Residence times of land-sourced contaminants in the Great Barrier Reef lagoon and the implications for management and reef recovery

J. Brodie[1]

E. Wolanski[1, 2]
S. Lewis[1]
Z. Bainbridge[1]

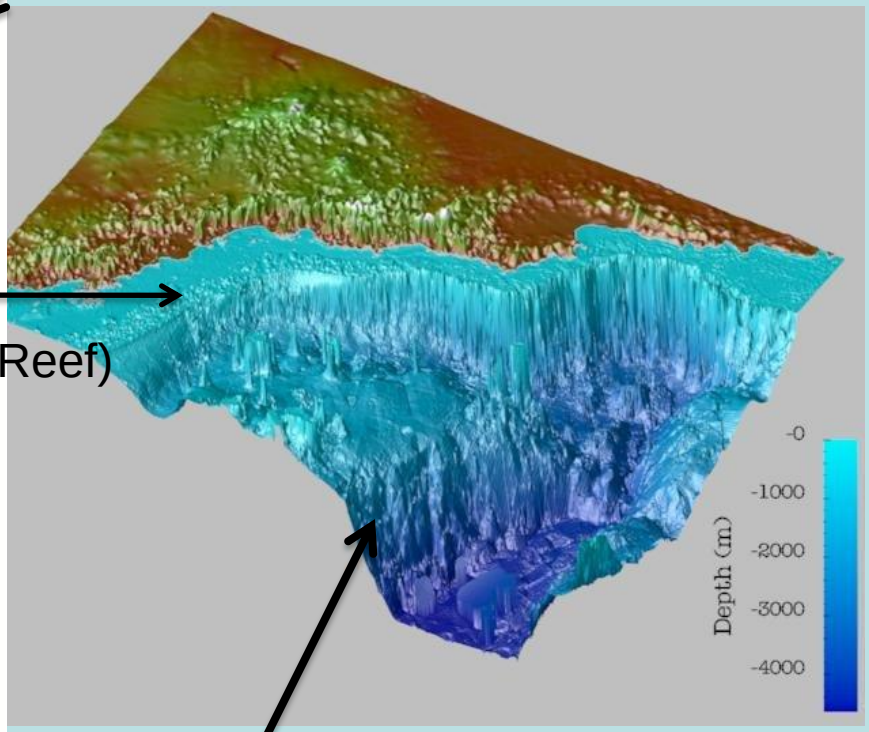
[1] ***Australian Center for Tropical Freshwater Research***
James Cook University
Townsville, Qld. 4811, Australia.
[2] ***Australian Institute of Marine Science***
Townsville, Qld. 4810, Australia.

JAMES COOK UNIVERSITY
AUSTRALIA
Australian Centre for Tropical Freshwater Research

