Environmental flows science to save rivers in the face of uncertainty

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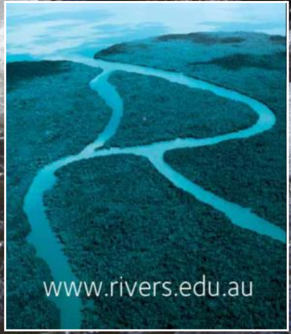


Griffith UNIVERSITY

Themes

- Improving the science of e-flows
- Learning from ELOHA
- Murray-Darling Basin e-flows
- So what of e-flows science?

Environmental Flows

Environmental flows describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend upon these systems

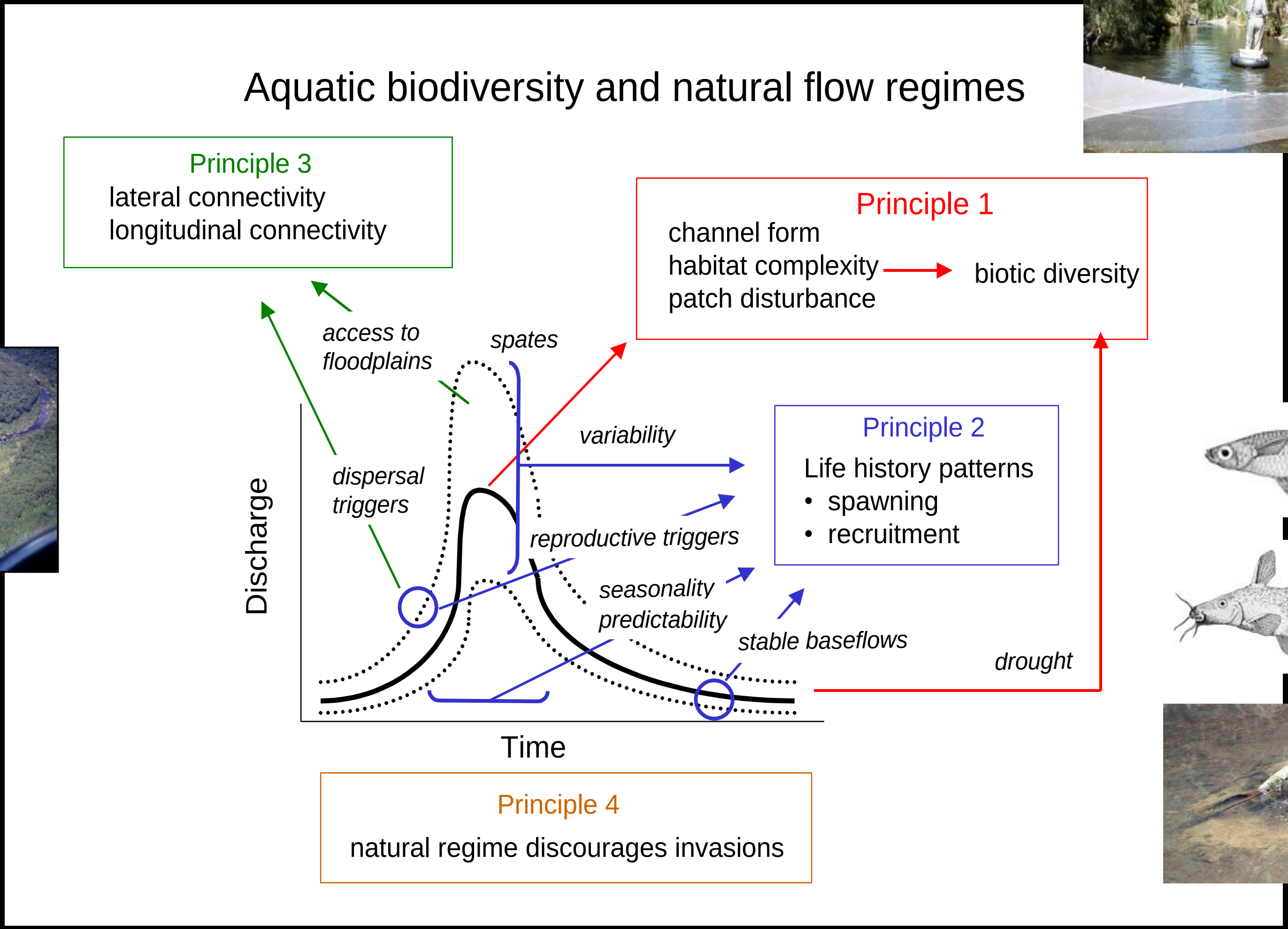
Brisbane Declaration 2007

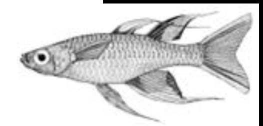
International Environmental Flows Conference, Brisbane, September 2007

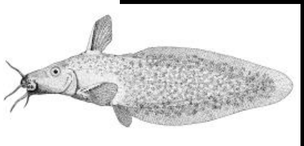
750 delegates from over 50 countries

General flow-ecology principles

Bunn & Arthington (2002). *Environmental Management* 30.







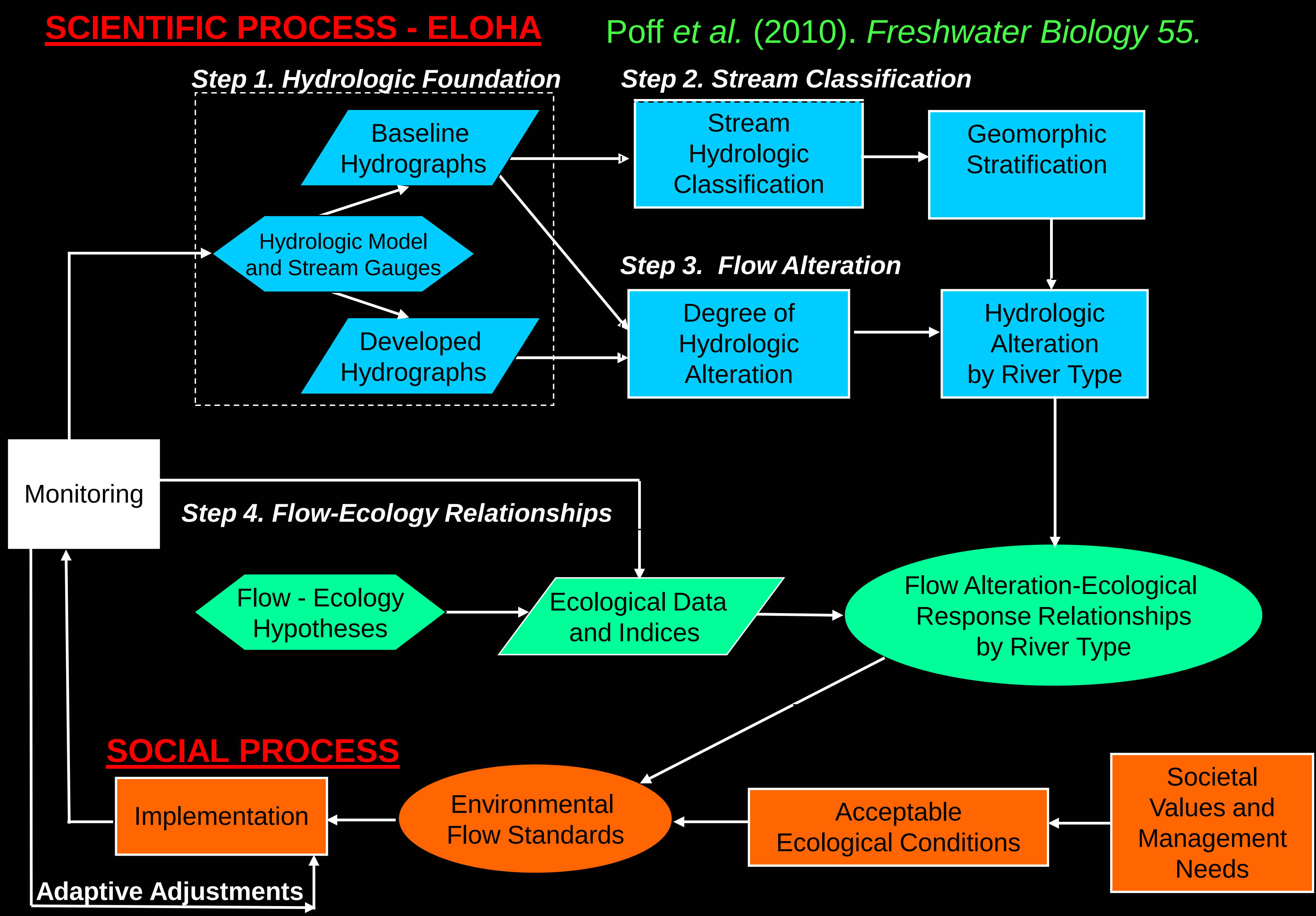
Literature compilations and meta analysis

- Lytle and Poff (2004). *Trends in Ecology and Evolution 19.*
  Adaptation to natural flow regimes.

