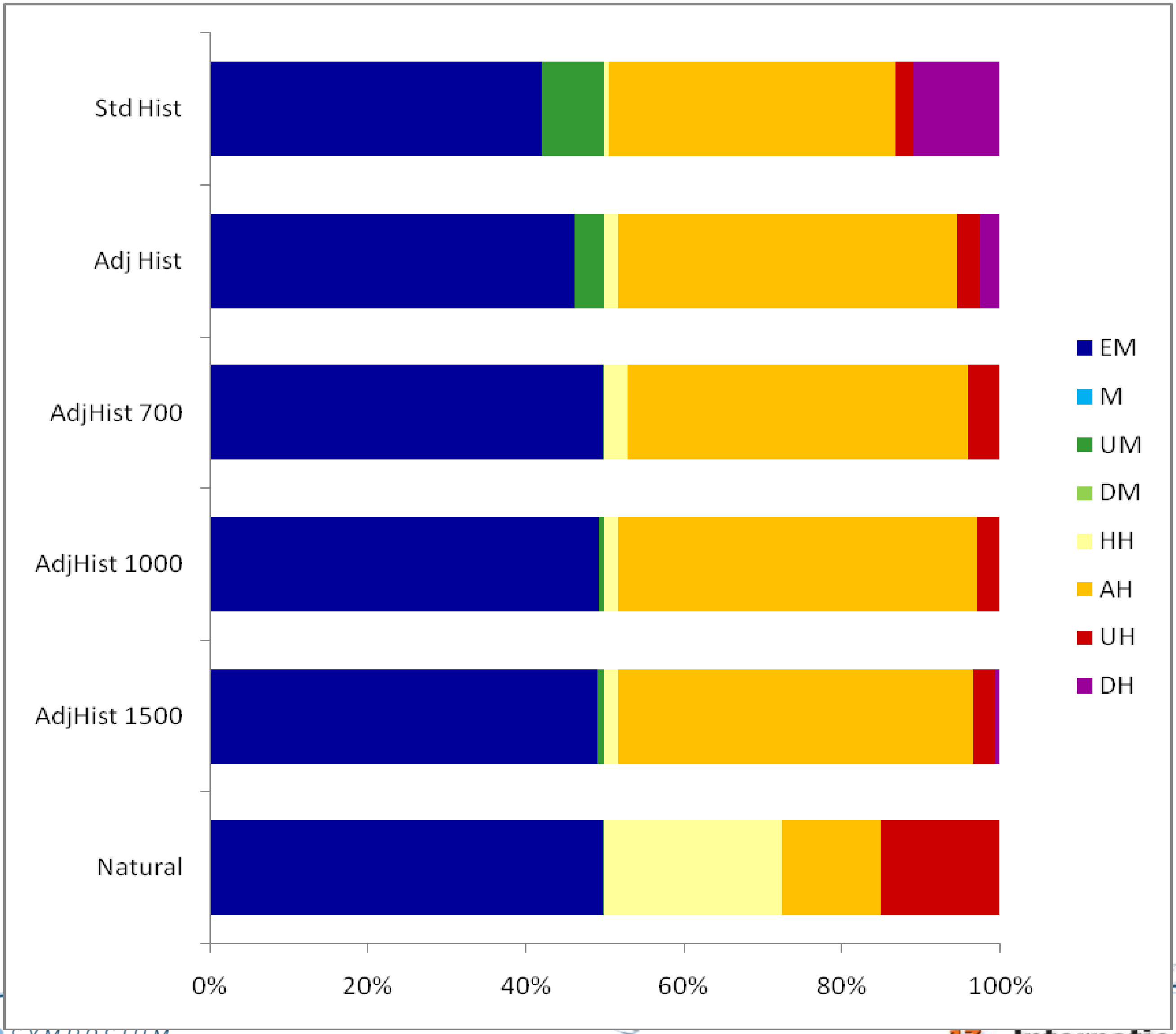
Resultant flow requirements

- Minimum EWRs slightly less than those for Lakes targets
  – to prevent certainty of exceeding salinity target in Coorong & 100% degraded ecosystem states
- But, also identified a high flow requirement
  – 6000 & 10 000 GL required every 3 & 7 yrs
  – needed to create ecosystem state associated with high flows