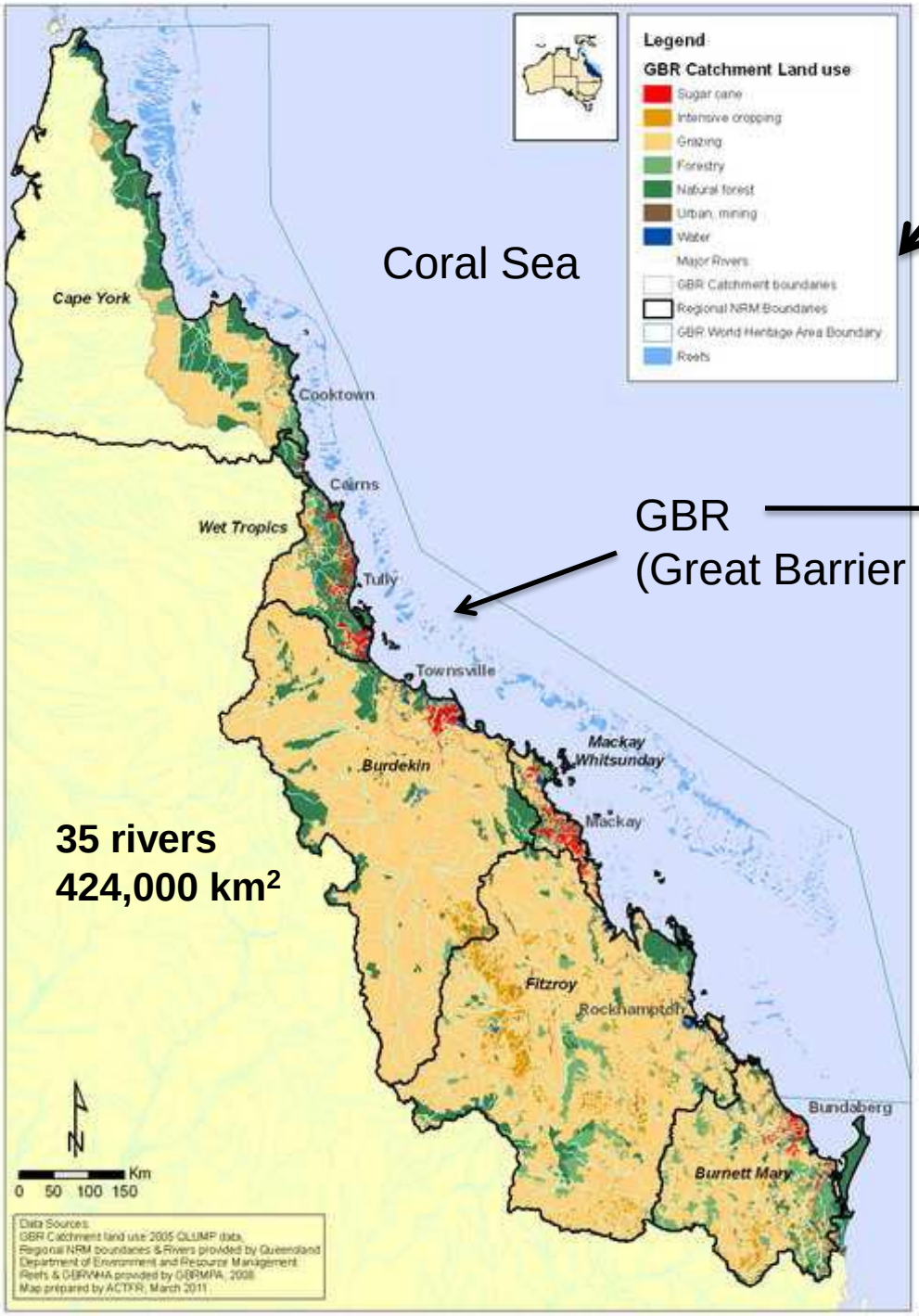
Stressor on land

Coral Sea

GBR
(Great Barrier Reef)

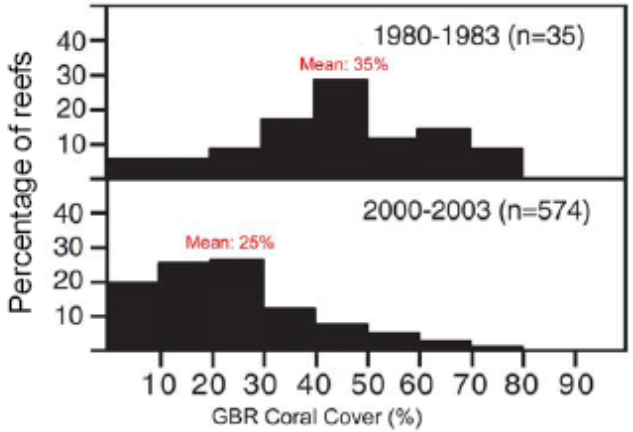


Stressor at sea
(global warming, ocean acidification)



Observations

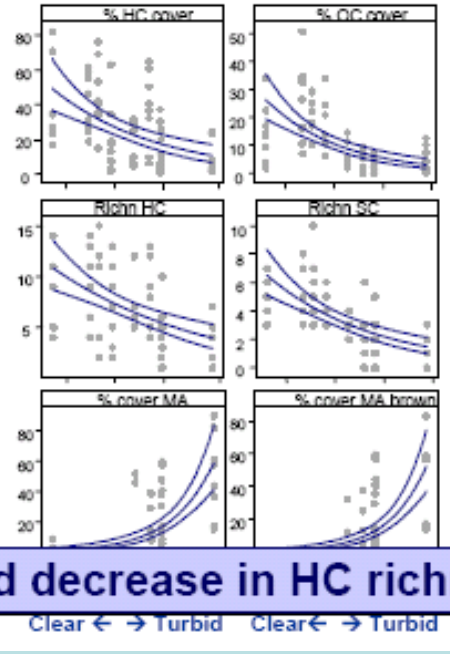
Declining coral cover in the GBR



Baseline (pre-1960s): 50% coral cover??

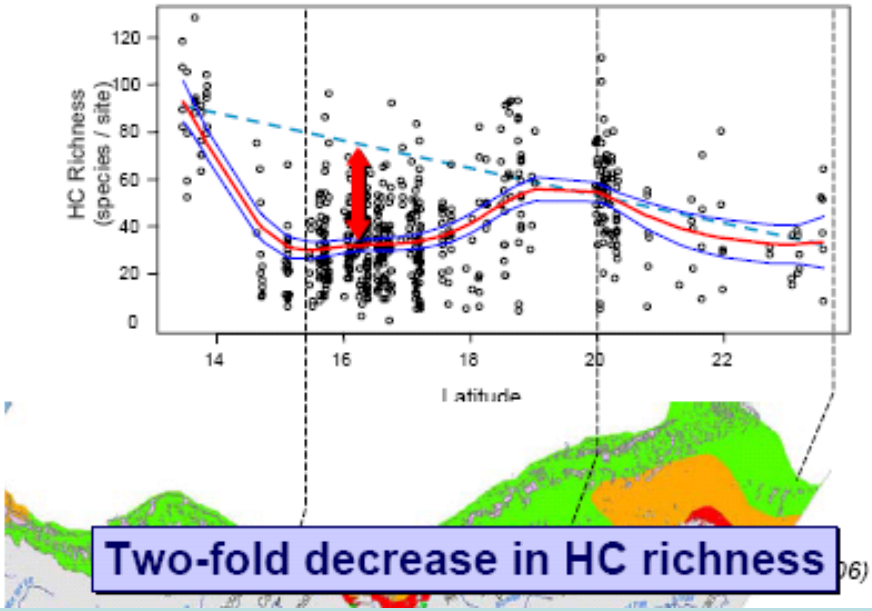
Bruno and Selig, PLOS (2007)

