Phosphorus management in a changing world: using models to build a bridge between science and policy

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IPW

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Talk outline

- Setting the stage
- Thames and its catchment
- INCA-P model
- INCA-P simulation of SRP in Thames
- A changing world
- Scenarios
- Conclusions

Models – a bridge between science and policy

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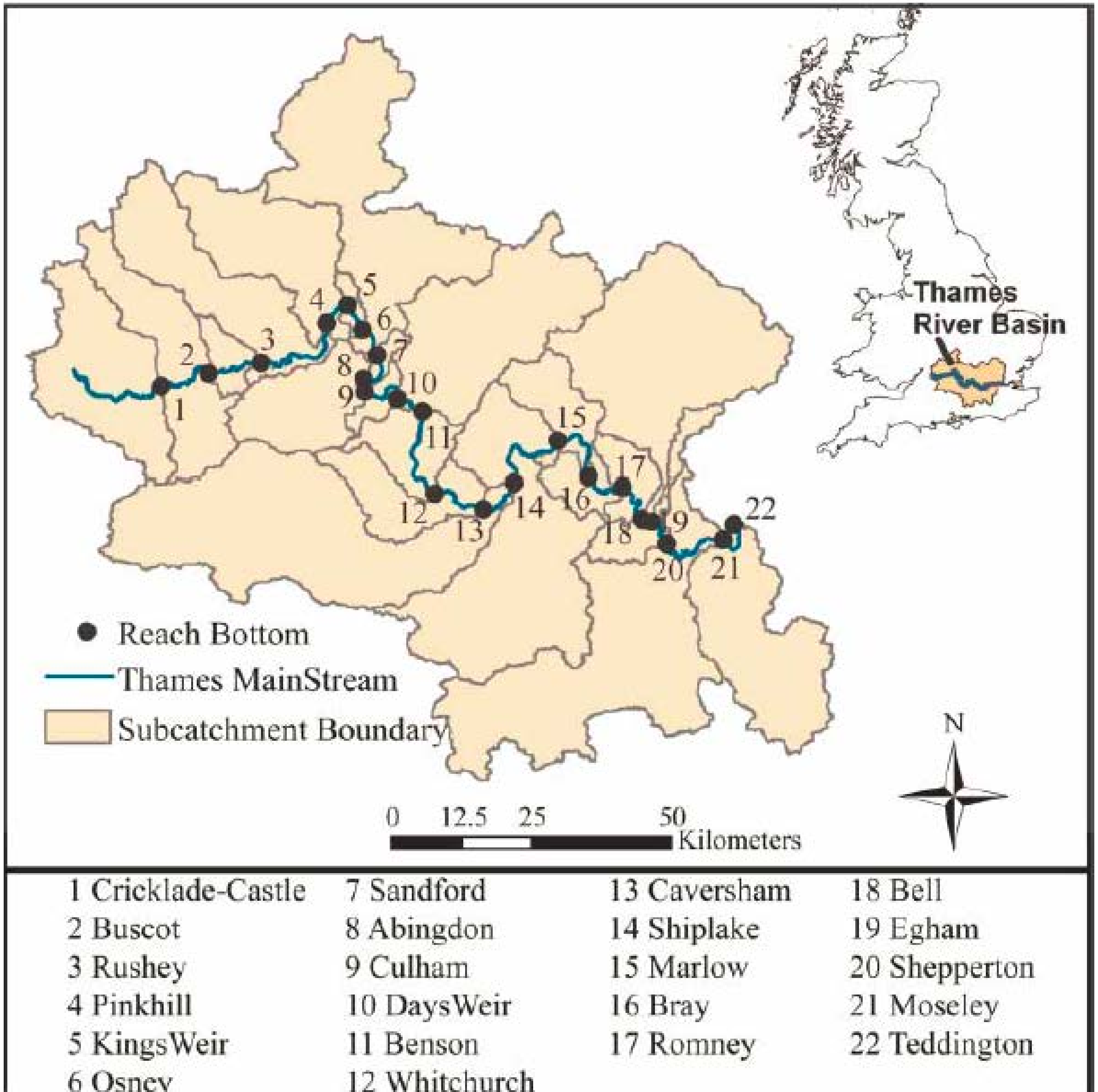
Models cannot provide answers, but they can help to frame a dialog about how to best manage in a changing world: EU legislative compliance, climate change, food and water security, legacy environmental issues, etc.

