Global Water Security: Challenges and Opportunities

by

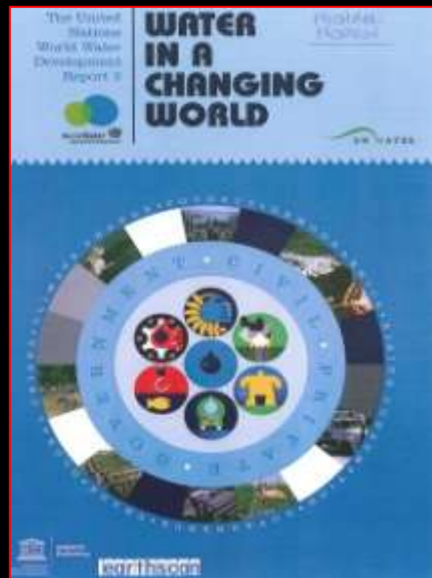
Professor Roger A. Falconer FREng
Professor of Water Management
Past IAHR President (2011-15)

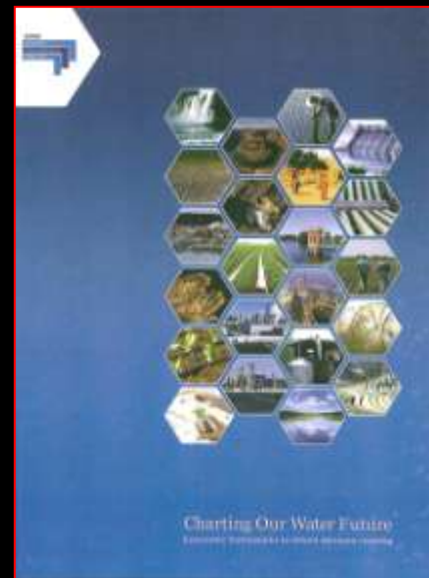
Hydro-environmental Research Centre (HRC)
School of Engineering, Cardiff University

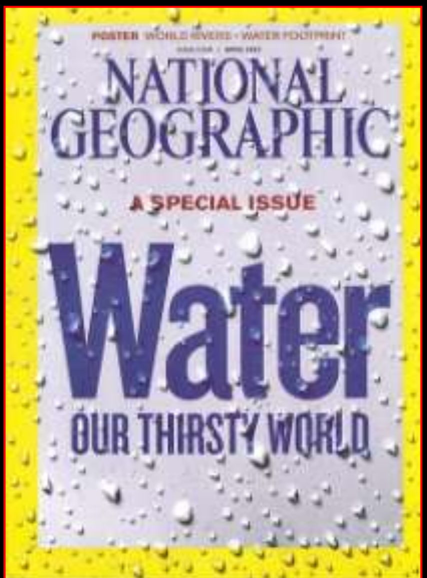
CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Water Security: Increasing Attention







CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

World of Water

Key facts:

- Total global volume ≈ 1.4 billion km^3
- Only 35 million km^3 of freshwater
- Only 105 thousand km^3 is accessible (0.01% of total vol.)

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Water Availability - Some Challenges

- Nearly 70% of world's fresh water is locked in ice
- Aquifers are being drained much more quickly than natural recharge rate
- 2/3rd of world's water is used to grow food
- 83 million more people live on planet each year
- Current demand for fresh water is not sustainable
- On average, every $1 invested in water and sanitation provides an economic return of $8

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Water Security - Some Challenges

- 1.2 bn people have no access to safe drinking water and 2 m die annually of diarrhoea
- 2.4 bn people do not have access to basic water sanitation and 10 m contact hepatitis A annually
- Women in developing countries walk an average of 6 km daily to get water
- Flooding causes many deaths globally - e.g. Aceh
- More than 1/2 hospital beds in world are filled by people with water related diseases (BMJ 04)