Macroalgal cover increases along WQ gradient



Two-fold decrease in HC richness

Hard coral diversity: Changes along inshore Great Barrier Reef



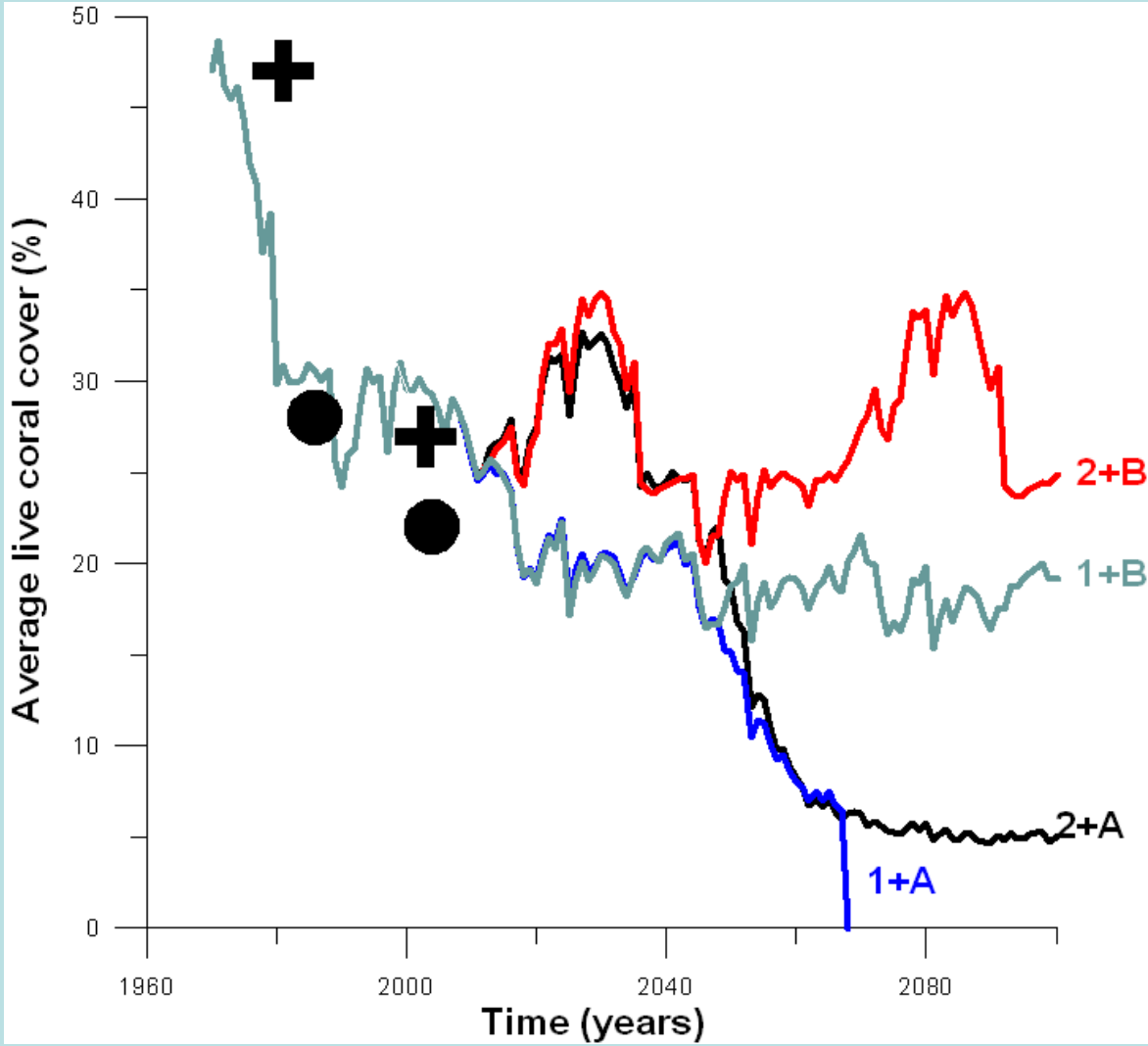
Two-fold decrease in HC richness

Devantier et al. (2006); Fabricius (2009)

Hindcasting past coral cover and predicting future coral Cover.

For Australia:
scenario 1 = business as usual;
scenario 2 = halving fine sediment and nutrients.

For the world:
scenario A = business as usual, 850 ppm CO_2 by 2100;
scenario B = climate change stabilized at 350 ppm CO_2.



(Bohensky et al., 2011)

What is being done?

1. Managing fishing.

1.1. MPAs: 20-35% area is closed (no-take) but in practice only 10-15% of reefs are closed. Trawling is extensive.

1.2. Closure of spawning fin fisheries in the whole GBR (not just in MPAs): originally 3 X 9 days closure; now 2 X 5 days closure.

1.3. Recreational fisheries: bag limits.

2. Global warming +ocean acidification:

Carbon tax under discussion.