Managing phosphorus in a changing world is not only about agriculture

Thames River and catchment

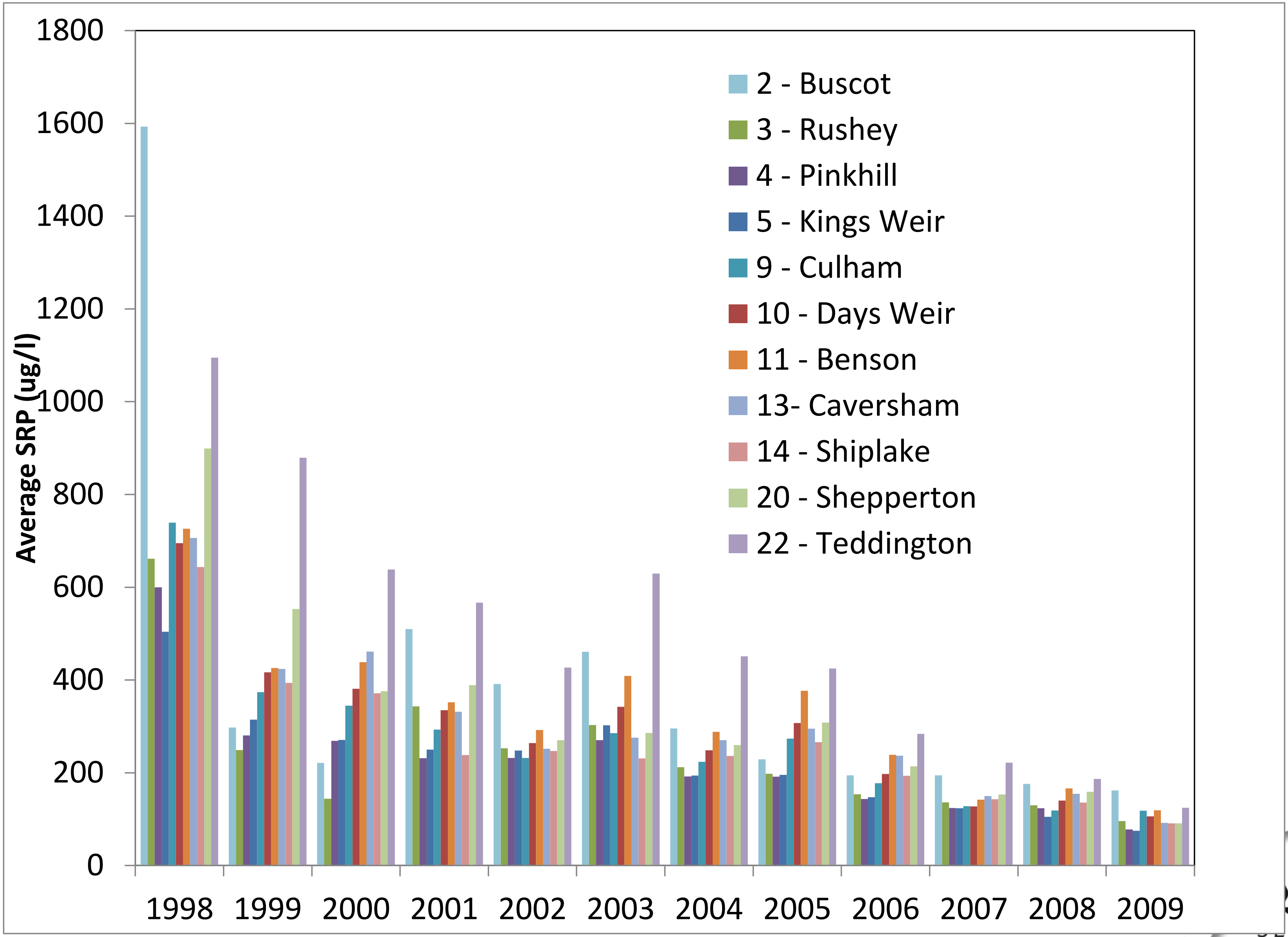


Pressures on the Thames and its catchment

- WFD Compliance: eutrophication and hydro-morphological alteration
- Can GES be achieved ?

- Drinking water supply for greater London (~14M people)
  - Summer low flows similar to abstraction rates
  - Aging, leaky infrastructure; lead pipes
- Food security
  - Agricultural catchment, arable (36%), livestock and pasture