Water Security - Typical Challenges

Source: http://water.org/learn-about-the-water-crisis/

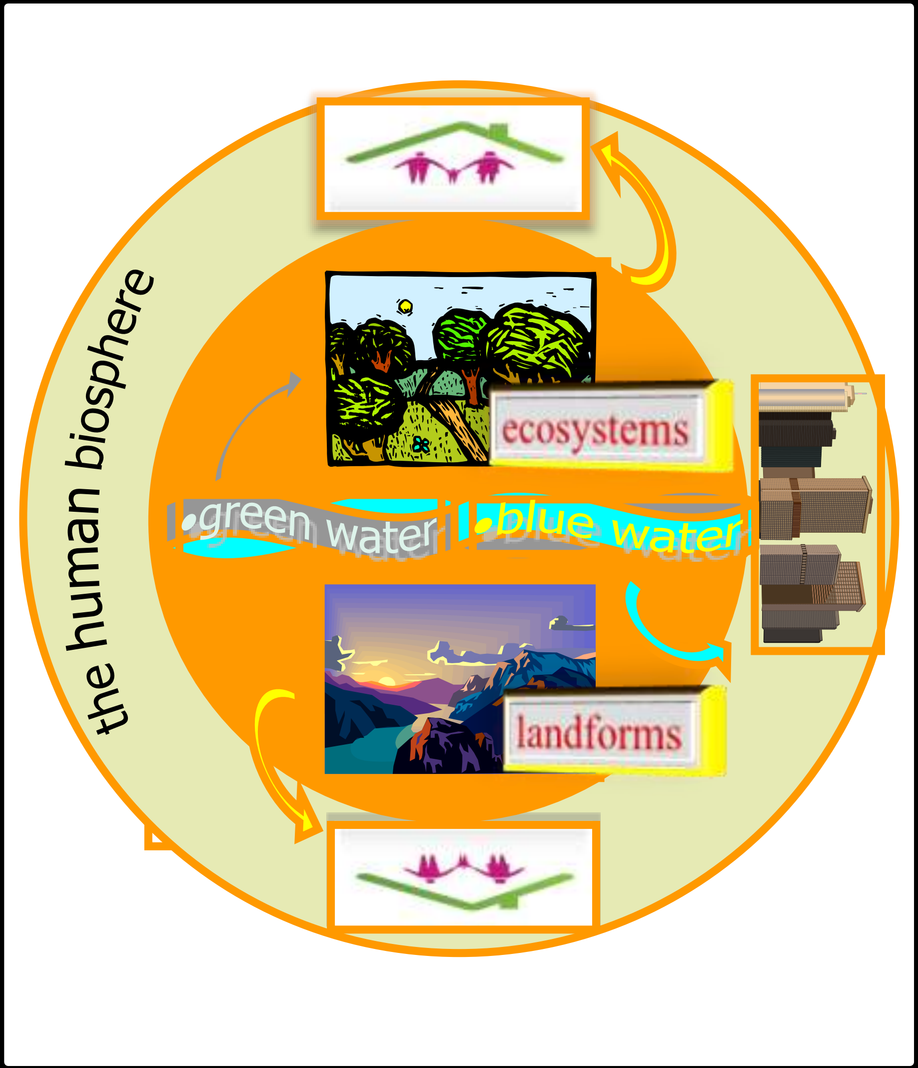
Water Security - Typical Challenges

Source: http://water.org/learn-about-the-water-crisis/

Water Security - Typical Challenges

Source: http://water.org/learn-about-the-water-crisis/