Testing the effect on Coorong salinity



Testing the effects on Coorong ecosystem states

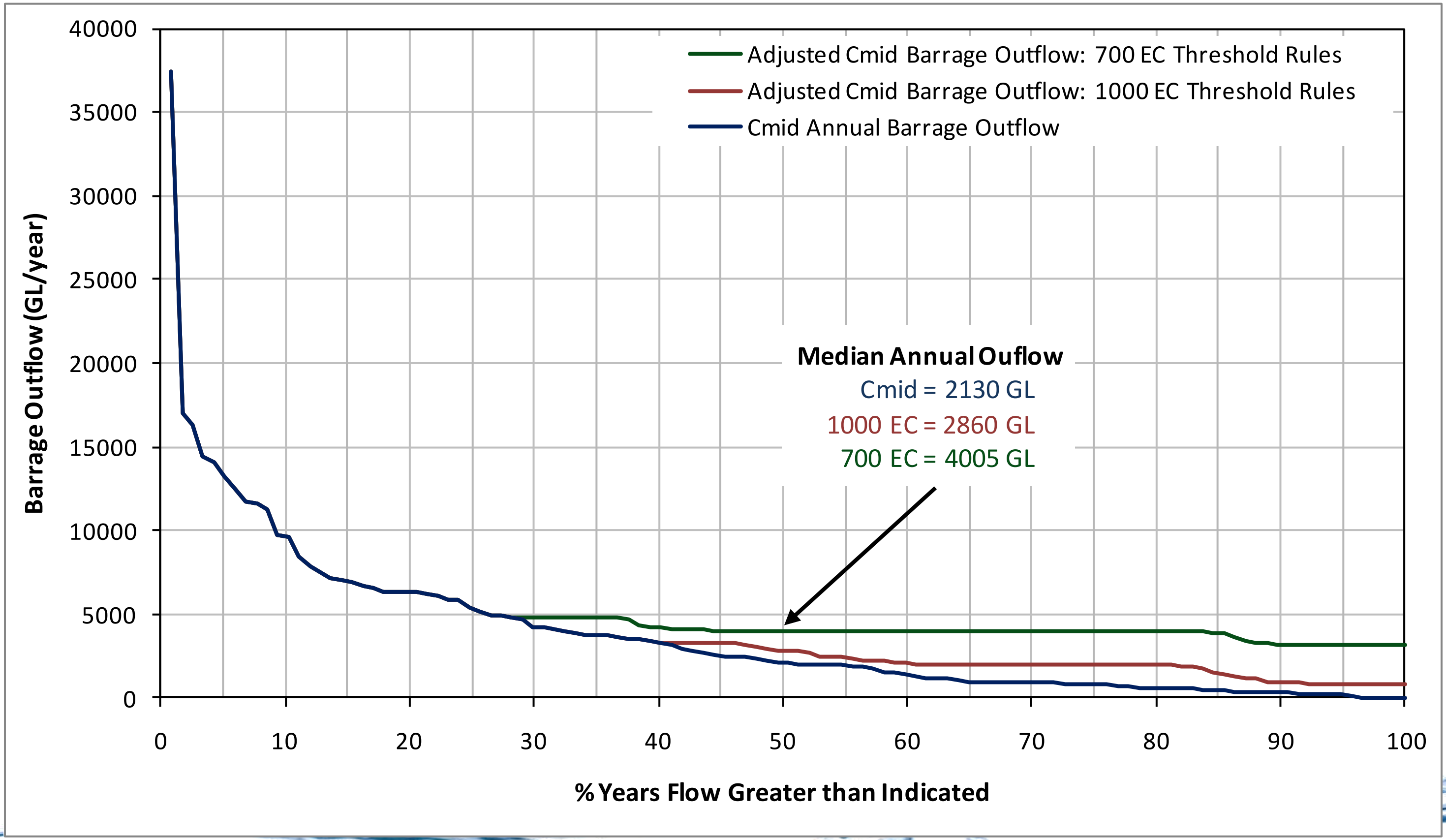


Summary of effects on Coorong

- Flows to meet targets of 700 or 1000 µS cm^{-1} EC in Lake Alex
  - Much lower salinities, improved water levels & depths
  - Prevented the most-degraded ecostates appearing
  - Prevented exceedence of SL salinity threshold
  - Did not increase appearance of high-flow ecostate
- Method of flow delivery was critical
  - Particularly under low flow conditions

Testing water availability

- Outflow frequency curves increased under median climate change
- Lower range for 1000 EC threshold, larger range for 700 EC threshold



Water availability under a median future climate

- Evaluated natural flows for lowest inflow sequence on record
- Water needs to meet 1000 µS cm^{-1} threshold
- In 1 of the 5 driest years, there was a deficit (2006/07)
  - but is likely a result of "flow timing"
- Therefore, there is enough water
  - except possibly under extreme climate change
- Needs to be verified after water availability data are available

Synthesis of CLLMM EWRs

- EWR for the Coorong, Lower Lakes & Murray Mouth:
  - – Flows to maintain salinity targets of 700 - 1000 µS cm^{-1} EC in Lake Alex
    - Equates to a minimum of 650 GL with a rolling 3-yr average of 2000-4000 GL yr^{-1}
  - – High flows of 6000 & 10 000 GL every 3 & 7 yrs on average