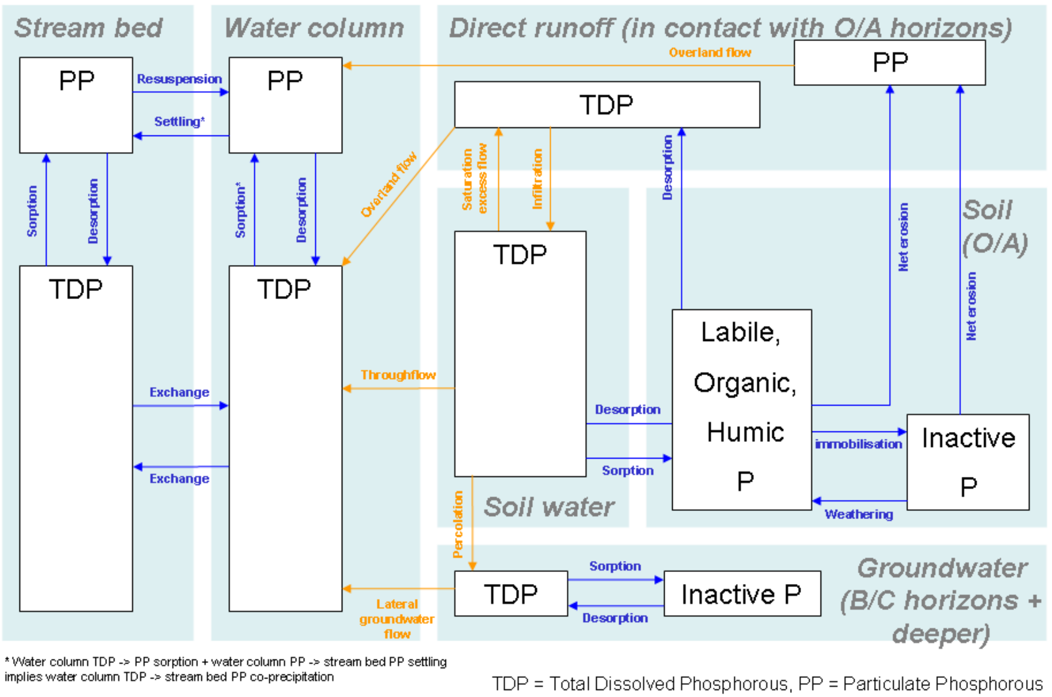
Thames soluble reactive P



INCA-P Factors affecting surface water P concentrations

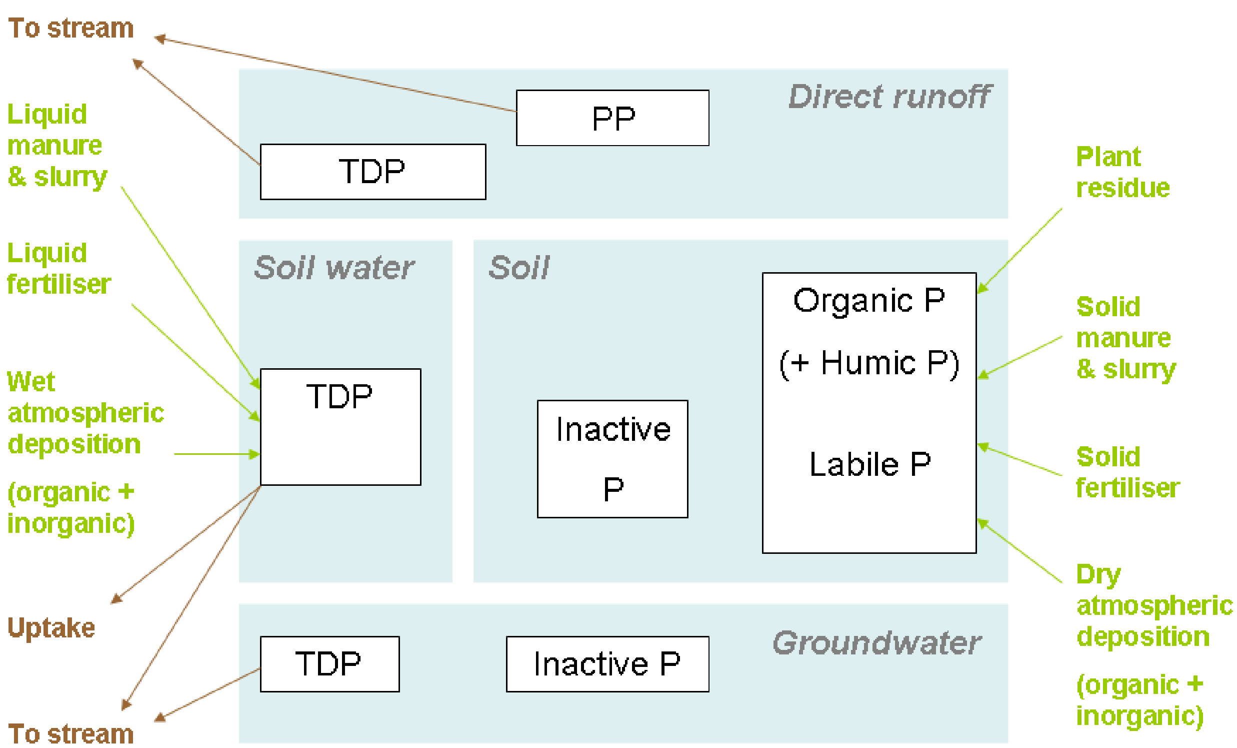
- Climate (changing T, P and soil moisture)
- Hydrology
  - storm events & resultant changes in flow pathways affecting P transfer from land to stream
- Land Use and Management
  - sediment availability and transport
  - changes in crop cover
  - changes timing of P additions throughout the year
- Geochemistry
  - sorption and release of P to and from sediment;
  - in-stream P sources and sinks
  - accumulation and depletion of P in soils and groundwater
- Ecology
  - interactions between P and biology.

INCA-P model overview



Dynamic, semi-distributed, daily time step model simulating total dissolved (TDP) and particulate (PP) phosphorus in the land, water column and stream bed. Soluble reactive P (SRP) simulated as a fraction of TDP.