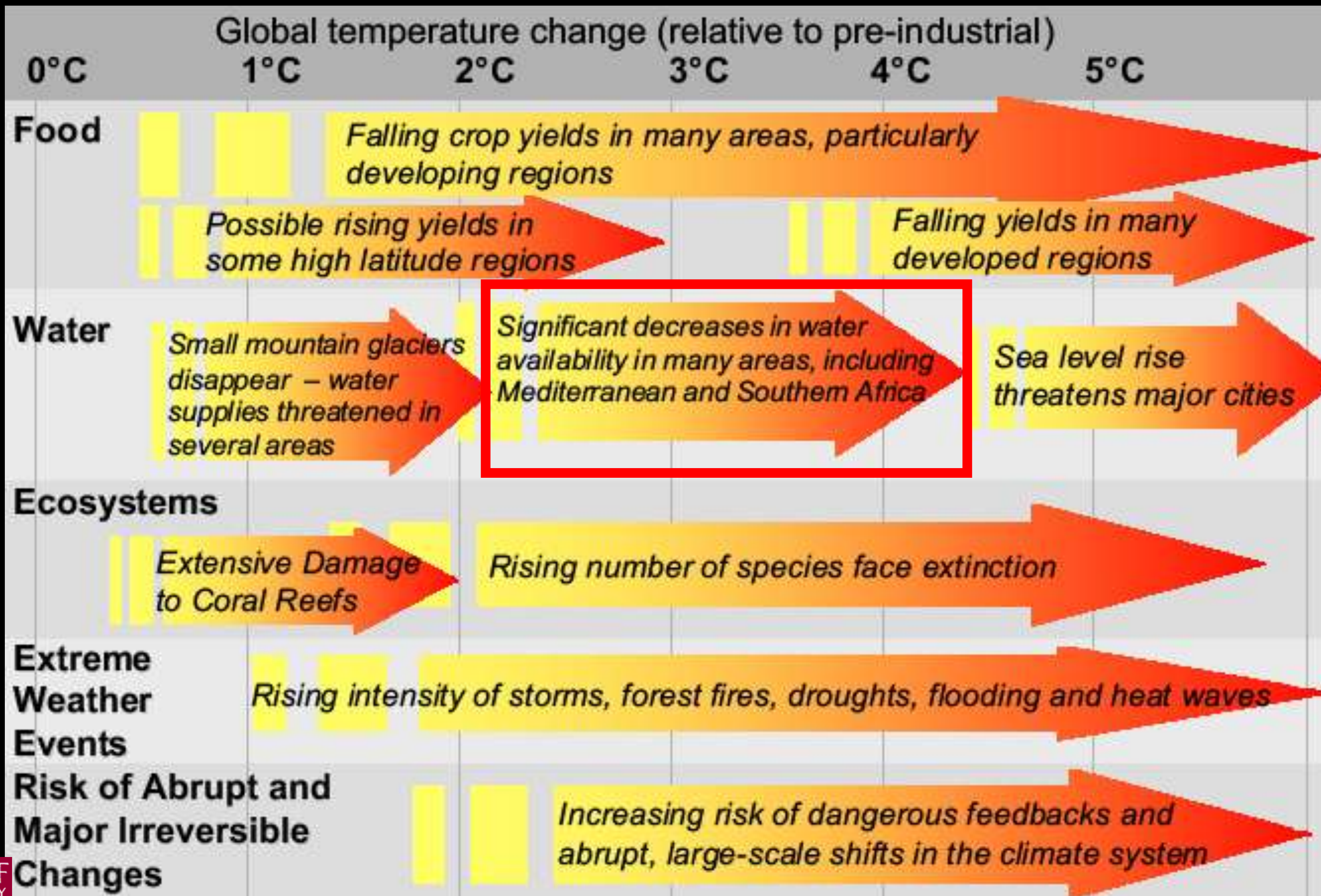
Limited but Vital Resource



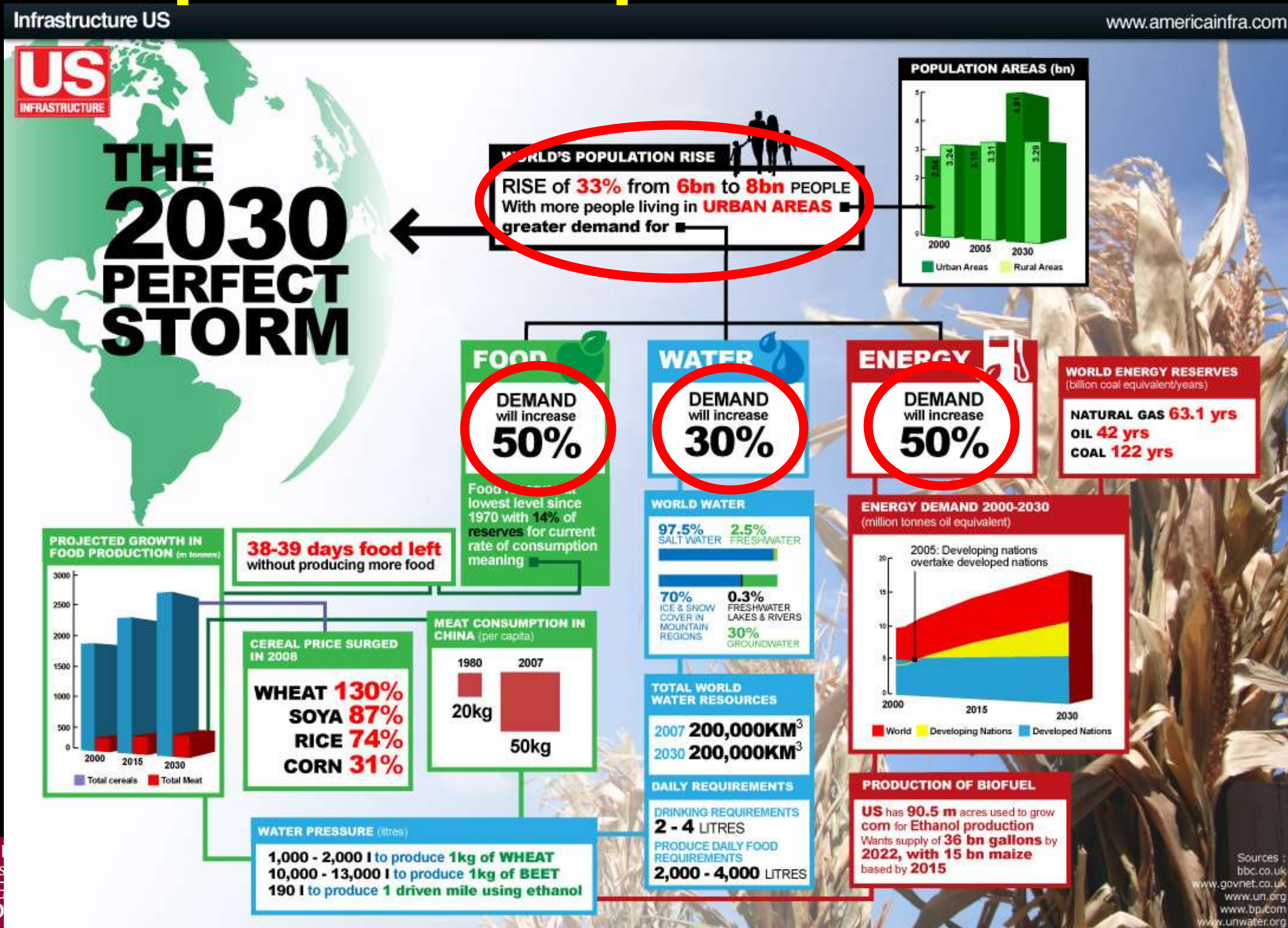
Water is needed to:

- Sustain human life
- Support production of food
- Support production of energy
- Sustain industry
- Maintain ecosystems biodiversity and landforms