- Poff and Zimmerman (2010). *Freshwater Biology 55.*
  Ecological responses to altered flow regime.

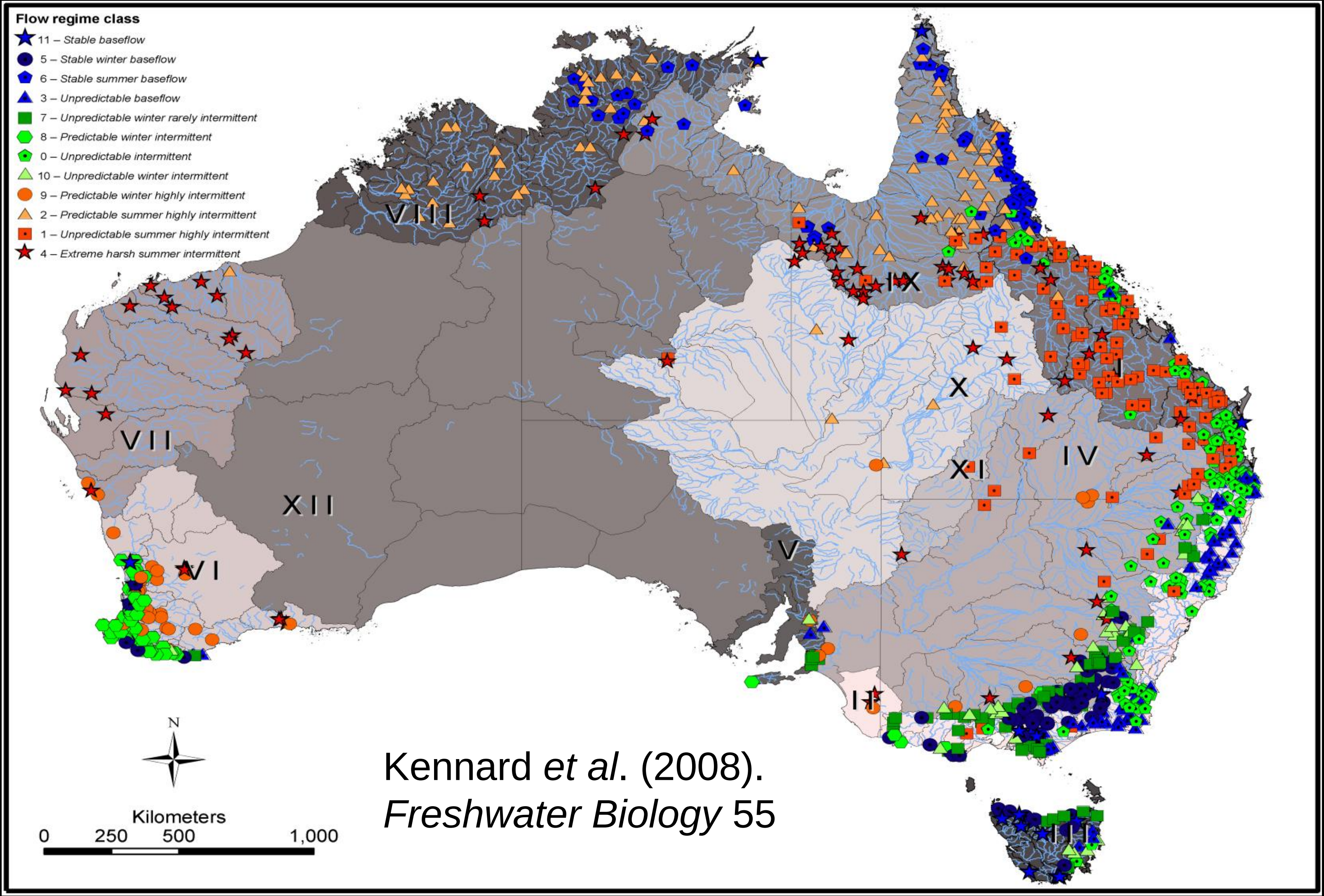
- Gillespie *et al*. (2015). *Freshwater Biology 60.*
  A critical analysis of regulated river ecosystem responses to managed environmental flows from reservoirs.

General principles and patterns emerge but the literature cannot deliver specific e-flow rules


SCIENTIFIC PROCESS - ELOHA
Poff et al. (2010). Freshwater Biology 55.
Step 1. Hydrologic Foundation
Step 2. Stream Classification
Baseline Hydrographs
Stream Hydrologic Classification
Geomorphic Stratification
Hydrologic Model and Stream Gauges
Step 3. Flow Alteration
Developed Hydrographs
Degree of Hydrologic Alteration
Hydrologic Alteration by River Type
Monitoring
Step 4. Flow-Ecology Relationships
Flow - Ecology Hypotheses
Ecological Data and Indices
Flow Alteration-Ecological Response Relationships by River Type
SOCIAL PROCESS
Implementation
Environmental Flow Standards
Acceptable Ecological Conditions
Societal Values and Management Needs
Adaptive Adjustments

Geographical variation in 12 natural flow regime classes in Australia

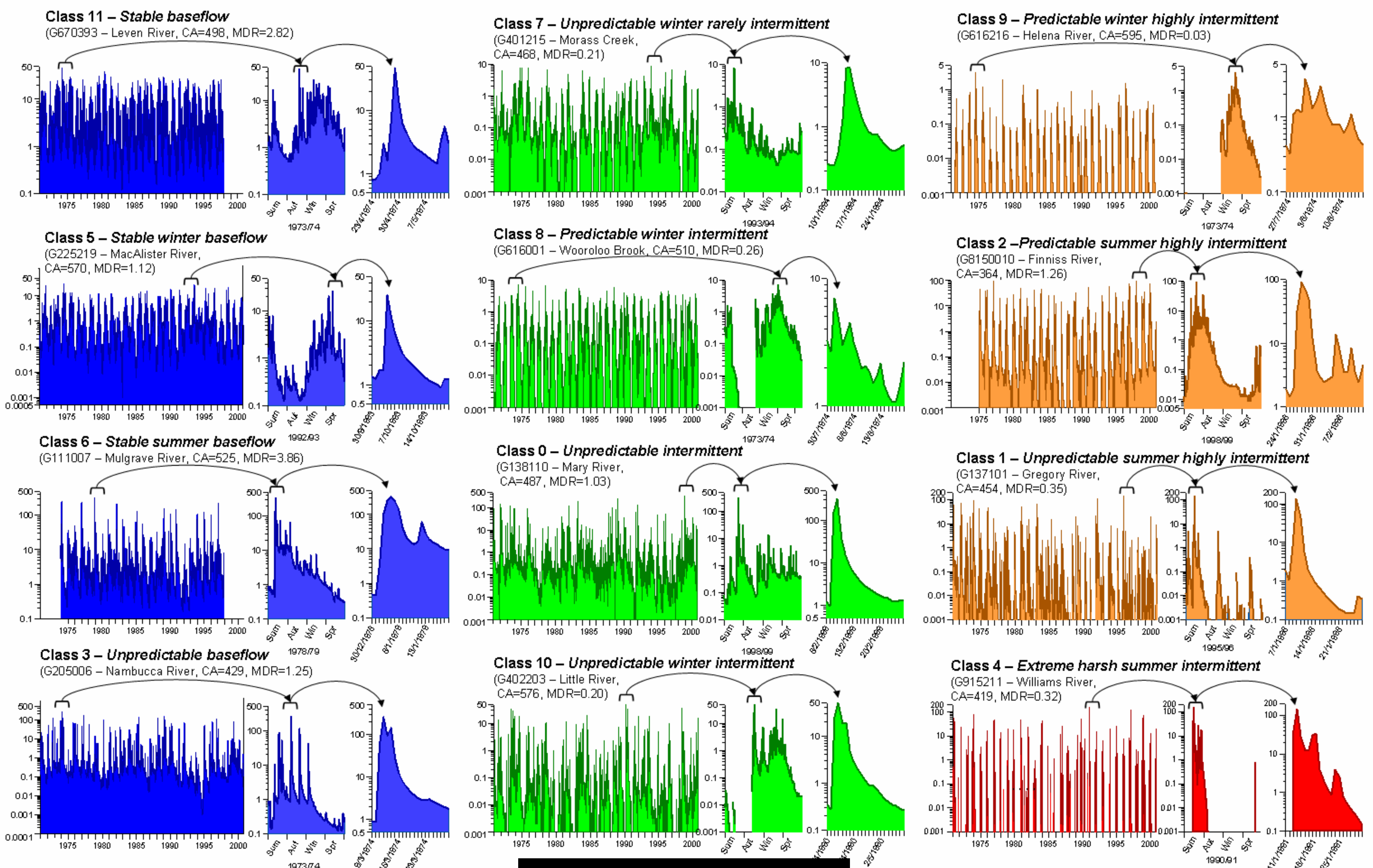
Classes defined using Bayesian classification of 120 hydrological metrics describing the natural flow regime at 830 stream gauges