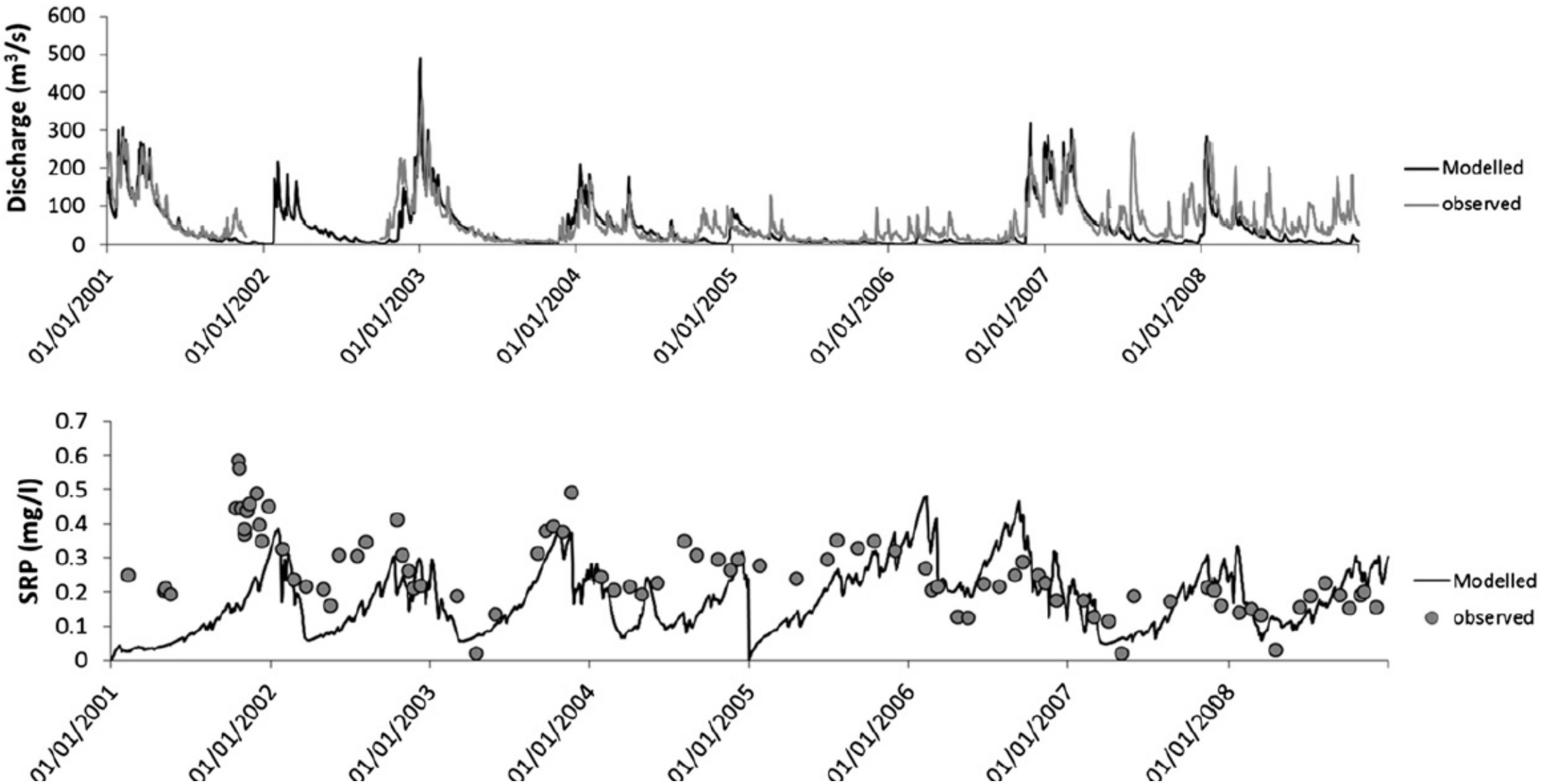
Anthropogenic P sources modelled in INCA-P



TDP = Total Dissolved Phosphorous, PP = Particulate Phosphorous

INCA-P simulates agricultural, waste water treatment plant (WWTP) and atmospheric P inputs.

INCA-P modelled and observed flow and SRP at Lower Thames (22 - Teddington)



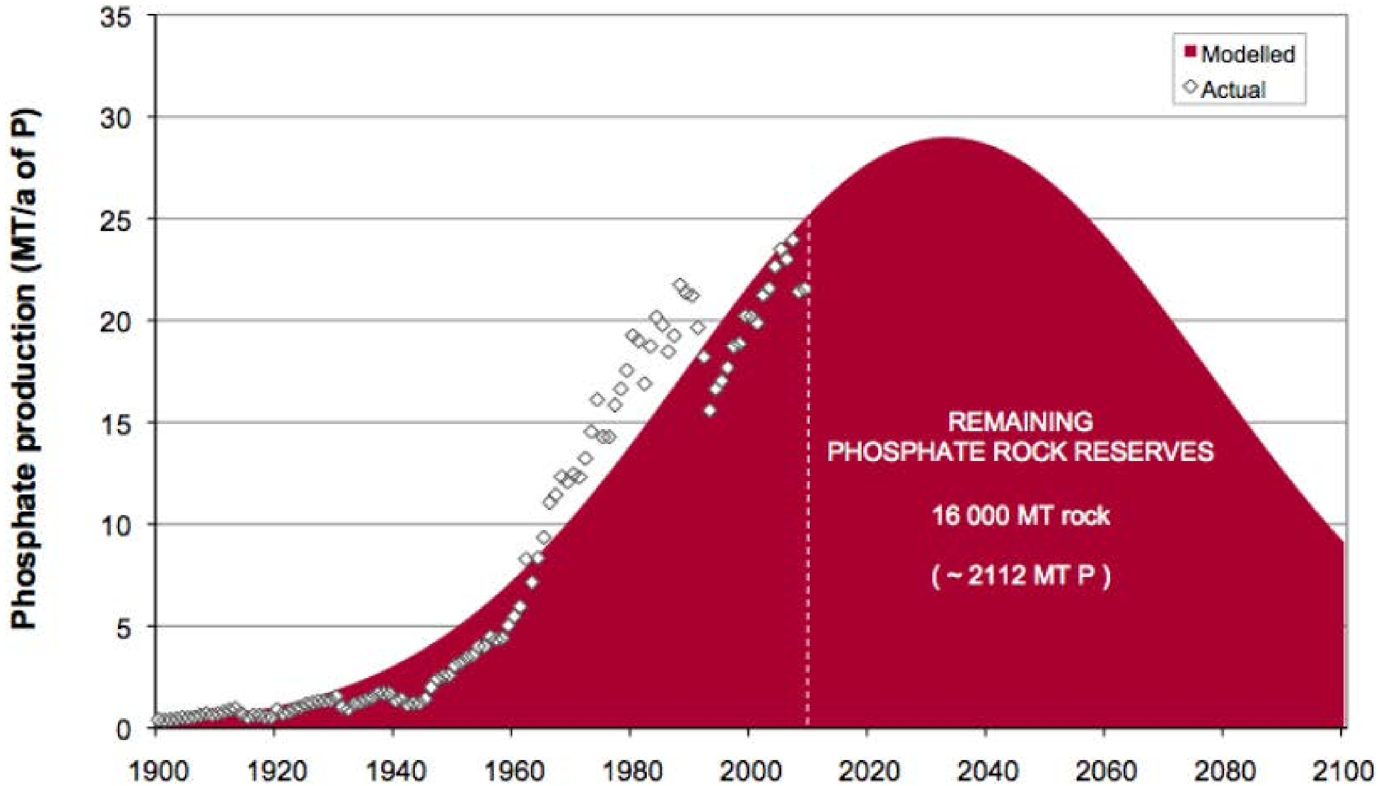
Changing world – UKTAG & WFD classification