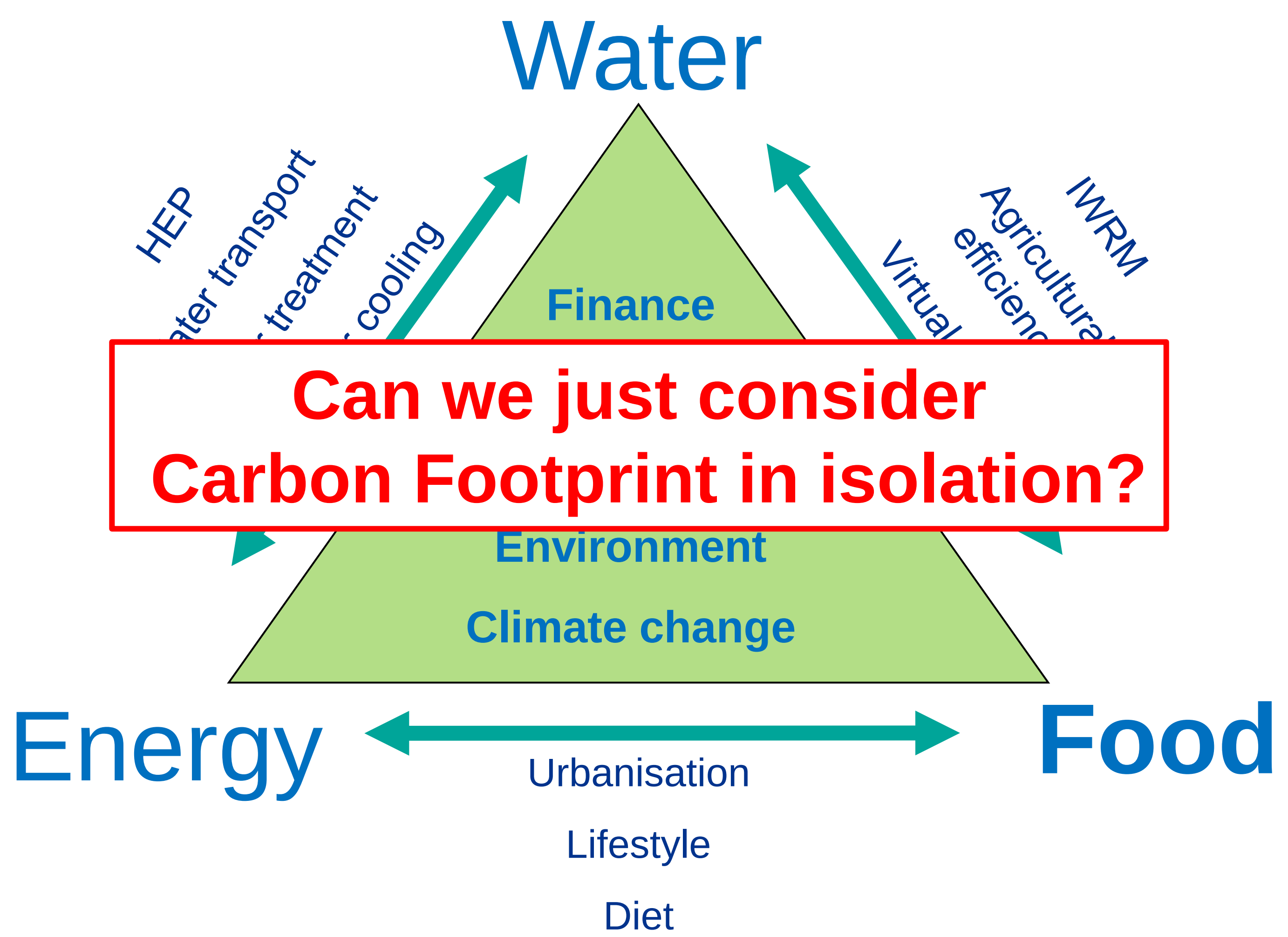
Stern 2006: Climate Change Impacts



Impacts of Population Growth



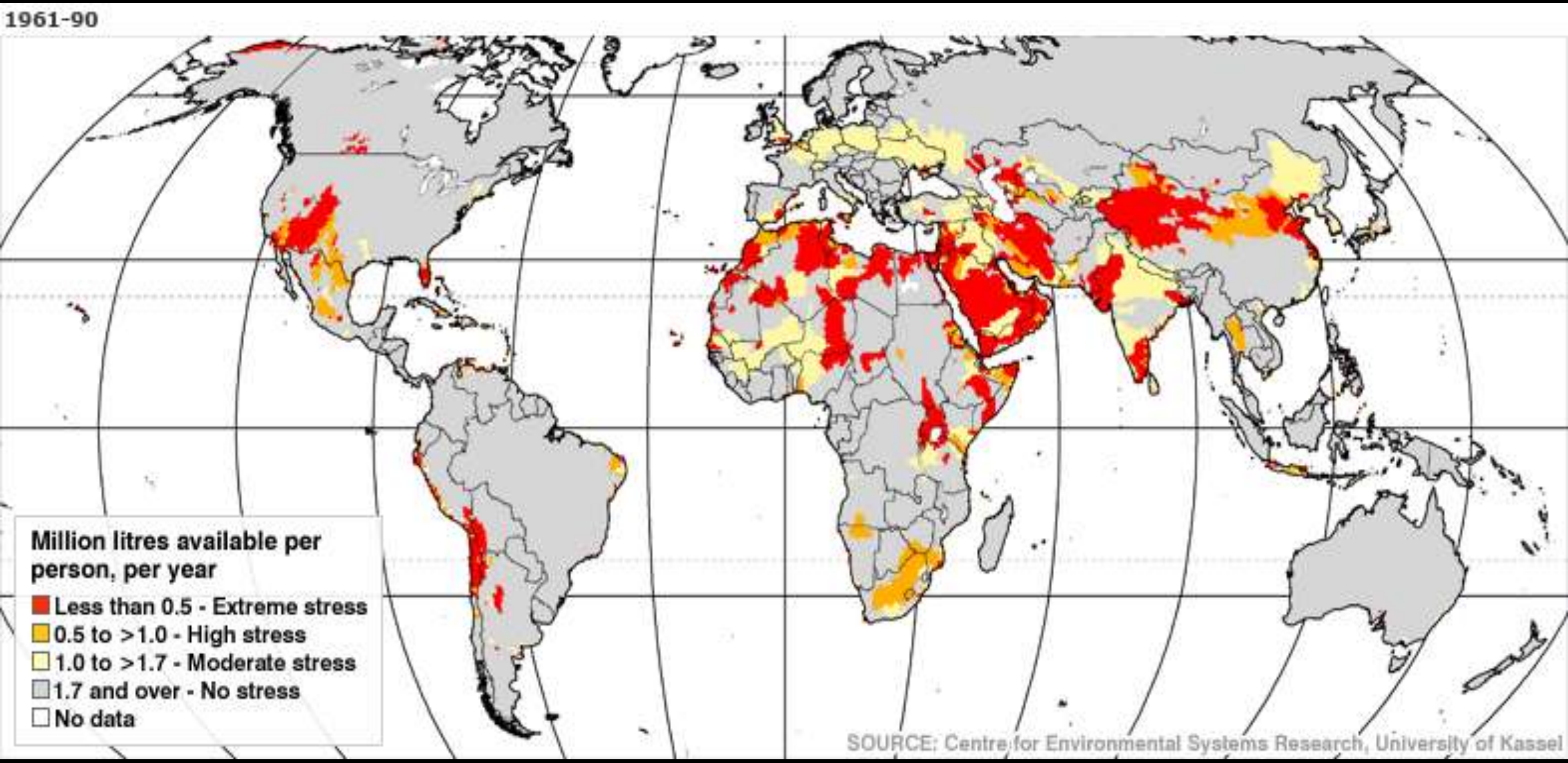
Water-Food-Energy Nexus