Kennard *et al*. (2008). *Freshwater Biology* 55

Example hydrographs of daily runoff for a typical stream gauge in each flow regime class

Variation in runoff is shown for three scales of temporal resolution including the long-term record, and for the year and three-week period encompassing the flow event with the highest peak magnitude.



Kennard *et al*. (2008)

ELOHA Flow-Ecology Database

TRaCK
Tropical Rivers and Coastal Knowledge

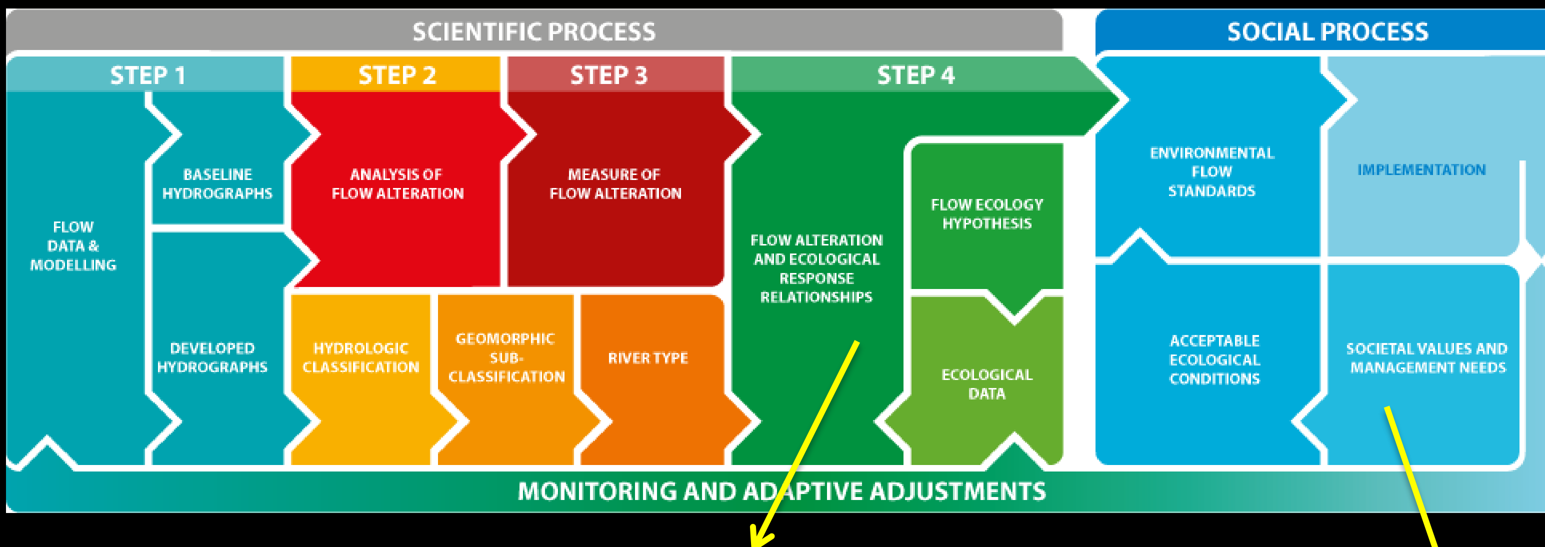
NEWT:
Northern Environmental Water Tools
Pusey (2011-12)

- Hydrological classification of northern rivers
- Conceptual, empirical and Bayesian models of flow-ecology relationships
- 42 principles to guide water management and e-flows

http://www.track.org.au/showcase/northern-environmental-water-tool-newt

ELOHA Process Navigator

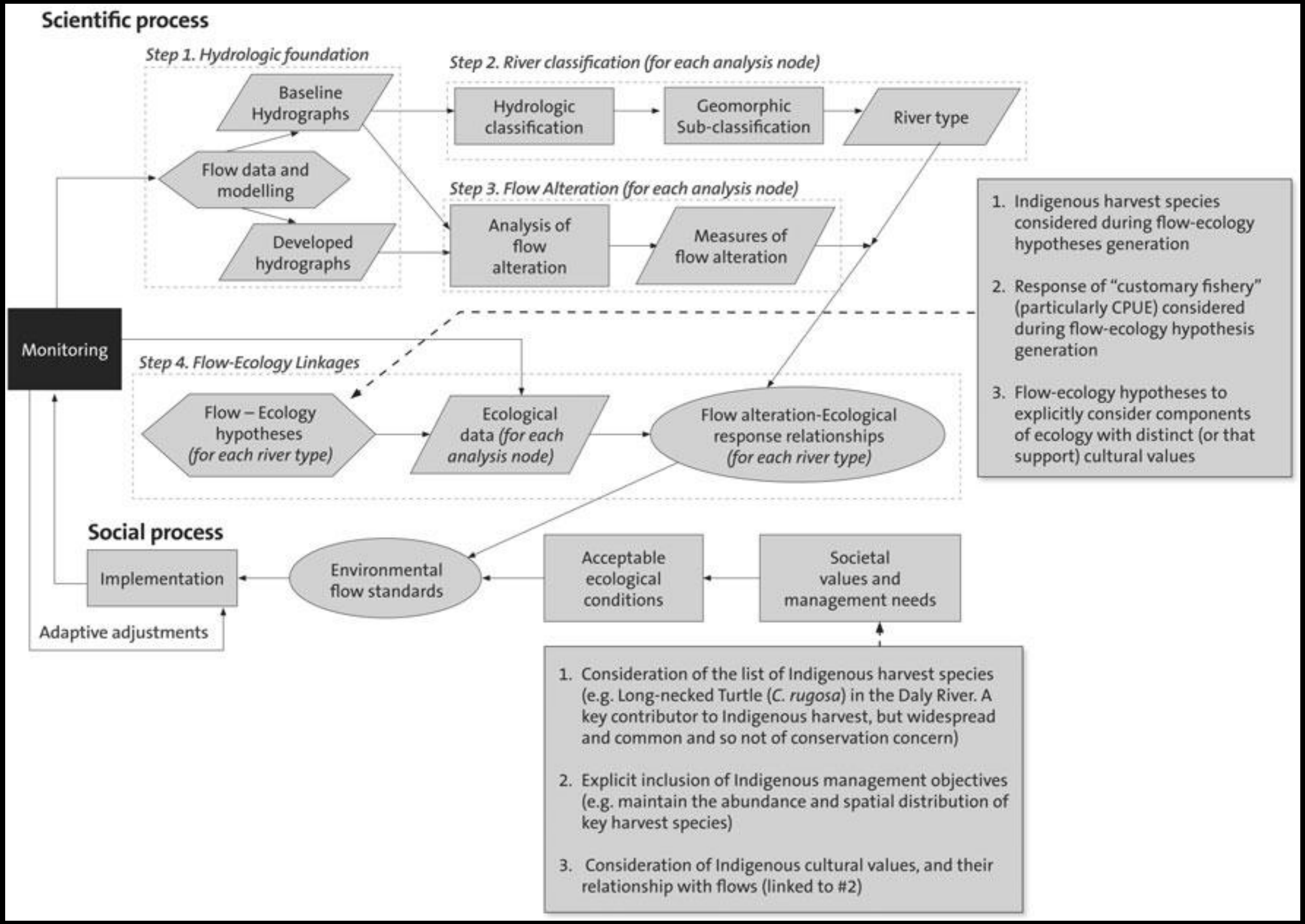
http://atlas.track.org.au/newt/overview



Warfe *et al*. (2011). The “wet-dry” in the wet-dry tropics drives river ecosystem structure and processes in northern Australia. *Freshwater Biology* 56. http://www.track.org.au/publications/registry/track960