3. Land-use: the focus of this talk.

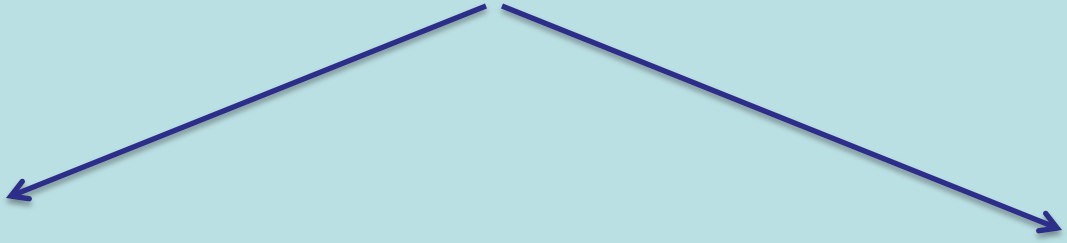
Queensland and Commonwealth governments plans for land-use in the GBR

Reef Plan (2003; 2009):

-Reduce the load of pollutants from diffuse sources: for diffuse sources, 50% decrease of N, P, pesticides and 20% decrease of sediment

-Rehabilitate and conserve areas of the Reef catchment that remove water borne pollutants

-"to halt and reverse the decline in water quality entering the Reef within 10 years" (by 2013)



Commonwealth Government

Reef Rescue (2007)

200 million $ over 5 years for voluntary program of better land-use practices.

Queensland Government

Reef Protection Act (2009)

Legislation for some river catchments only

–beef grazing (*on landcover*)

-sugarcane

-pesticides

-fertlisers

The question:

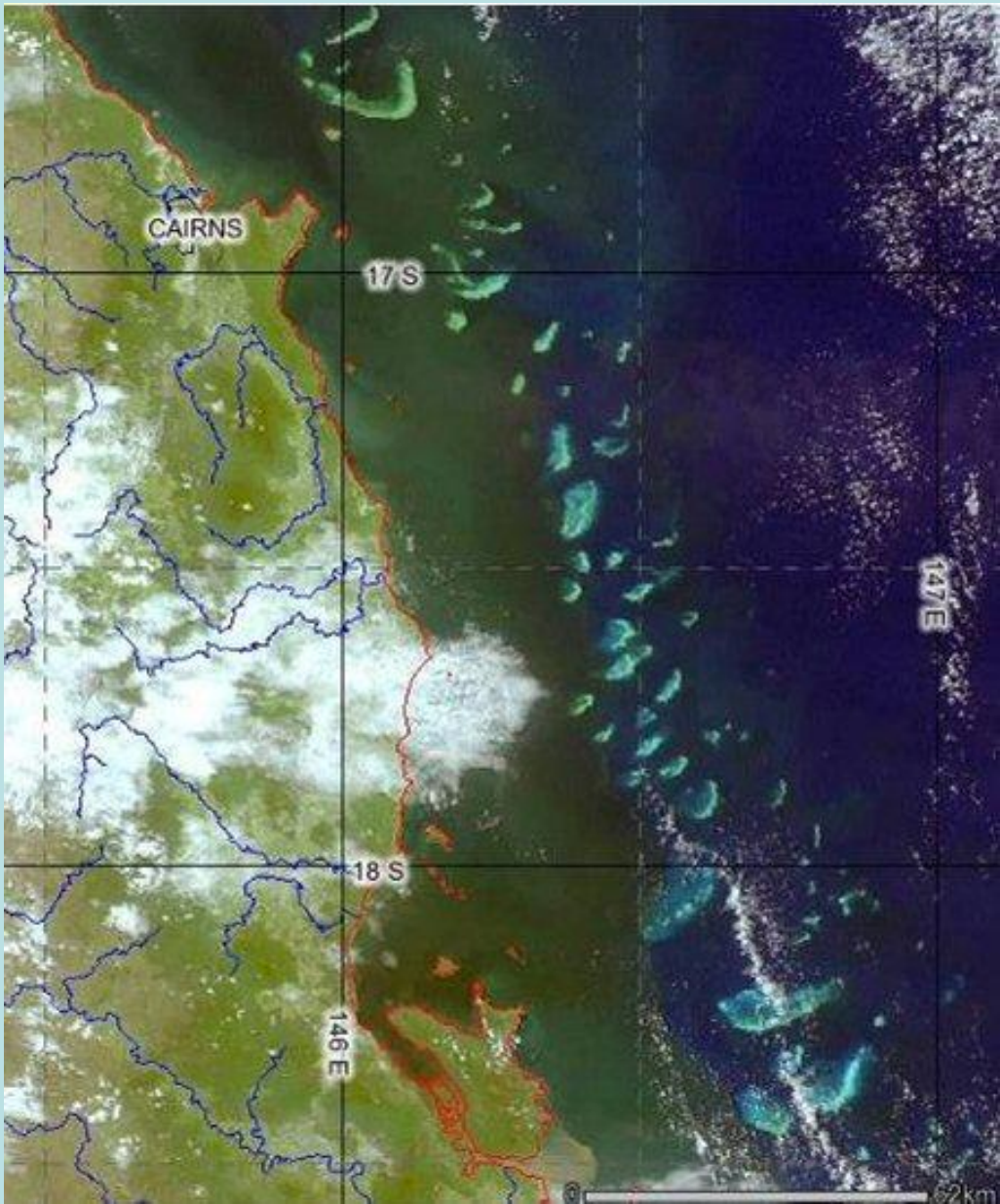
Will it deliver the outcome?

The answer: this talk!