Table 1: Comparison of existing and revised standards for phosphorus

Type (for existing standards)	Annual mean of reactive phosphorus (µg per litre)							
	High		Good		Moderate		Poor	
	Existing	New	Existing	New	Existing	New	Existing	New
Lowland, low alkalinity	30	19 (13-26)	50	40 (28-52)	150	114 (87-140)	500	842 (752-918)
Upland, low alkalinity	20	13 (13-20)	40	28 (28-41)	150	87 (87-117)	500	752 (752-851)
Lowland, high alkalinity	50	36 (27-50)	120	69 (52-91)	250	173 (141-215)	1000	1003 (921-1098)
Upland, high alkalinity	50	24 (18-37)	120	48 (28-70)	250	132 (109-177)	1000	898 (829-1012)

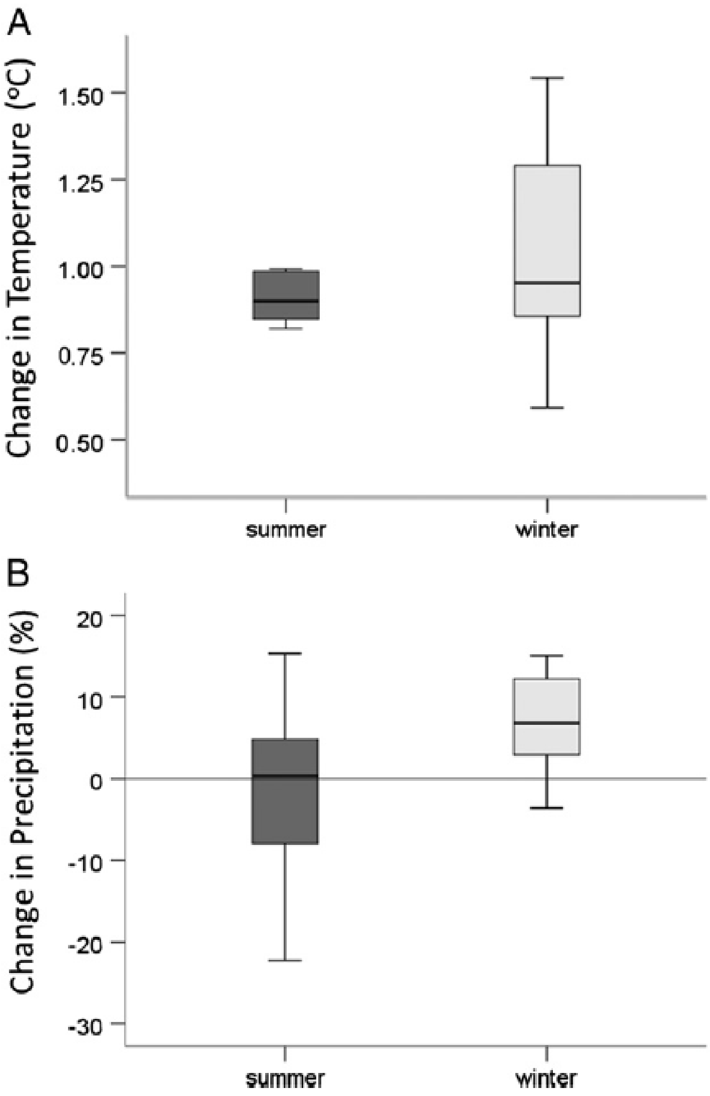
New science (Aug 2013) is changing the target SRP concentrations for WFD class boundaries