Jackson *et al*. (2012). Principles and guidelines for good practice in indigenous engagement in water planning. *J Hydrology* 474. http://www.track.org.au/publications/registry/track1818

Extended ELOHA framework to incorporate indigenous values

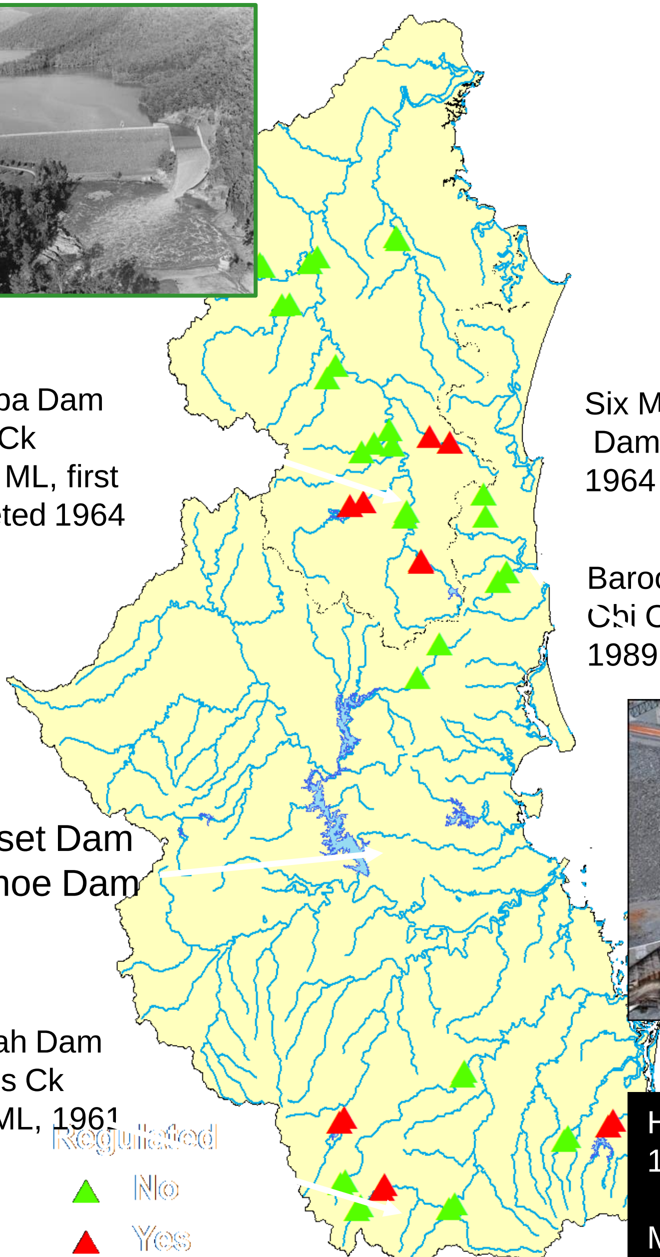


Finn and Jackson (2011). Protecting indigenous values in water management: a challenge to conventional environmental flow assessments. *Ecosystems* 14.

ELOHA Trial
SE Queensland

- Dams and weirs store ~ 38% MAR
- Storage capacity 730 - 1 150 000 ML
- Most built in 1970-1980s
- Mostly urban and irrigation supplies
- Extensive unsupplemented extraction

Borumba Dam
Yabba Ck
42 600 ML, first
completed 1964

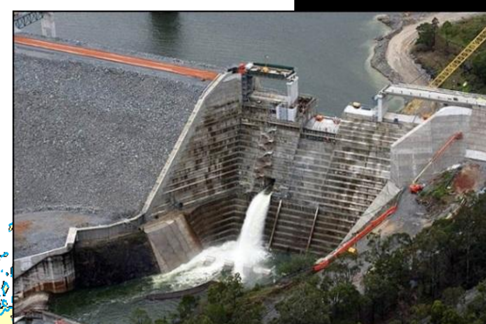


Six Mile Creek
Dam, 9300 ML
1964

Baroon Pocket Dam
Obi Obi Ck, 61 000 ML
1989

Somerset Dam
Wivenhoe Dam

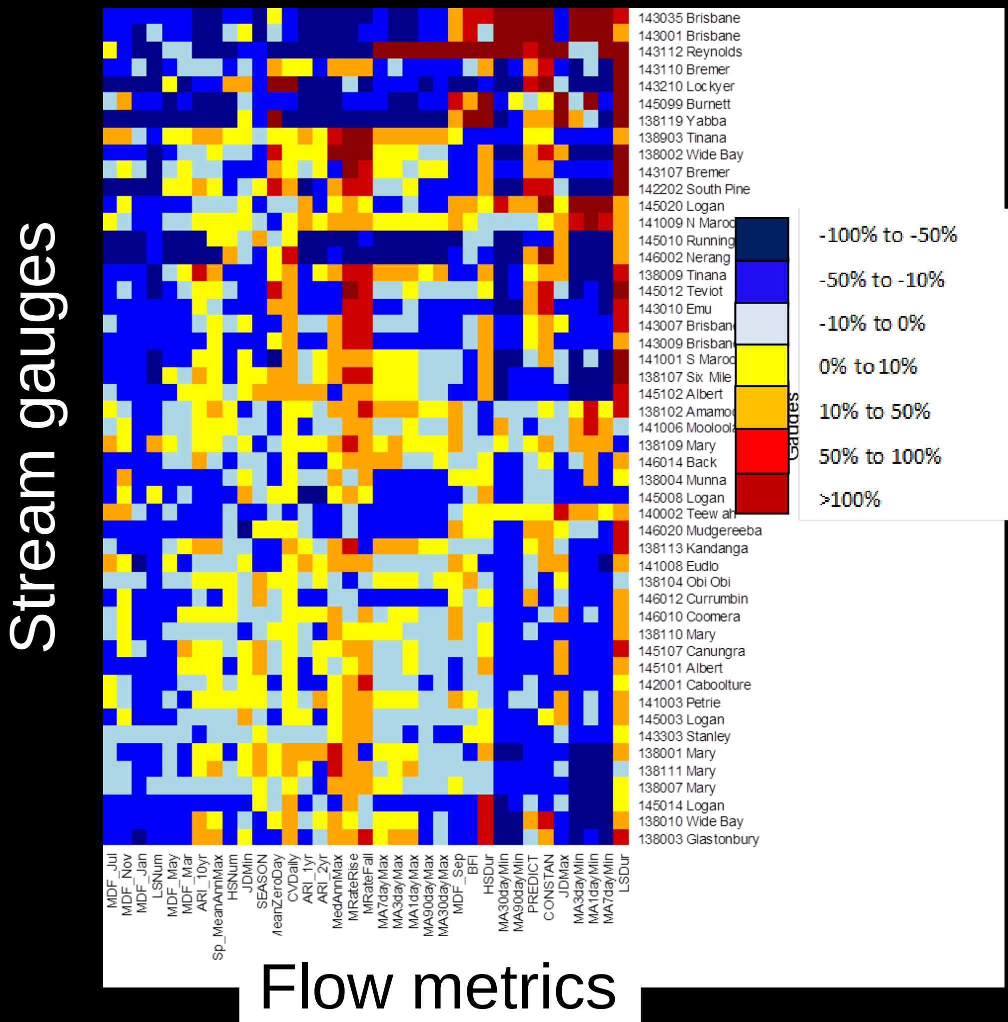
Moogerah Dam
Reynolds Ck
92 500 ML, 1961