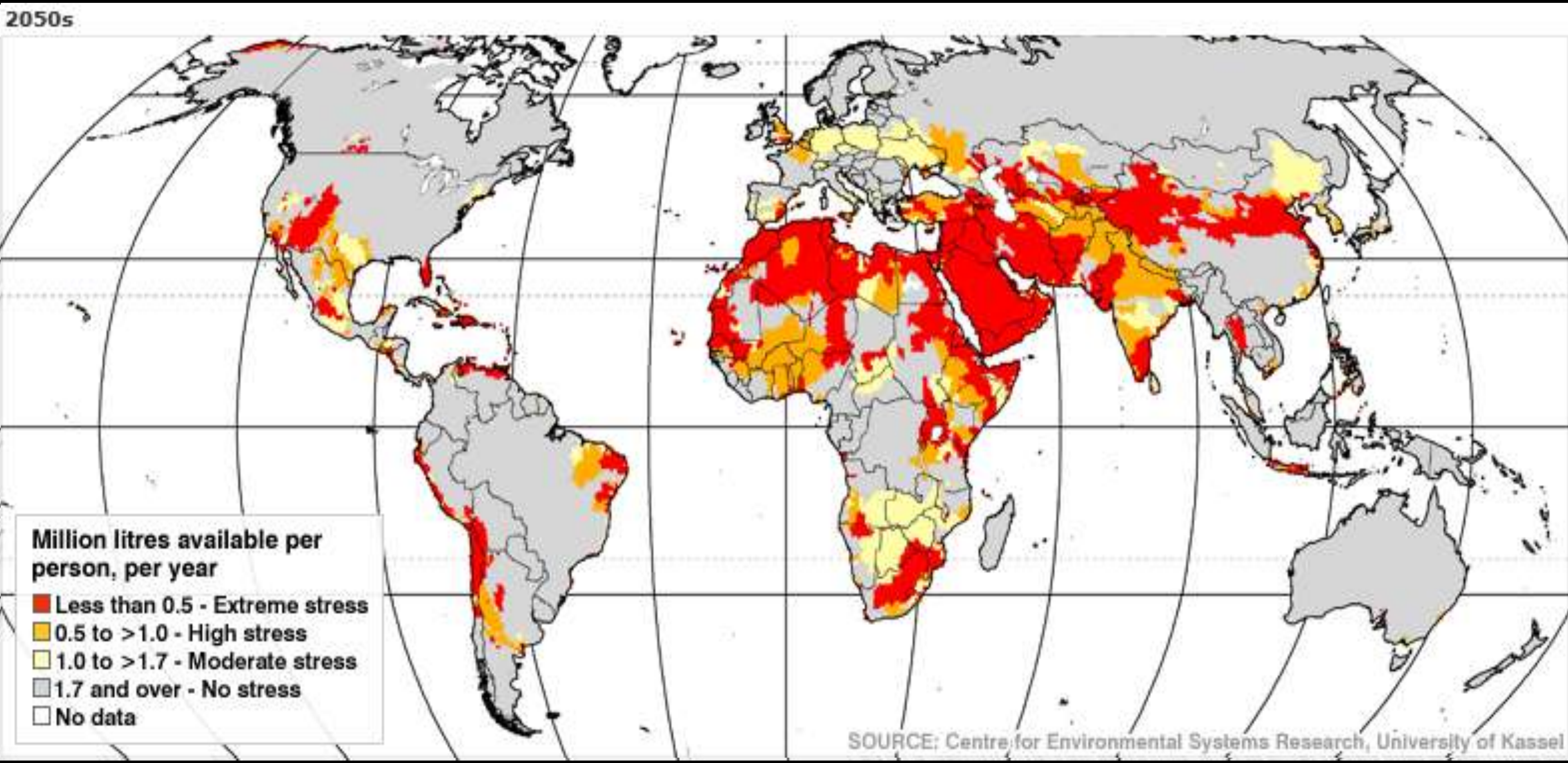
Water Abstraction - Food Link

		Africa	Asia	EU	Global
• Domestic		7%	6%	13%	**8%**
• Industry		5%	8%	54%	**23%**
• Agriculture		88%	84%	33%	**69%**