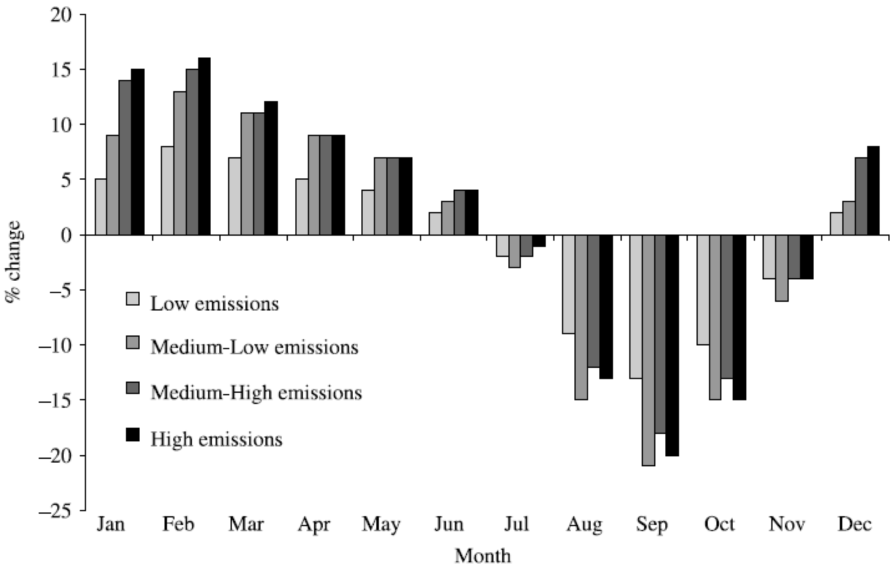
Changing world - Peak phosphorus



Cordell, D., & White, S. (2011). Peak phosphorus: clarifying the key issues of a vigorous debate about long-term phosphorus security. *Sustainability*, *3*(10), 2027-2049.

Possible future climate



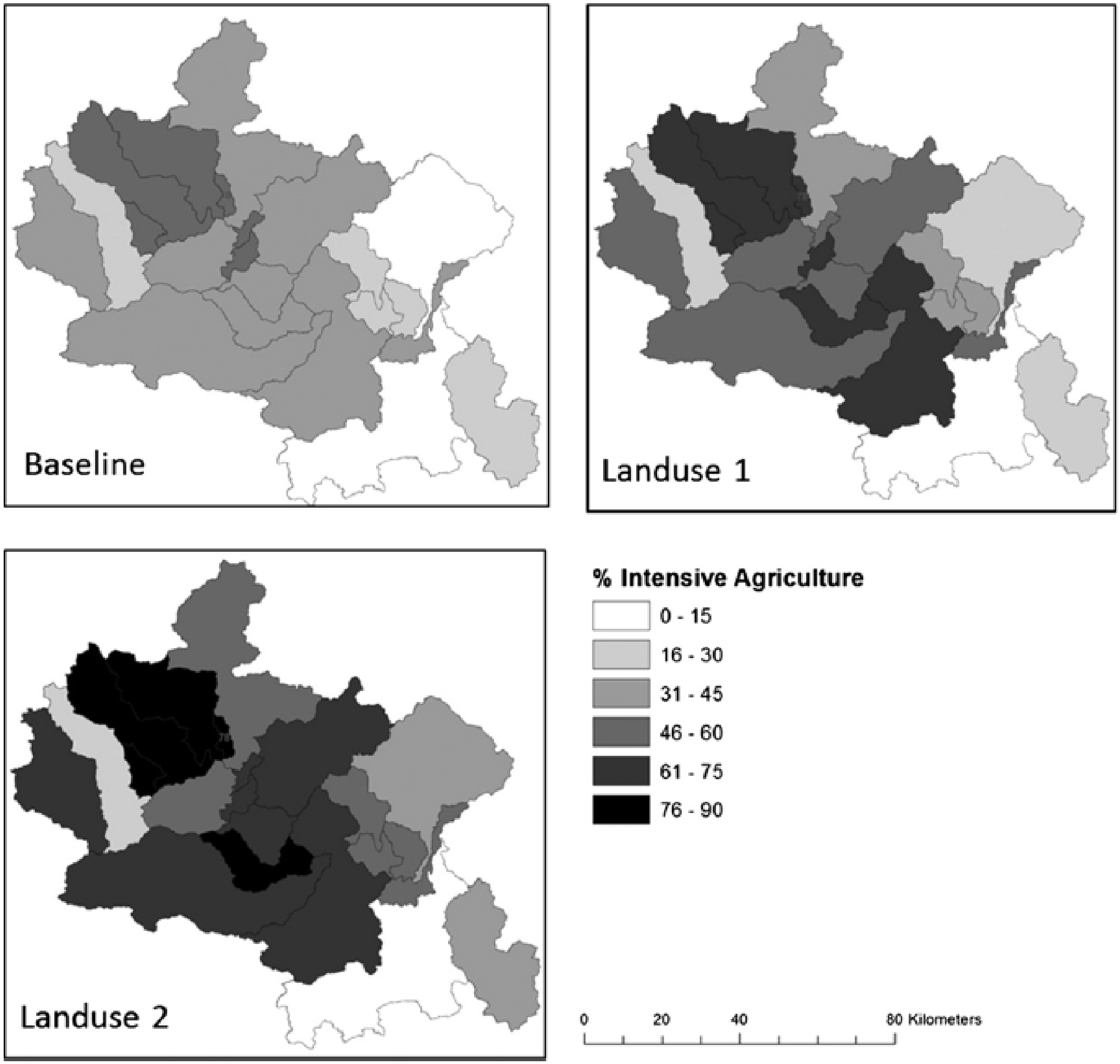


Warmer temperatures, increased winter rainfall and a likely decline in summer rain (left) may lead to higher winter and lower summer flows (above)