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- DENR: Dr Alec Rolston, Russell Seaman
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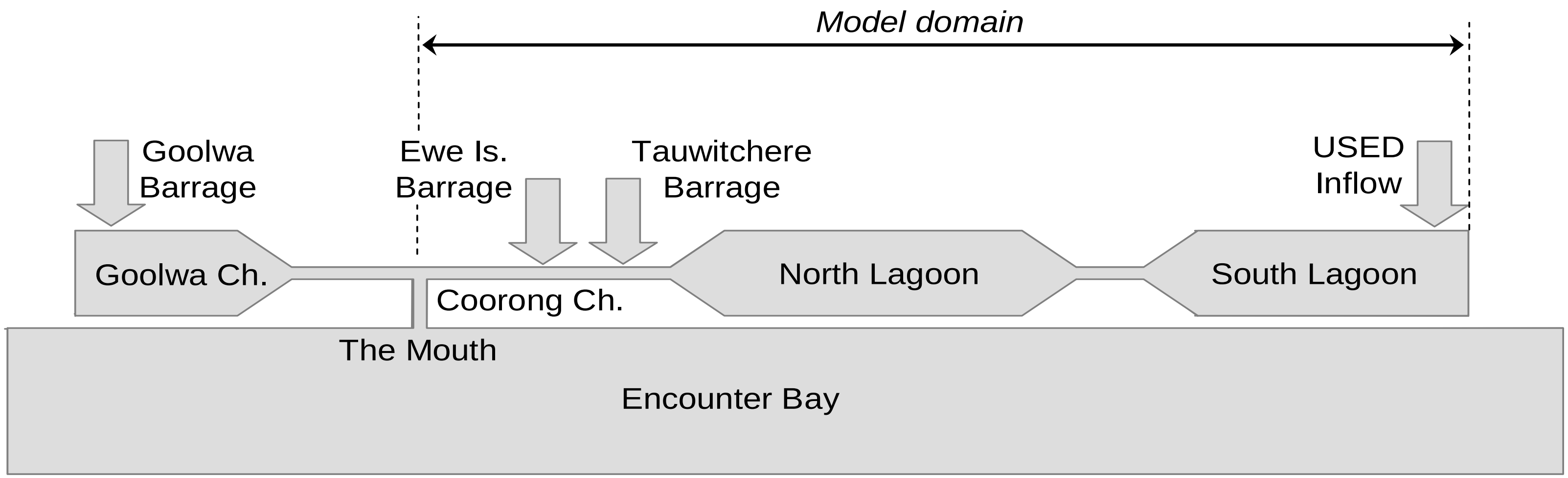
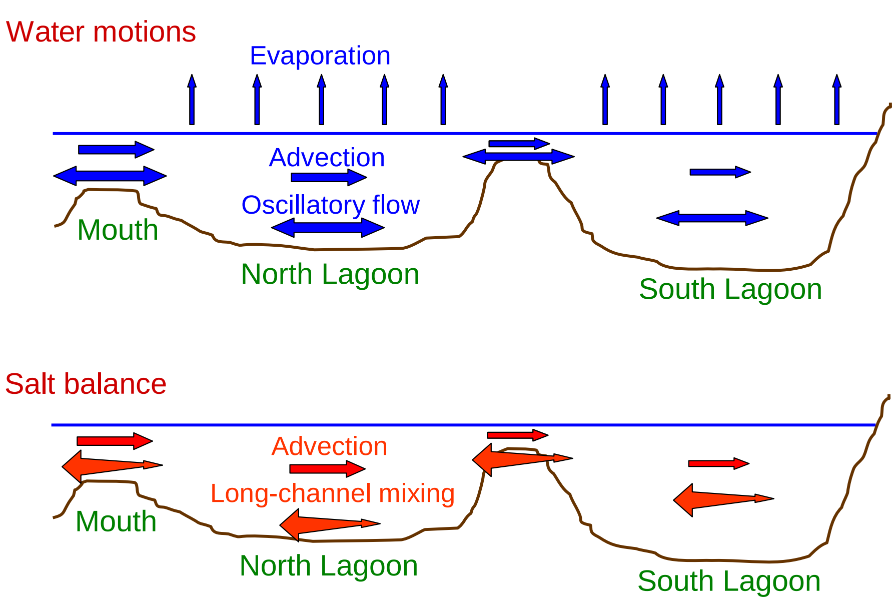