Water Stress Globally: 1990



Water Stress Globally: 2050

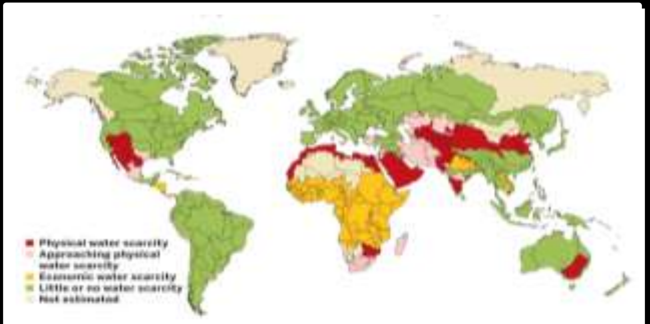


CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Four Reasons for Action

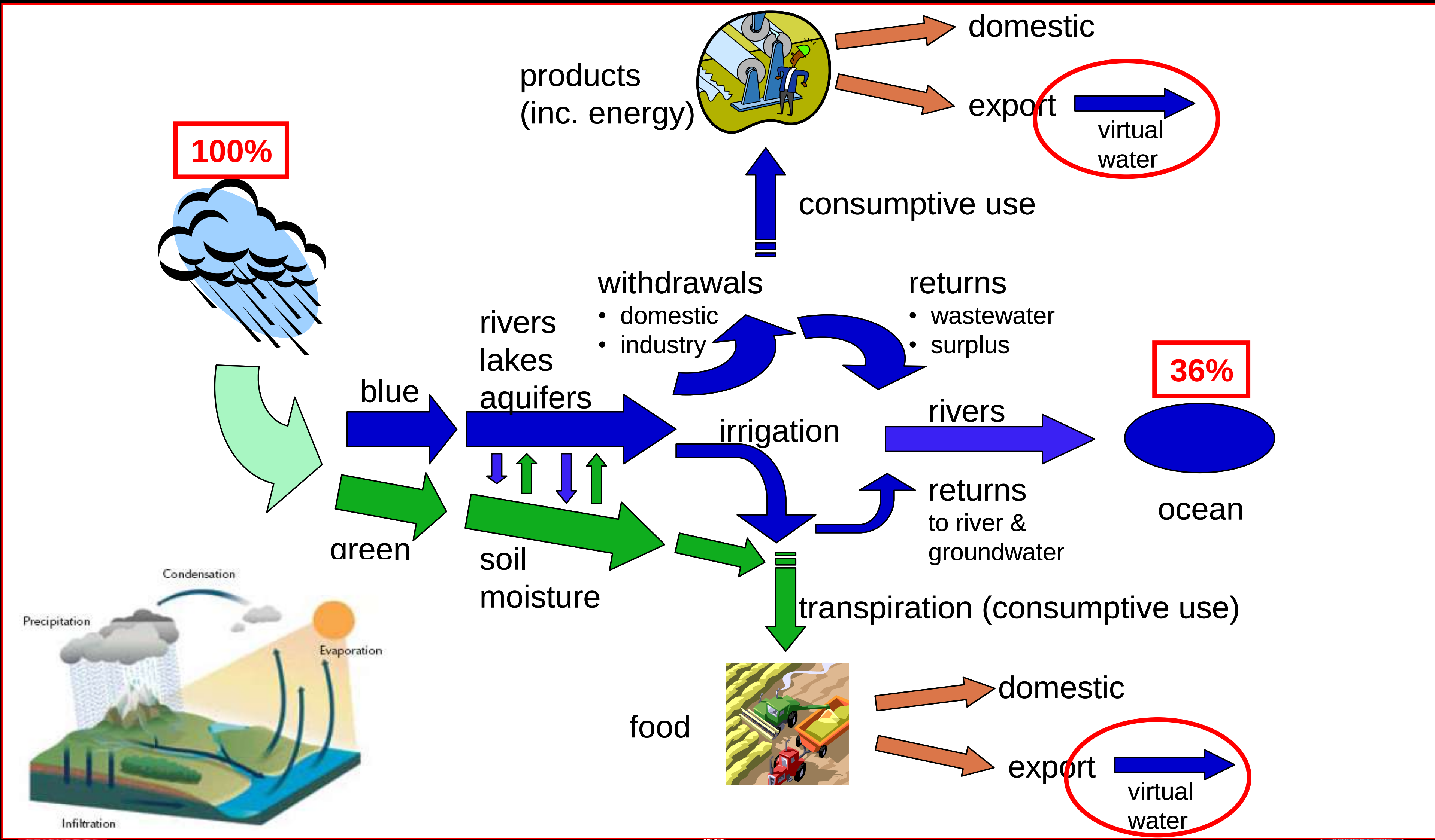
- Water scarcity is increasing with 1/5th of world's population living in areas of water scarcity
- Sustainable Development Goals - 5 linked to water issues
- Conflicts over water have taken place and are likely to rise
- Economic growth affected by water availability and quality