Water resources - water security in London

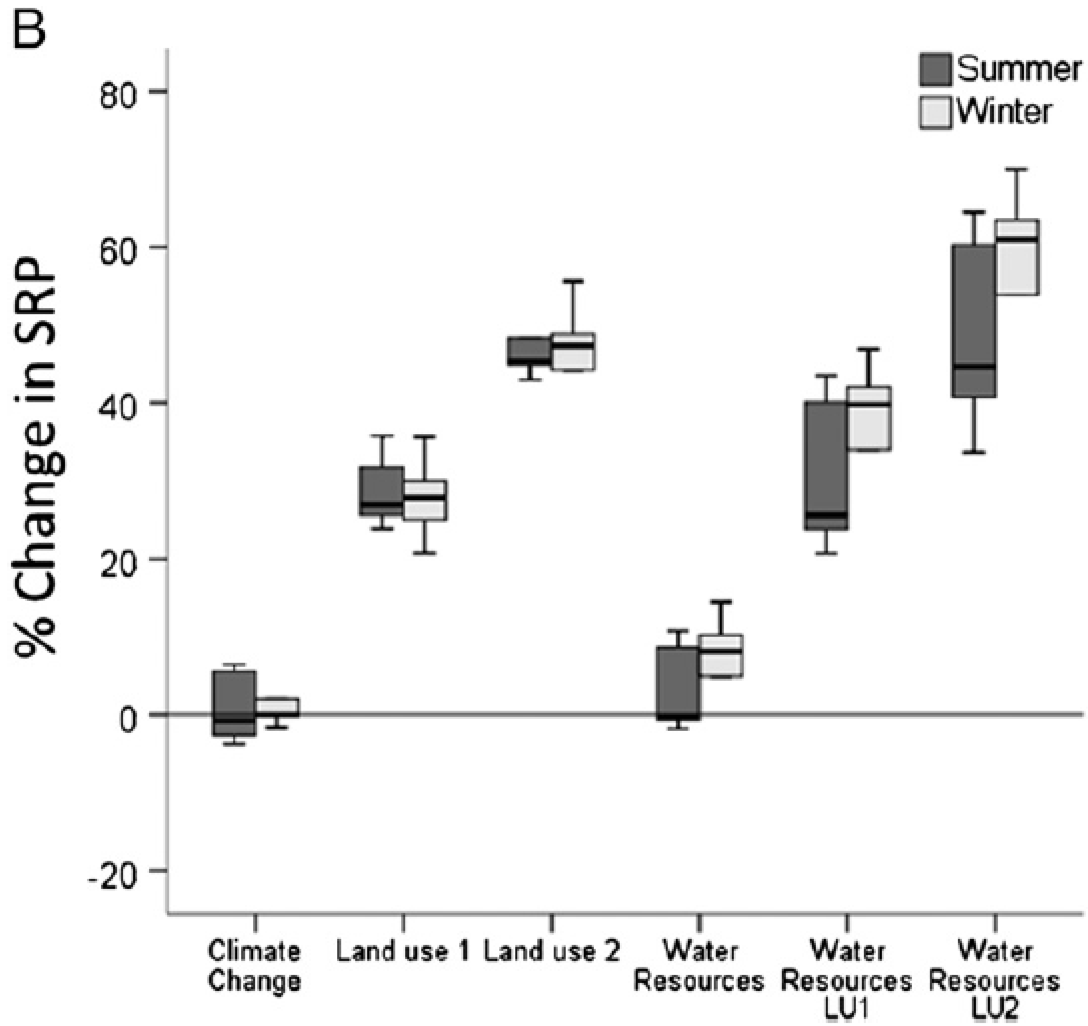
Drinking water demand was equal to river flow in summer 1976; Thames Water proposed a reservoir at Abindgon. The proposal was rejected in 2011; smaller reservoirs may be built

UK food security



Today, arable agriculture occupies 36% of the catchment. Scenarios increasing % arable to 50 (Landuse 1) and 60% (Landuse 2) were evaluated. It was assumed that present day agricultural practices would be used.