The pollutants are:

1. **Fine sediment**
2. **Nutrients**
3. **Pesticides**

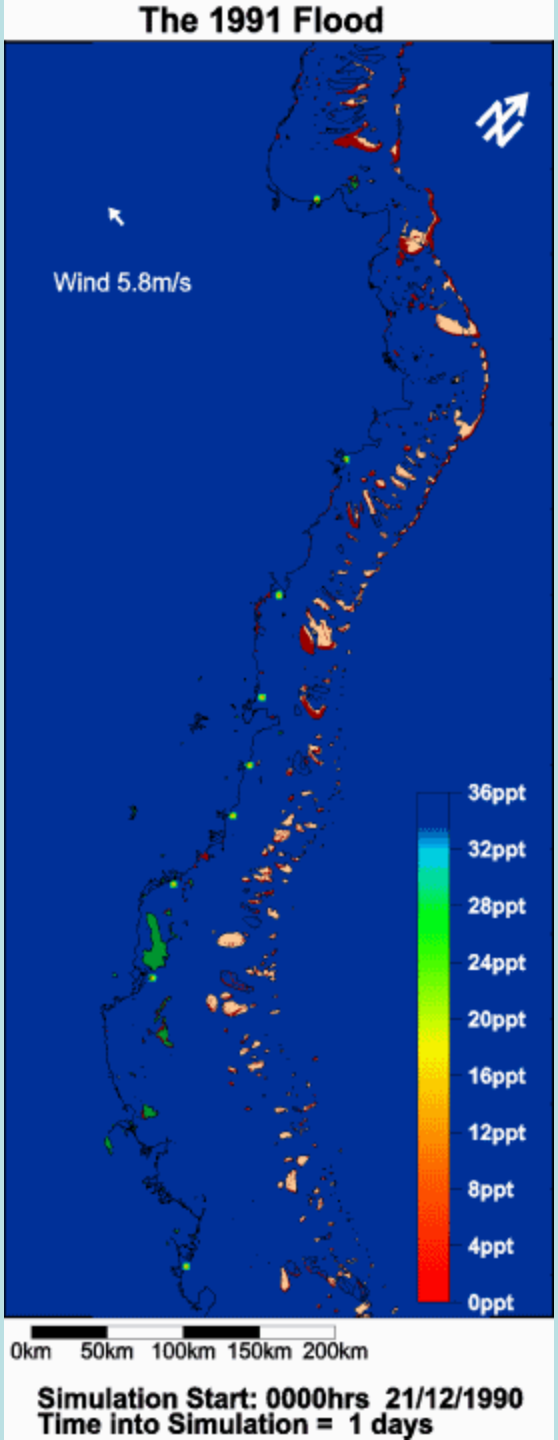
- **Queensland river flows varies seasonally.**
- **Most of the flux of sediment, nutrients and pesticides to the reef occurs during river floods.**
- **The flood plumes are extensive and readily extend to the reef.**



Terra 11 Feb 2007

The flood plumes are transient and short-lived.

If the land-derived pollutants were carried by the water conservatively, they would be swiftly flushed out of the GBR and have negligible impact on the GBR.

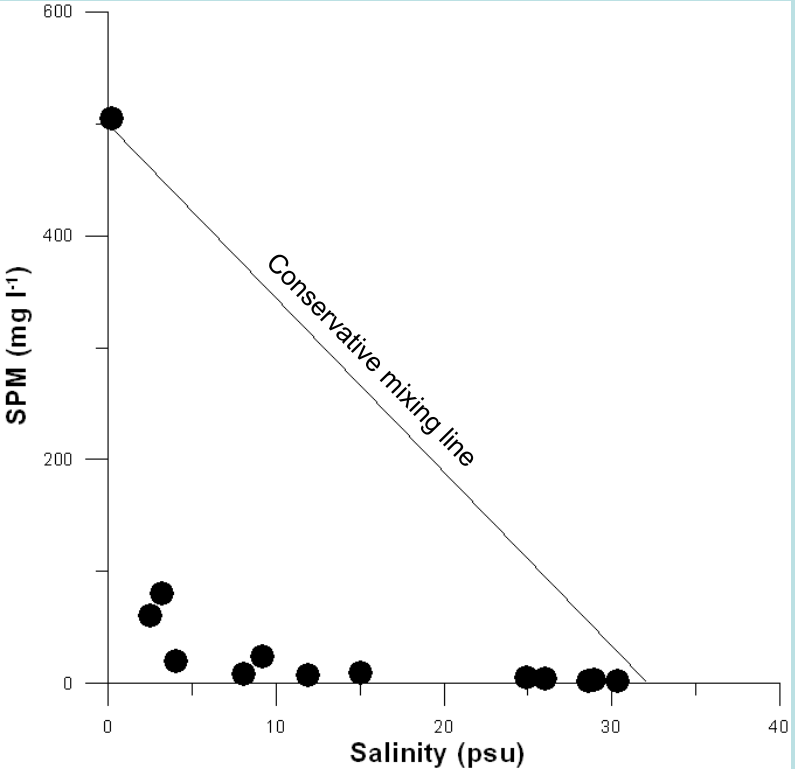


(King et al., 2001)