Hinze Dam. Nerang River
165,000 ML, first completed 1989

Maroon Dam
Burnett Ck, 38 400 ML, 1974

Summary of % change in gauged flow relative to modelled natural flows



Brisbane River:

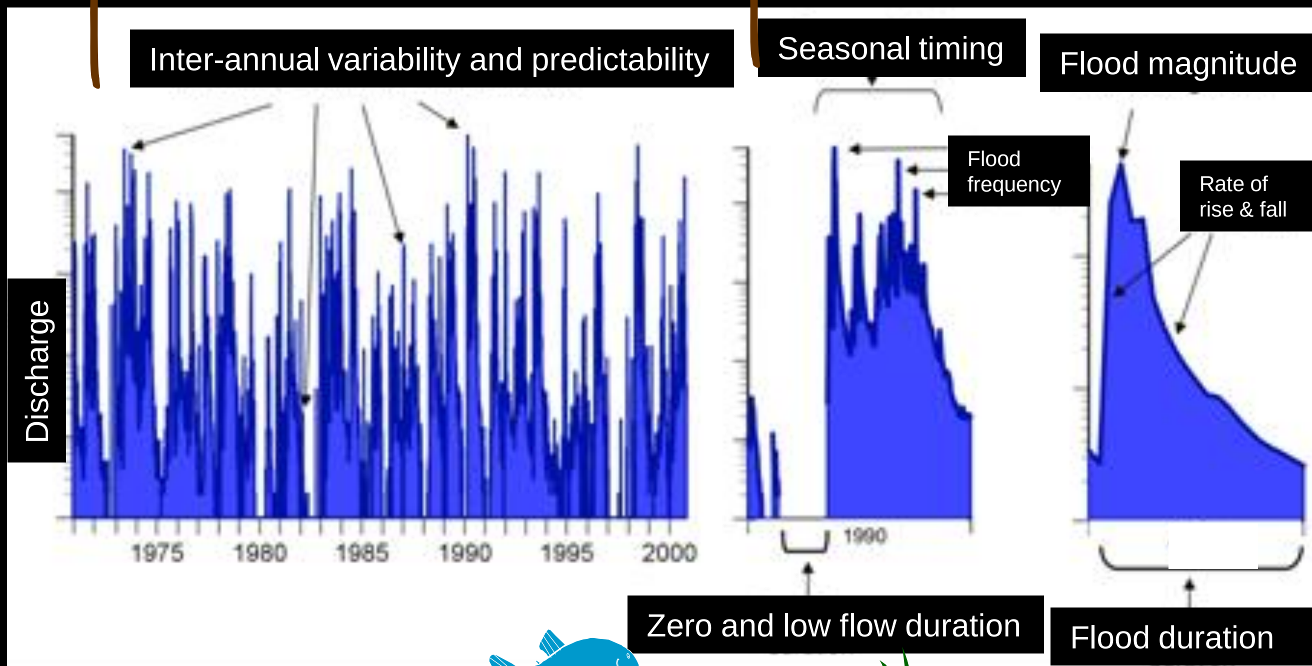
- highly regulated by dam
- elevated low flows
- fewer zero flow days
- more constant flows
- fewer high flow events

Flow-ecology relationships

Quadratic Species richness
Interannual CV

+ve linear Species richness
vs constancy and predictability

-ve linear Total species richness, species per ha,
basal area late succession species,
no regenerating species per ha
vs CV daily flows in the dry season



-ve linear
Species rich/density
vs median daily flow,
10-year ARI

-ve
Aquatic plant cover
vs high spell duration

Mixed response
Species richness
vs change in CV daily flows

+ve linear
Density alien fish species
vs no. zero flow days

% days over 12 months when discharge
was above threshold to mobilise substrrate
-ve linear
Total in-stream vegetation cover
Total in-stream vegetation density
Emergent vegetation cover and density

Murray-Darling Basin

>1 million km^2, 4 states and ACT

>77,000 km of rivers, creeks and watercourses, 30,000 wetlands

Average inflows 31,600 GL per year
Range 6,700 GL -117,900 GL

River Murray Commission 1917
M-D Basin Commission 1985
Water use audit 1995, water take capped
National Water Initiative 2004, ESD principles

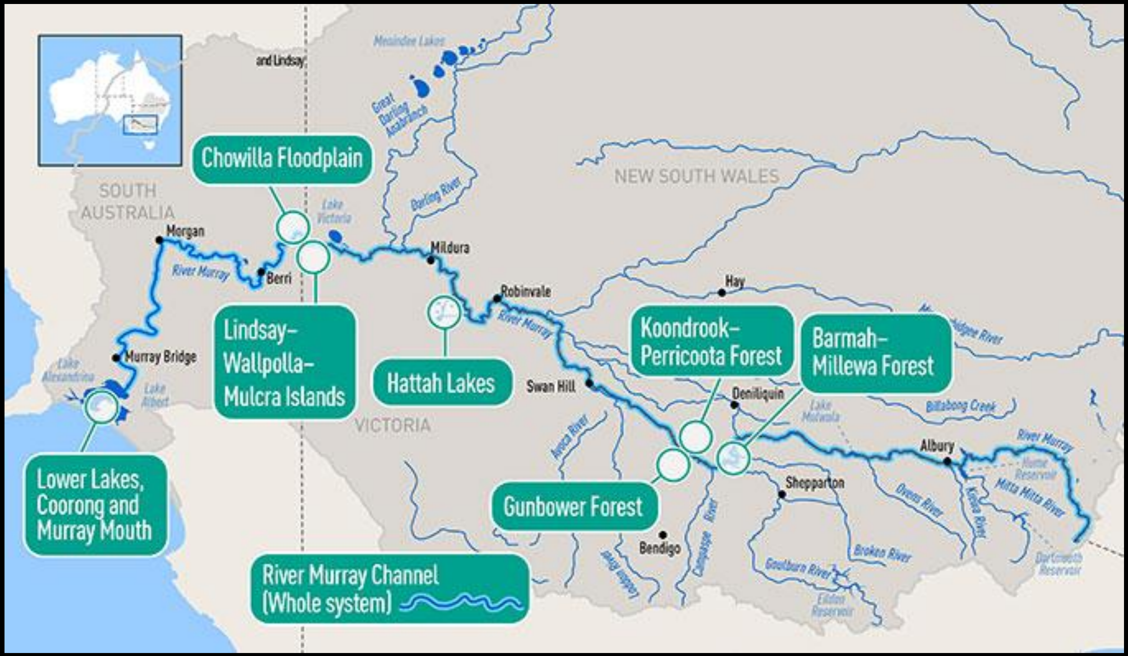
Water Act 2007, M-D Basin Plan 2012
Commonwealth Environmental Water Holder

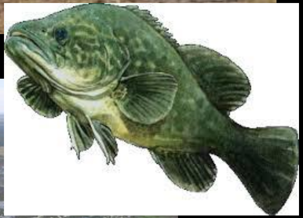
$AUD 9 billion for e-water purchases and water infrastructure

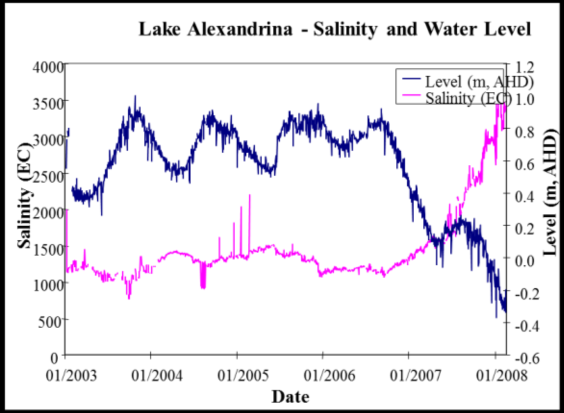
Average of 2,750 GL recovered per year (20% reduction in consumptive use)