Possible effects of a changing world on mean SRP in lower Thames



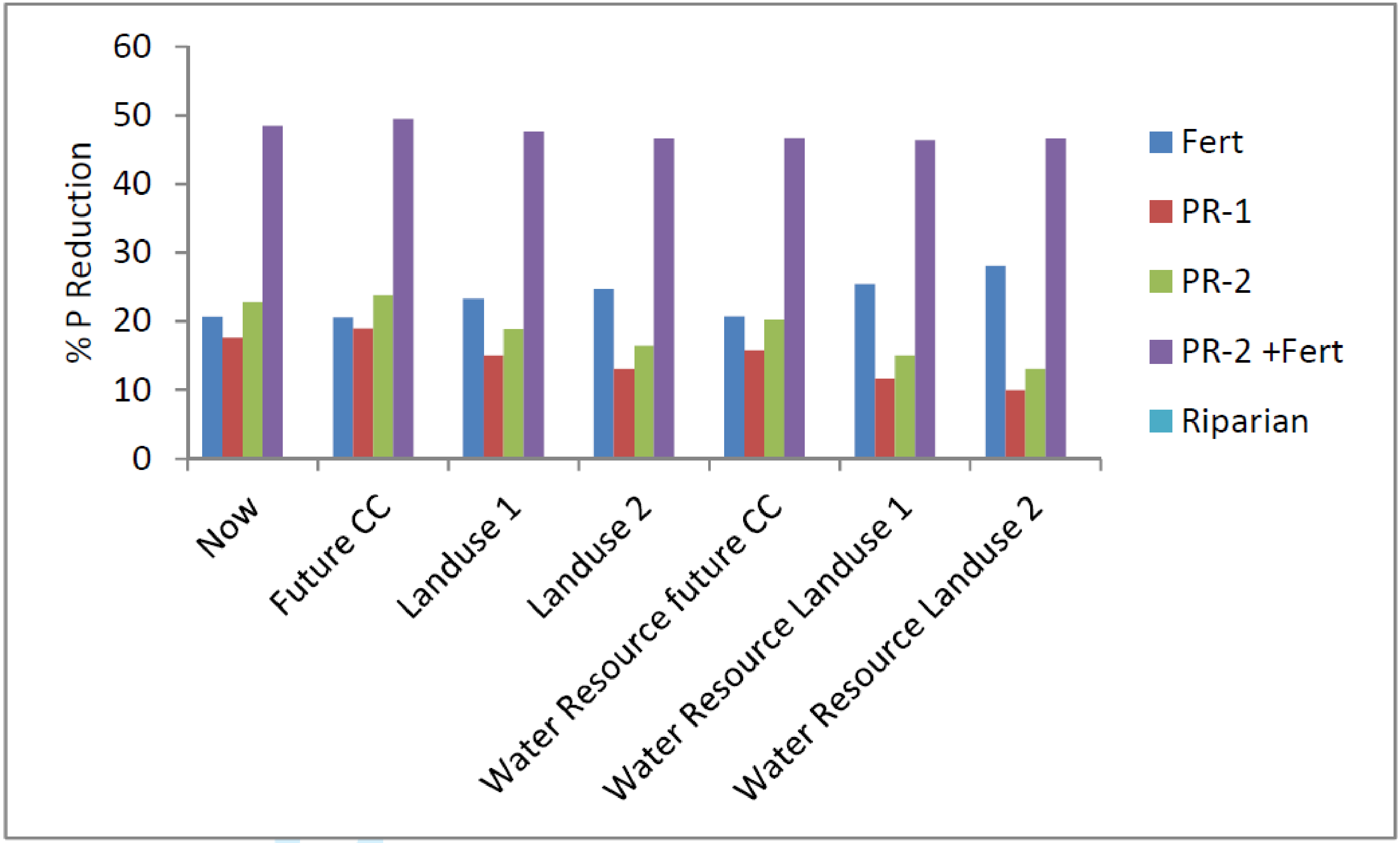
Possible P mitigation measures

- Reduce P losses from agricultural land
    - Reduced application rate
    - Use of buffer zones and riparian wetlands
    - Better livestock management
- Tertiary treatment at waste water treatment plants (WWTP)
    - Iron dosing to reduce P to 1 mg/l (required under EU Wastewater Treatment, WFD, Birds & Habitats Directives)
    - Enhanced technology using optimized dosing and ultrafiltration (currently not feasible in UK)
- Source control of P entering WWTP via sources other than natural diet
    - Domestic laundry cleaning products (to be banned by 2015)
    - Automatic dishwashing detergents
    - Tap water dosing for controlling lead in drinking water
    - Use of P in food additives

Mitigation scenarios

- Baseline – present day, business as usual
- 20% Fertiliser reduction, present day arable area
- PR 1 – P removal at WWTP to meet 1 mg/l discharge total P concentration
- PR 2 – P removal at WWTP to meet 0.3 mg/l discharge total P concentration
- 20% fertiliser reduction plus PR2
- Riparian buffer strips

Mitigation effectiveness under different scenarios



Projected SRP concentrations, Lower Thames

Scenario	Baseline	20% Fertiliser Reduction	PR-1	PR-2	PR-2 + 20% Fertiliser Reduction	Riparian
Present	187	149	154	145	97	186
Future CC	186	148	151	142	94	185
Land Use 1	232	178	198	189	122	231
Land Use 2	263	198	229	220	141	262
Reservoir + Future CC	185	146	156	147	99	184
Reservoir + Future CC + Land Use 1	229	171	203	195	123	228
Reservoir + Future CC + Land Use 2	261	187	235	227	139	260

Conclusions

- SRP concentrations have declined in the Thames
- New science leads to changes in management targets
- Achieving moderate WFD ecological status will be a challenge
- Climate change & reservoir may have limited effects on SRP concentrations
- Trade-offs are needed; lower SRP concentrations in WWTP discharge will allow some agricultural intensification

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Key Papers

- Crossman et al. 2013 The interactive responses of water quality and hydrology to changes in multiple stressors, and implications for the long-term effective management of phosphorus *Science of the Total Environment* doi:10.1016/j.scitotenv.2013.02.033.
- Whitehead et al. 2013. A Cost Effectiveness Analysis of Water Security and Water Quality: Impacts of Climate and Land Use Change on the River Thames System *Phil. Trans Royal Soc. A.* accepted
- Wade et al. 2007. Deliverable No. 185 The Integrated Catchment Model of Phosphorus (INCA-P), a new structure to simulate particulate and soluble phosphorus transport in European catchments

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