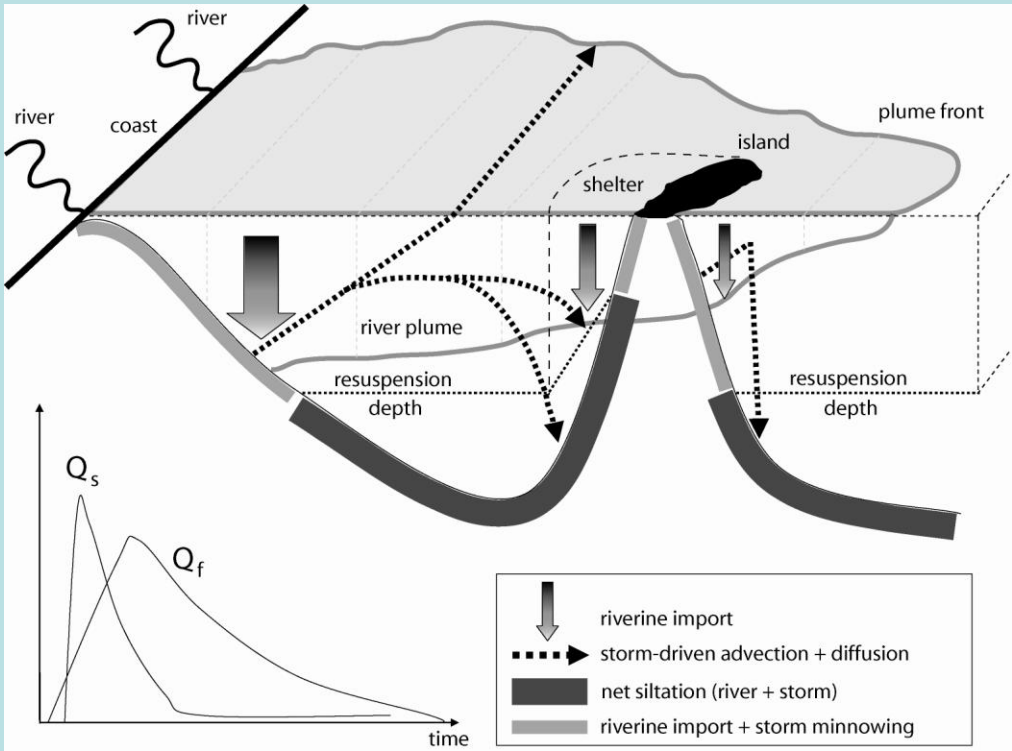
Pollutant # 1: fine sediment

Not conservative.
Rapidly drops out of suspension in the river plume.
Commonly resuspended by waves and settling in embayments and near islands and coastal reefs.
GBR has 100 years of excess sediment from land-use that needs to be flushed out or consolidated first before benefits will be seen from better land-use.

Fine sediment in the Burdekin River plume in flood. *(Bainbridge et al., subm.)*



Long-term transport of fine sediment *(Wolanski et al., 2008)*



Pollutant # 2: nutrients (N and P)

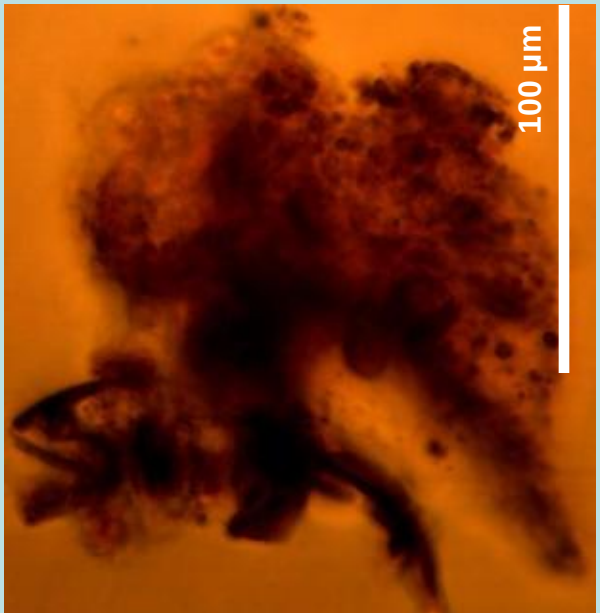
Riverine nutrients enter the GBR in 2 forms: particulate and dissolved

Their relative abundance is determined by the partition coefficient; typically 50-70% is in particulate form.

Dissolved inorganic nutrients move fairly conservatively in the plume until suspended sediment concentration is < 10 mg/L to allow photosynthesis.
Thus coral reefs and seagrass are bathed in nutrient-enriched waters.

Particulate nutrients settle out as muddy marine flocs.

(Bainbridge et al., subm.)