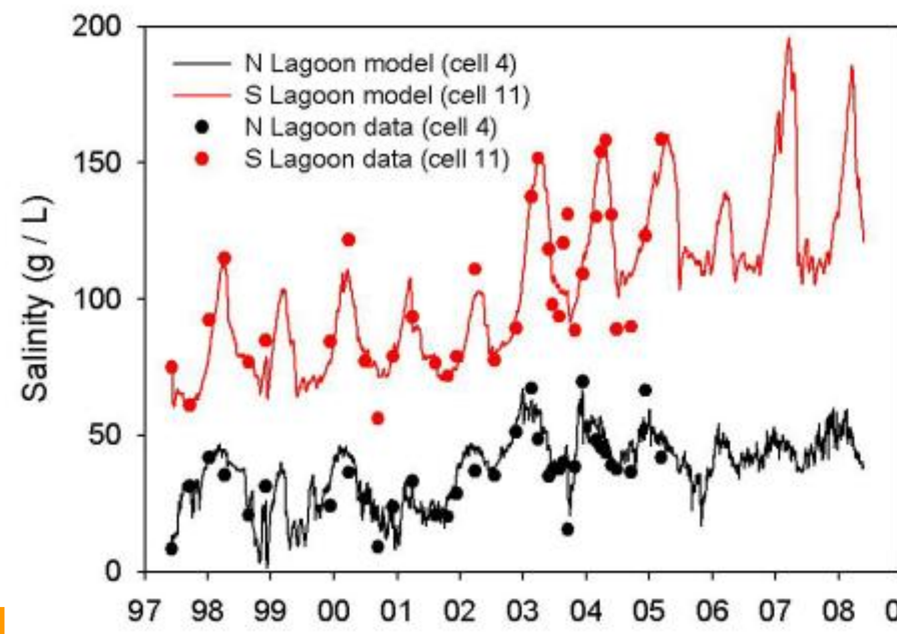
- Adelaide Uni: Dr Russ Shiel

- Refer to reports for all references when released later this year

Hydrodynamic model







Ecosystem states model