Geosciences Australia and MDBA 2008

The Living Murray Program - 500 GL per year to restore River Murray Icon Sites







Barmah–Millewa Forest Icon Site

http://www.mdba.gov.au/about-basin/river-murray-icon-sites/barmah-millewa-forest

66,000 ha of wetlands in NSW and Victoria

Moira Lake with Barmah Lake in background. Photo: Keith Ward

Ecological objectives

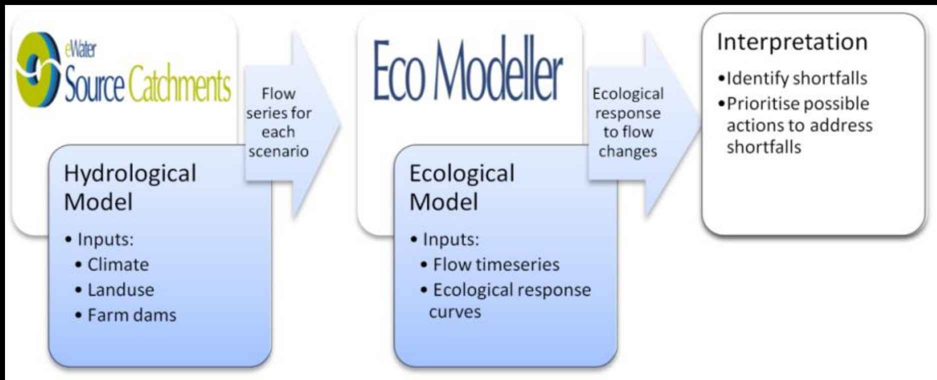
Restore healthy wetland and floodplain vegetation communities; sustain breeding and recruitment of native waterbirds and fish, provide habitat for native frogs, turtles and crayfish

.

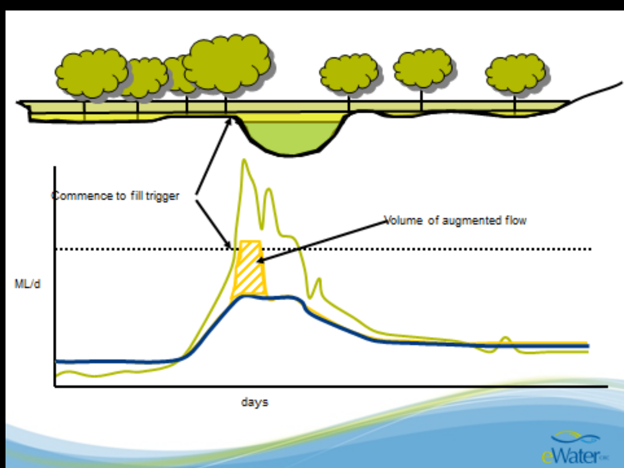
Past watering events

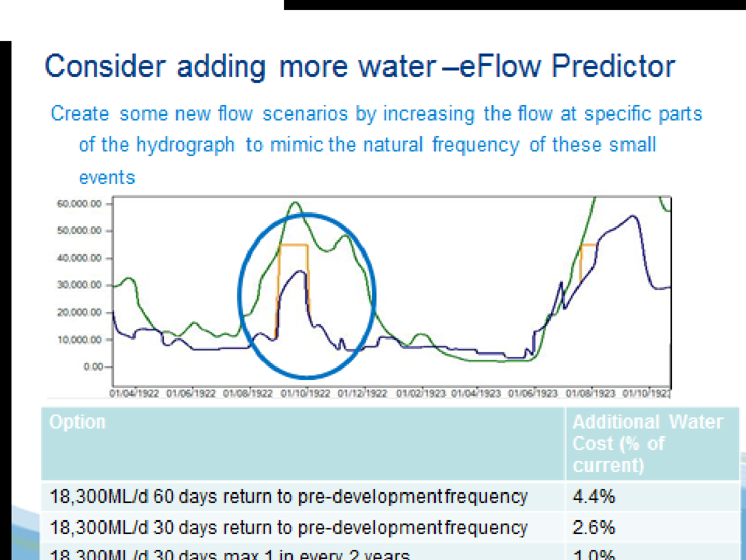
2013–14	355 GL	Successful growth and flowering of Moira grass, successful breeding of colonial waterbirds, improved health for floodplain vegetation and benefits for native fish and turtles.
2012–13	2.9 GL	Successful breeding of colonial waterbirds at Boals Deadwood.
2011–12	424.6 GL	Improved the health of river red gums and other floodplain vegetation, contributed to successful bird breeding, and provided a flow pulse for fish breeding.
2010–11	199 GL	Recovery and maintenance of wetland vegetation, and contributed to a successful bird breeding event.
2009–10	2.4 GL	Recovery and maintenance of wetland vegetation, and maintenance of bird breeding and foraging habitat.

e-Water tools:
Source Catchments and *Eco Modeller*



Little, Marsh *et al*. (2011)





Option	Additional Water Cost (% of current)
18,300ML/d 60 days return to pre-development frequency	4.4%
18,300ML/d 30 days return to pre-development frequency	2.6%
18,300ML/d 30 days max 1 in every 2 years	1.0%

40 – 50% decrease in mean annual River Red Gum habitat availability with current consumptive use of River Murray water

Ecological responses to altered flow regimes

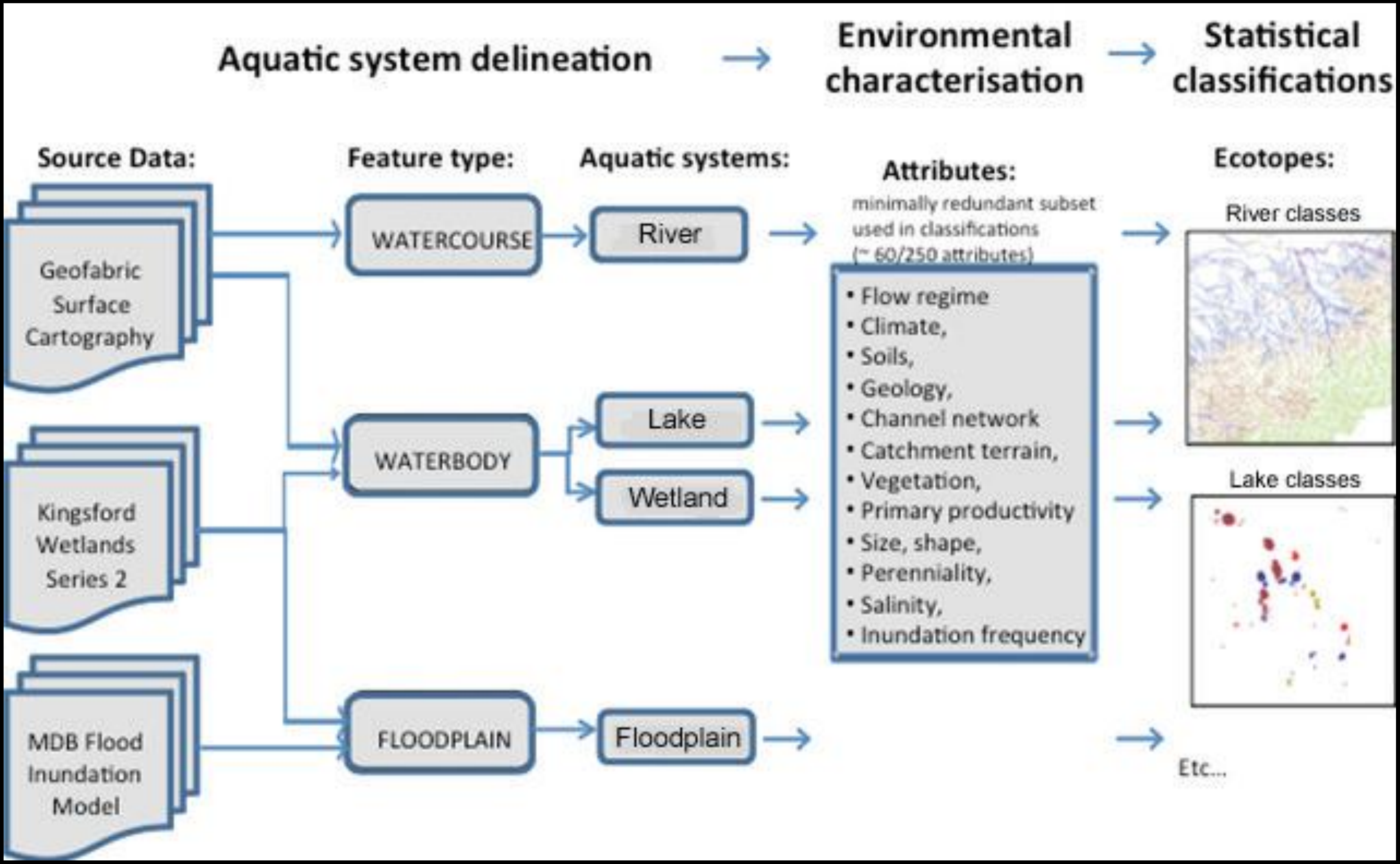
Bunn *et al.* (2014). Water For A Healthy Country Flagship, CSIRO