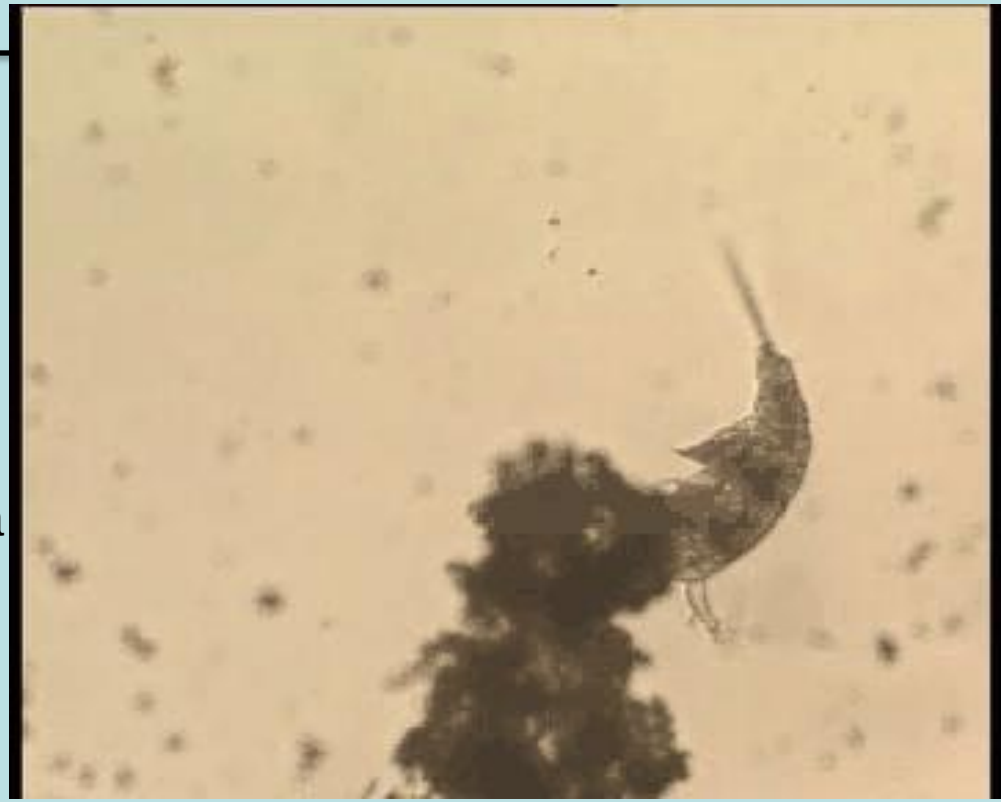


The fate of the particulate nutrients is controlled by the fine sediment.

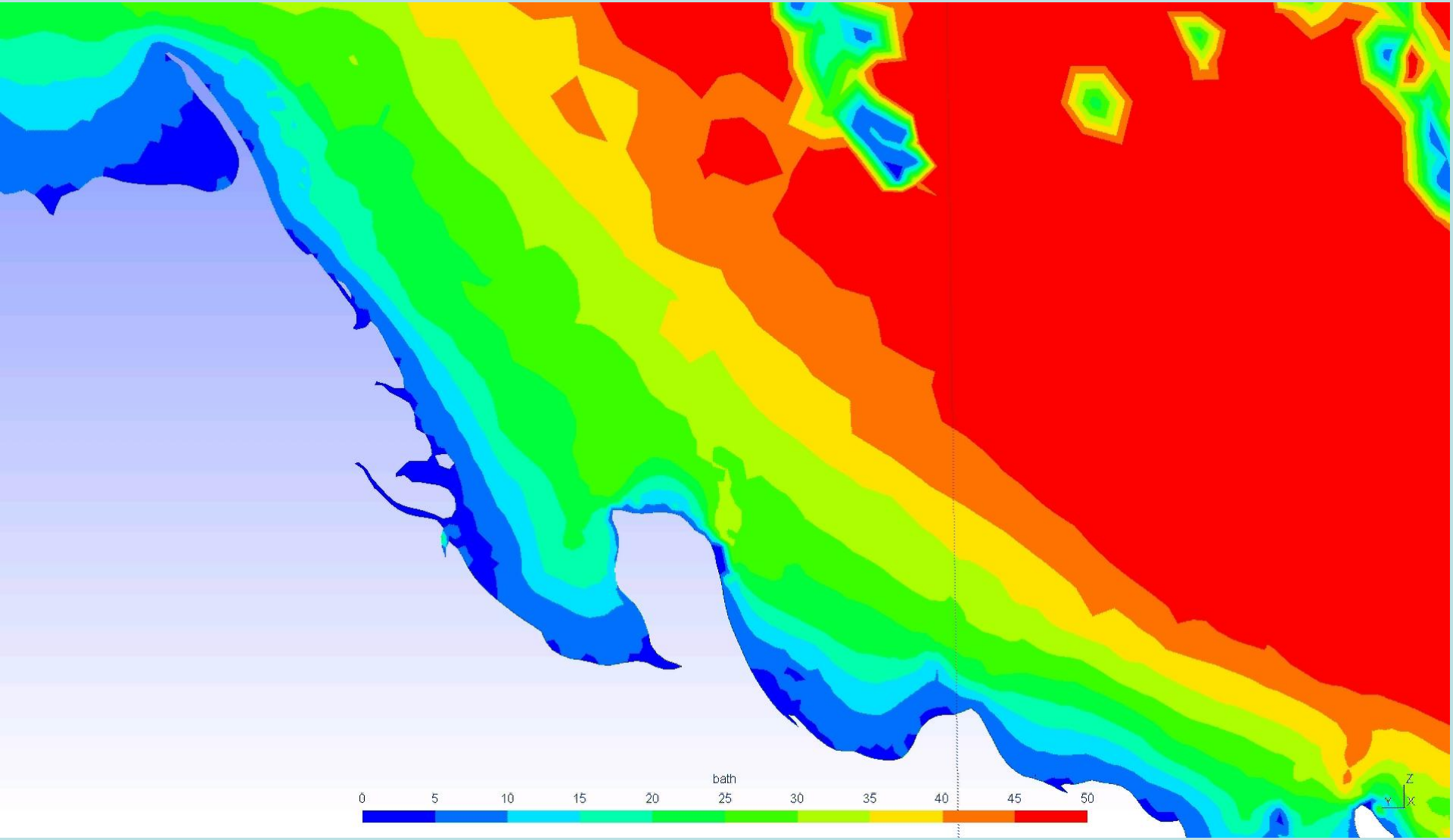
It is periodically resuspended during windy days, during which time some nutrients
•are released to the dissolved phase (the partition coefficient K_d) and thus promote algae and phytoplankton growth; early signs of eutrophication are evident. *(Brodie et al., 2011).*