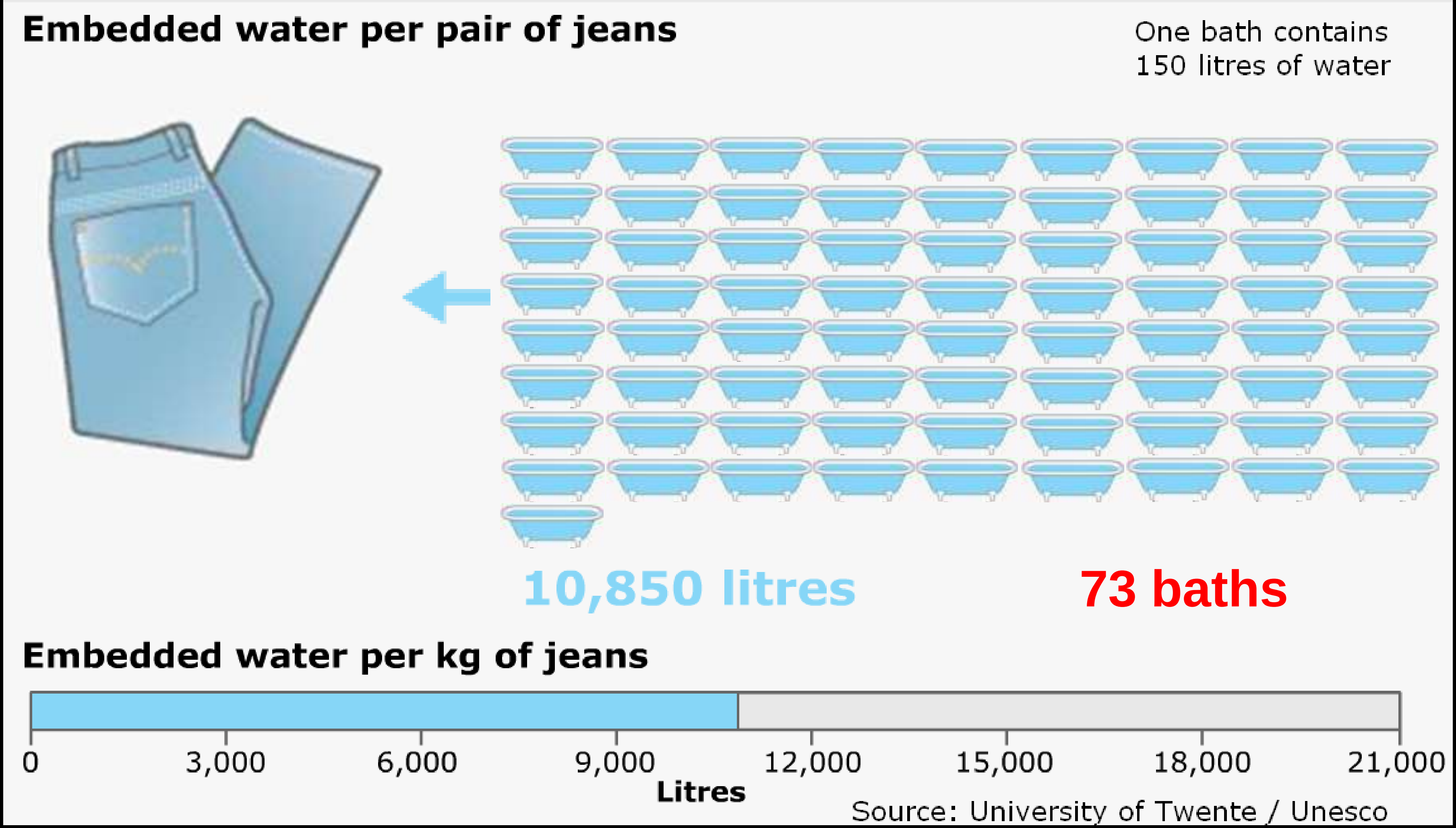
Pressure on Water Resources

- Population to increase by ≈ 50% over next 50 yr
- Urbanisation to city regions ⇨ particularly coastal
- Food production ⇨ needs to double in 40 years
- Industry demand ⇨ needs new energy sources
- More disposable income ⇨ change in diet & more meat consumption, e.g. China: 11 kg/person/yr in 1975 ⇨ 50 kg/person/yr in 2000 (FAO)
- Changing diets ⇨ more water:- 1 kg beef ≈ 15,500 litres of water, 1 kg of wheat ≈ 1,300 litres of water

Water Management - Water Cycle



Virtual Water Content



Water Footprint of a Nation

- Water used to produce goods and services consumed within a nation
- Two components:-