CSIRO & university collaborative research project applying ELOHA principles at Basin scale

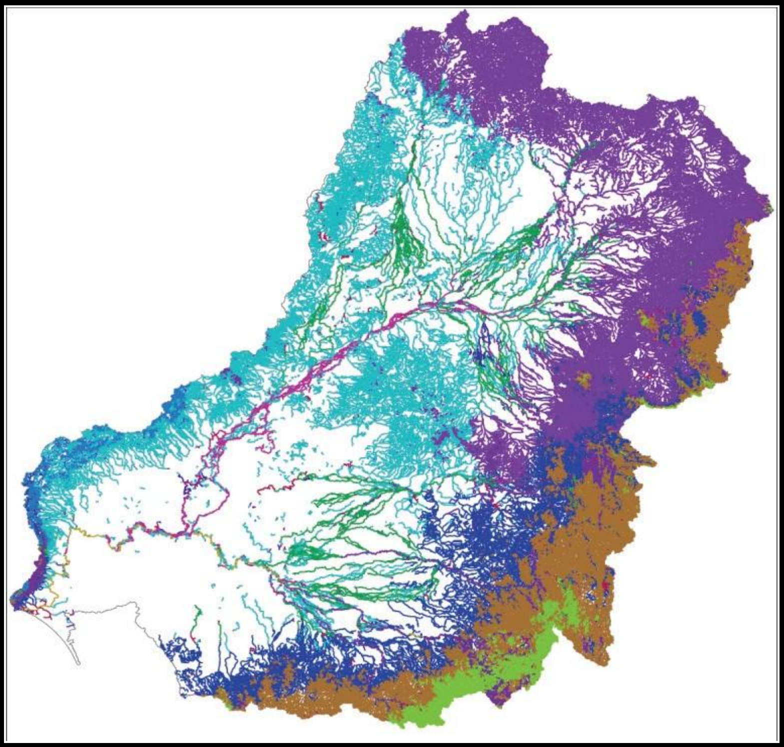
http://www.finterest.com.au/wp-content/uploads/2015/03/Bunn-et-al.-2014-Ecological-reponses-synthesis-lo-res.pdf

- Basin-scale classification and mapping of ecological assets
- Mapping of flow related and non-flow related threats to their ecological condition
- Flow-ecology response models for different components of the flow regime

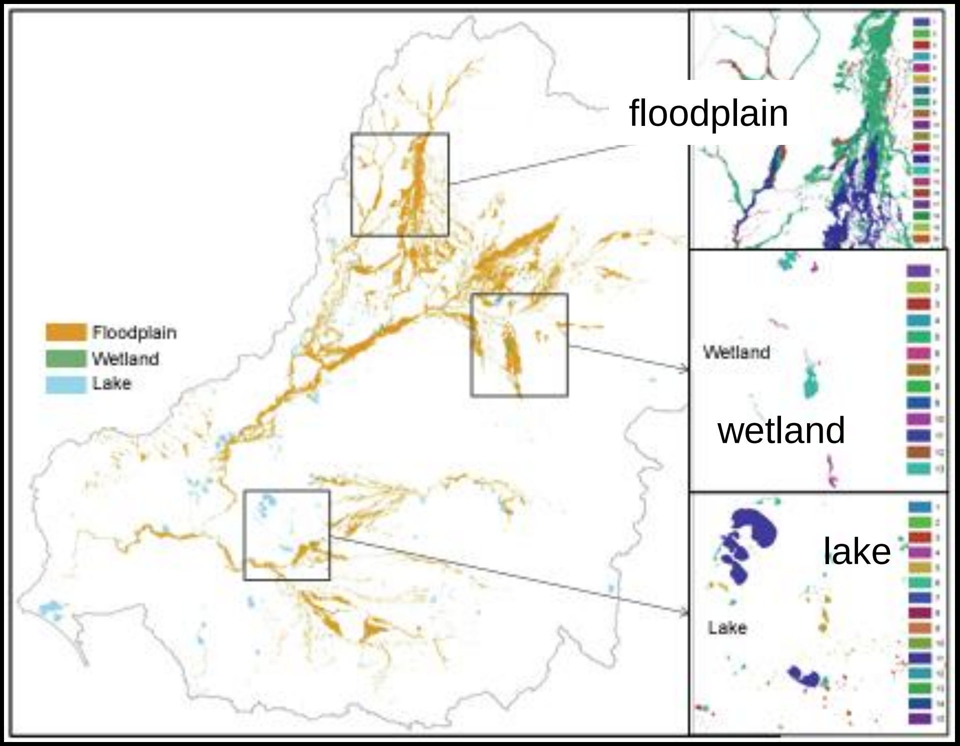
Approach to basin-scale classification and mapping of ecological assets