•are directly extracted by the zooplankton to enter the food web

•are released by mineralisation by bacteria



During these events, the nutrient-rich fine sediment is in suspension in coastal waters and while some is flushed, the rest is trapped in a coastal boundary layer between headlands.



Residence times of Reactive Nitrogen are years to decades due to nutrients being 'fixed' in organisms such as fish, plankton and algae.

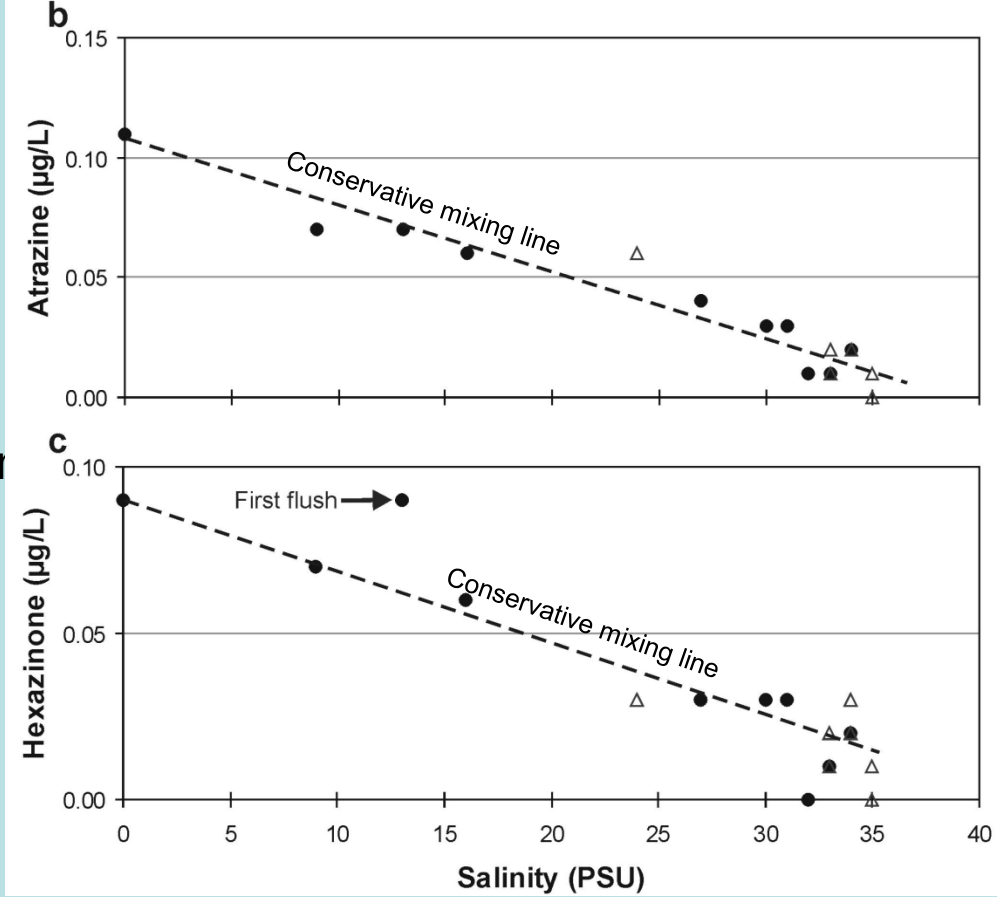
Pollutant # 3: pesticides

Photosystem II (PS-II) inhibiting herbicides (atrazine, hexazinone, tebuthiuron, simazine and ametryn) are soluble and detected

- in the dry season at ng L^{-1} concentration
- at concentration 100 larger in the wet season :conservative transport

Residence times >100 days and < 3 years

(Kennedy et al., in press, Shaw and Müller, 2005; Shaw et al., 2010; Lewis et al., 2009)



The exception may be diuron; about 1/3 is in particulate phase.
Diuron is detected in inshore sediments.
Its residence time is not governed by water flushing times but rather by its photo+microbial degradation rate and its association with particulates.

(Haynes et al. 2000; Davis et al. in press)

CONCLUSIONS

The residence times of **water** in the GBR lagoon = 30 to 100 days.

The residence times of the major pollutants are much longer.

- **Fine sediments** have residence times in the order of decades.
- **Nitrogen and phosphorus** in the forms of RN and RP are stored in the GBR for years in the mobile sediment, benthic biota and water column biota.
- The main mechanism of loss of N and P is by processes such as denitrification and P burial, and not flushing from the lagoon.
- **Herbicides** such as diuron and atrazine are also stored in the lagoon for up to three years.

- Thus, recovering **substrate quality** may take a few decades after land-use remediation.

- **Reef recovery** should be swift afterward *if climate change allows reefs to recover.*