Basin-scale classification and mapping of ecological assets

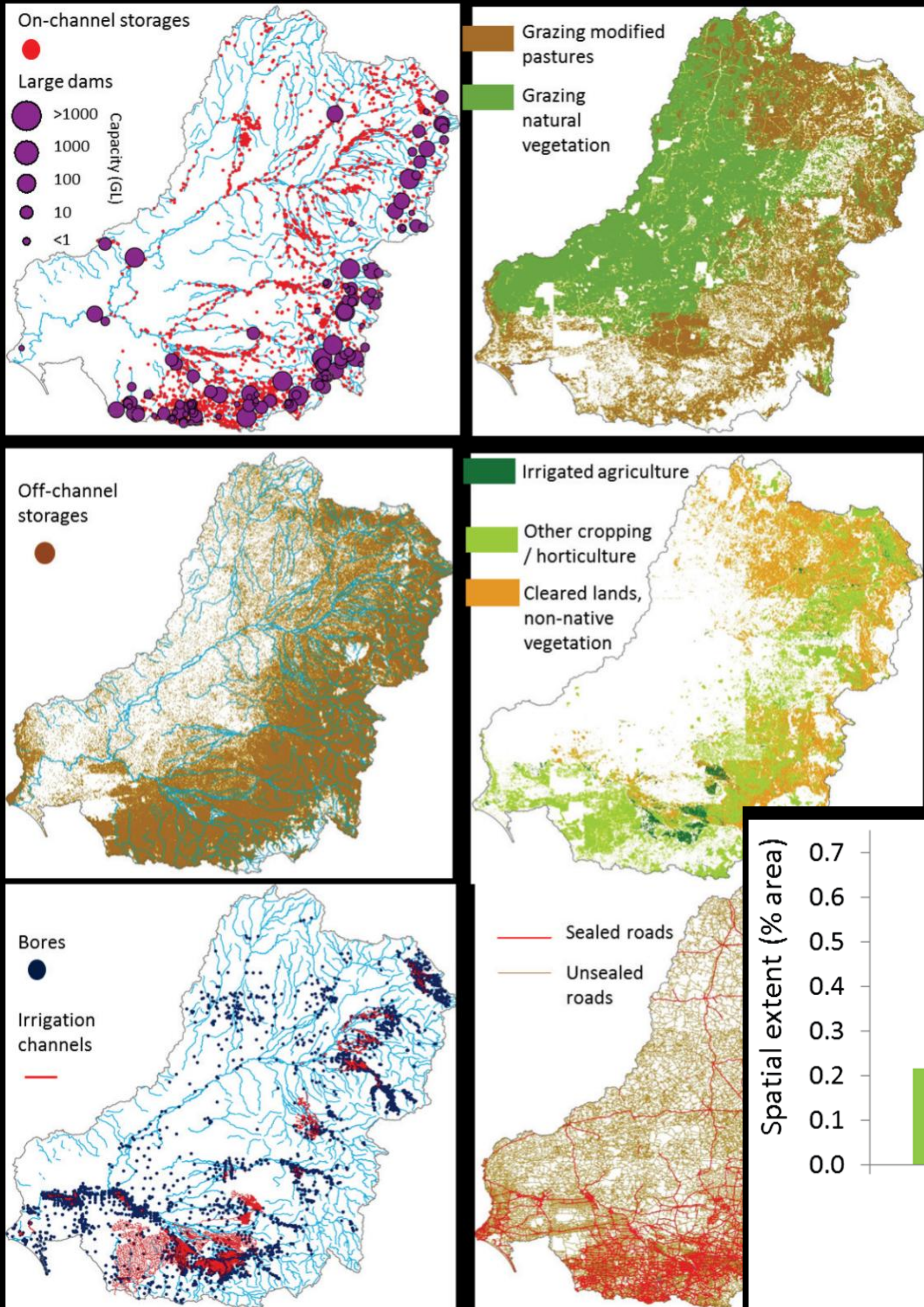


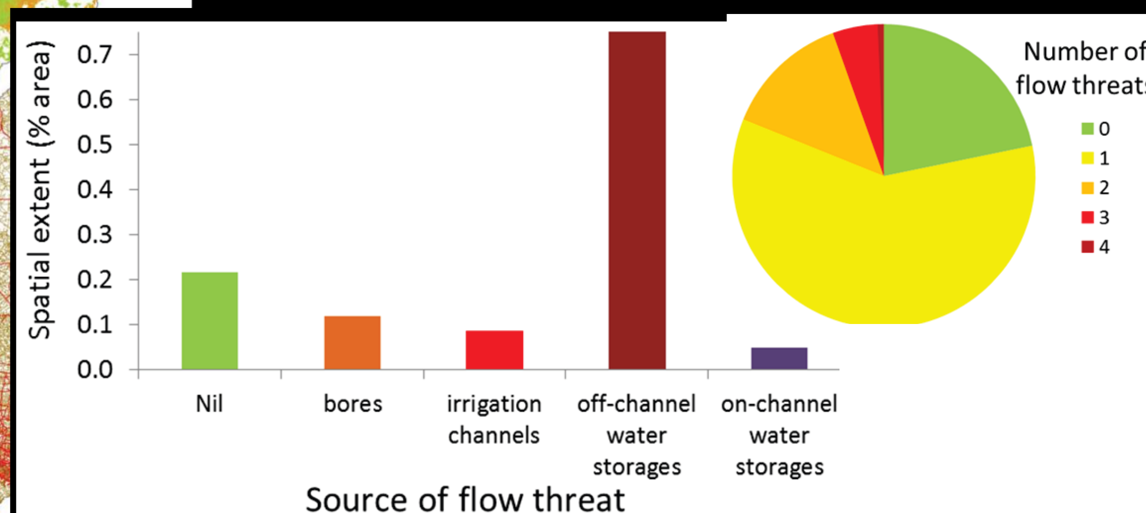
Distribution of the 14 riverine classes across the MDB, including large lowland rivers to small headwater streams



Distribution of floodplain, wetland and lake classes across the MDB

Basin-scale classification and mapping of flow related and non-flow related threats to asset condition





Expressing uncertainty of flow-ecology response models

- Models were developed from the literature, field research and expert opinion

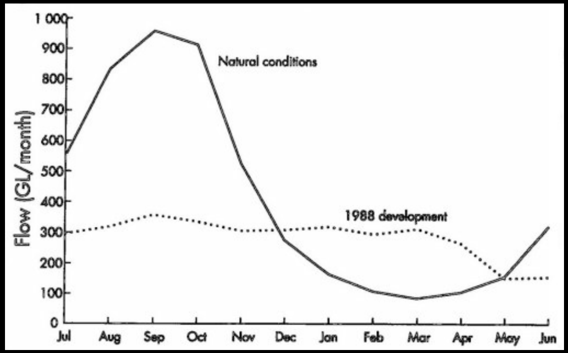
- Uncertainty in flow-ecology response relationships adopted language from the IPCC (Mastrandrea et al., 2010):

- • *Confidence* is a measure of the amount, quality and consistency of evidence and the degree of agreement (expressed as “low”, “medium” or “high”)
-
- • *Likelihood* is expressed in probabilistic terms (where “unlikely” <33%, “likely” >66%, “very likely” >90% and “virtually certain” >99% probability).

Flow-ecology response models for different components of the flow regime

Artificially stable high flows in summer are *likely* to reduce the spawning and recruitment success for native fish (*medium to high confidence*)

Reversed seasonality of flows is *likely* to reduce recruitment of riparian plant species, including river red gum, and increase the risk of blackwater (low oxygen) events in-channel, if flood flows inundate floodplains rich in organic matter during summer (*high confidence*)



In highly regulated rivers, it is *very likely* that wetlands will be disconnected from rivers for longer periods than under natural conditions with impacts on tree health, waterbird breeding and the abundance of some fish and frogs species (*high confidence*)

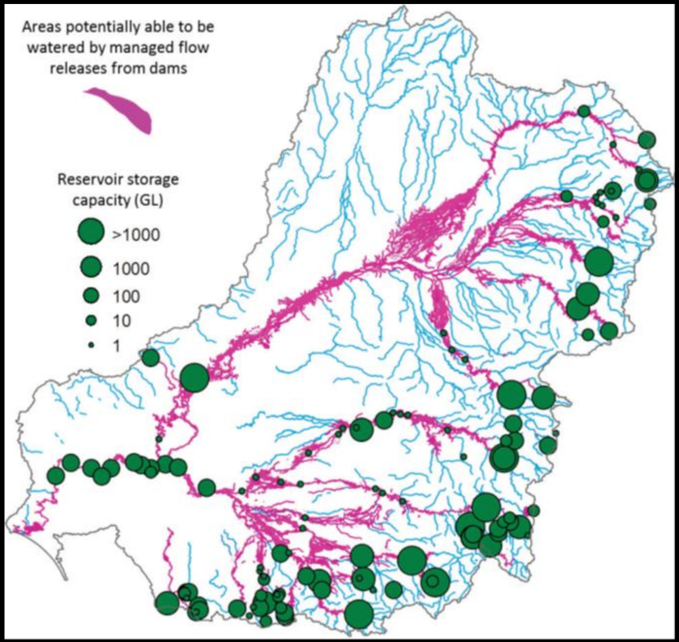
Flow management strategies in M-D basin

Areas potentially able to be watered by managed flow releases from large reservoirs to areas within lateral extent of a 10 year ARI flood

Estimates assume no constraints to water delivery (e.g. floodplain infrastructure, roads, bridges)

45% of the floodplains, 46% of lakes and 61% of wetlands could be watered by large dam releases

Flow management strategies also include water shepherding, water buy-backs to reduce water extraction or interception and groundwater management



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- Optimization modelling of environmental flows to inform the delivery of environmental water
- Methods for monitoring and assessing the outcomes of environmental water allocations

So what of e-flows science?

1. ELOHA offers a systematic process to assess the risk of altering the flow regime in particular ways in rivers of different hydrological character

2. Applications are increasing and already show valuable innovation around the process, e.g. classification methods, flow-ecology models, flow regime restoration

3. Allows multiple stressors on river ecosystems to be assessed, not just flow related impacts

4. ELOHA flow-ecology models can be used to predict likely outcomes under many scenarios of flow regime change, including climate change scenarios

5. Delivery of e-flows can be optimised using systematic conservation planning tools

6. E-flows and other conservation / restoration actions must be treated as experiments, with robust monitoring over time to document ecological responses under uncertainty from flow change, other stressors and climate change

Further light reading