  Internal water footprint - from inside country

  External water footprint - from other countries
- National water footprint =

National water use

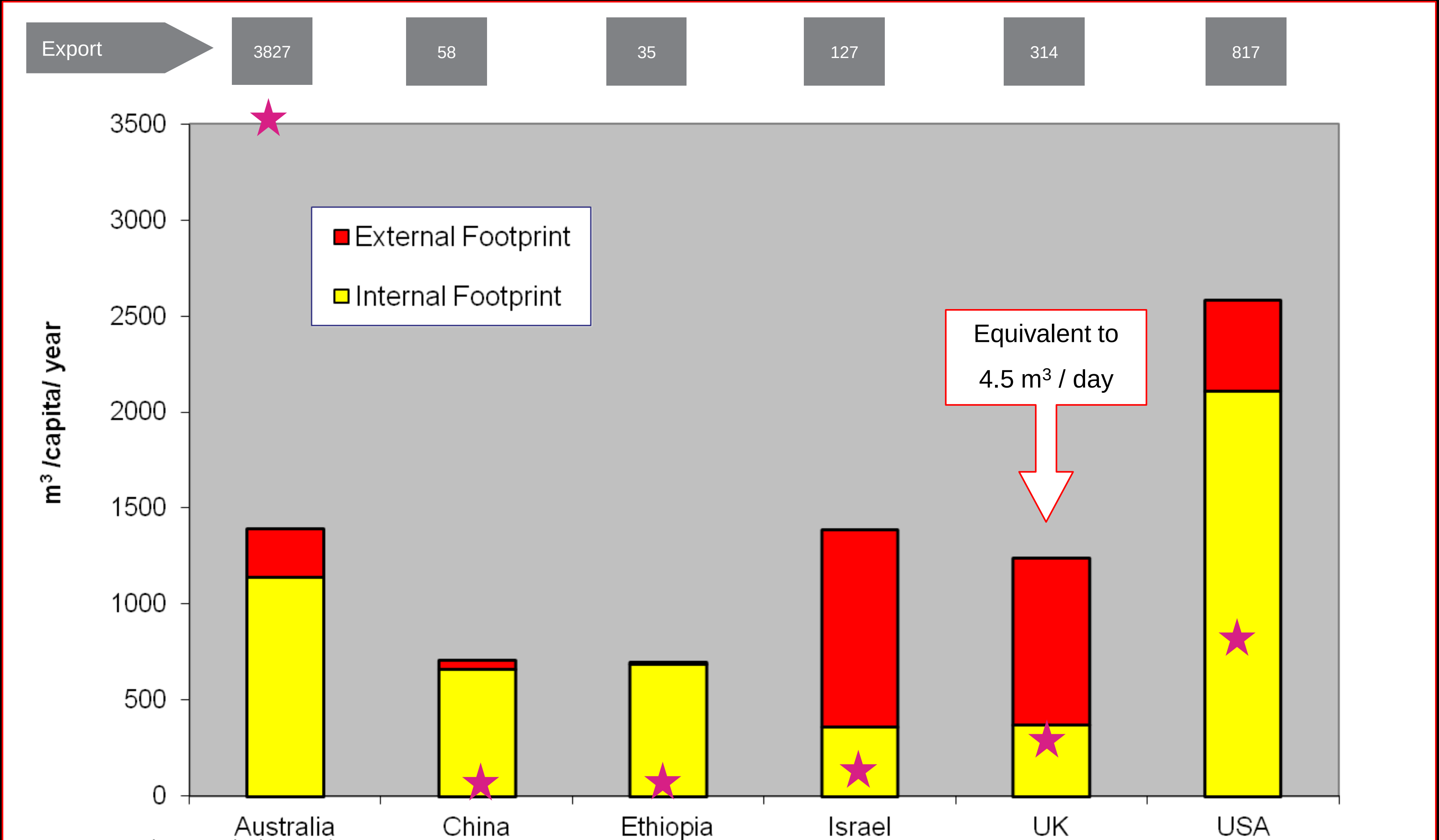
+

Virtual water import – Virtual water export

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

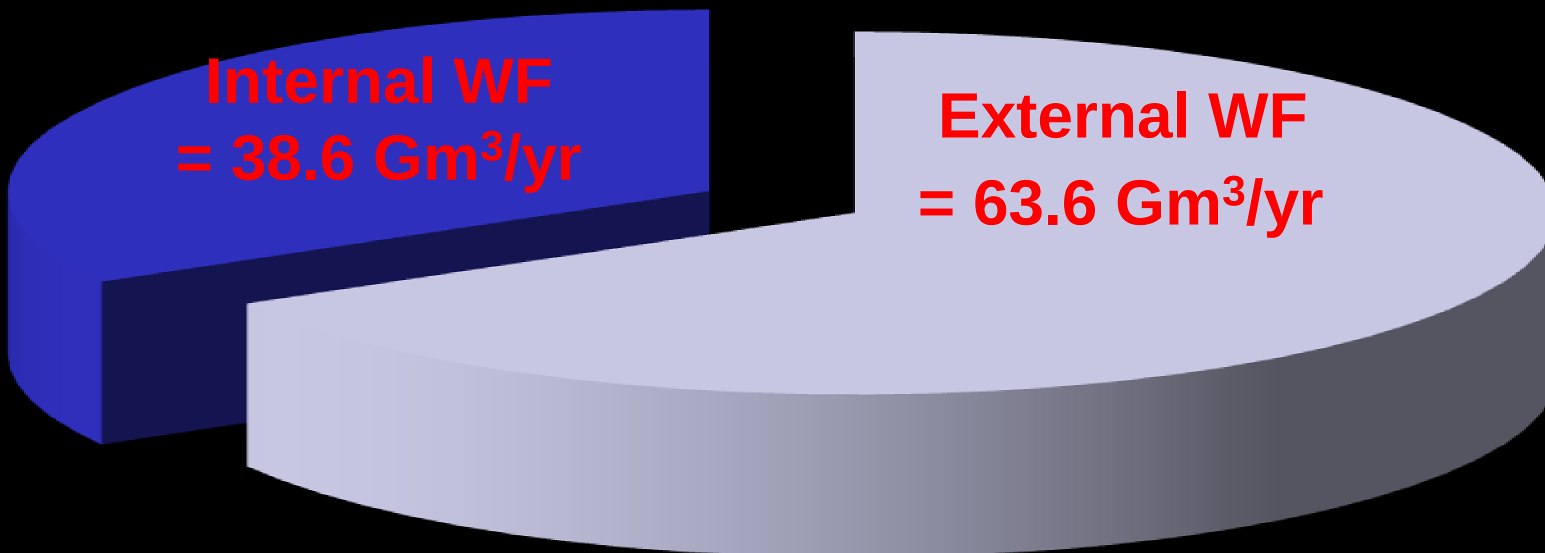
HRC Hydro-environmental Research Centre

Water Footprint of Nations



SOURCE: Hoekstra and Chapagain 2008

UK Water Footprint (WF)



Internal WF:-

Household = 3.3
Agriculture = 28.4
Industrial = 6.9

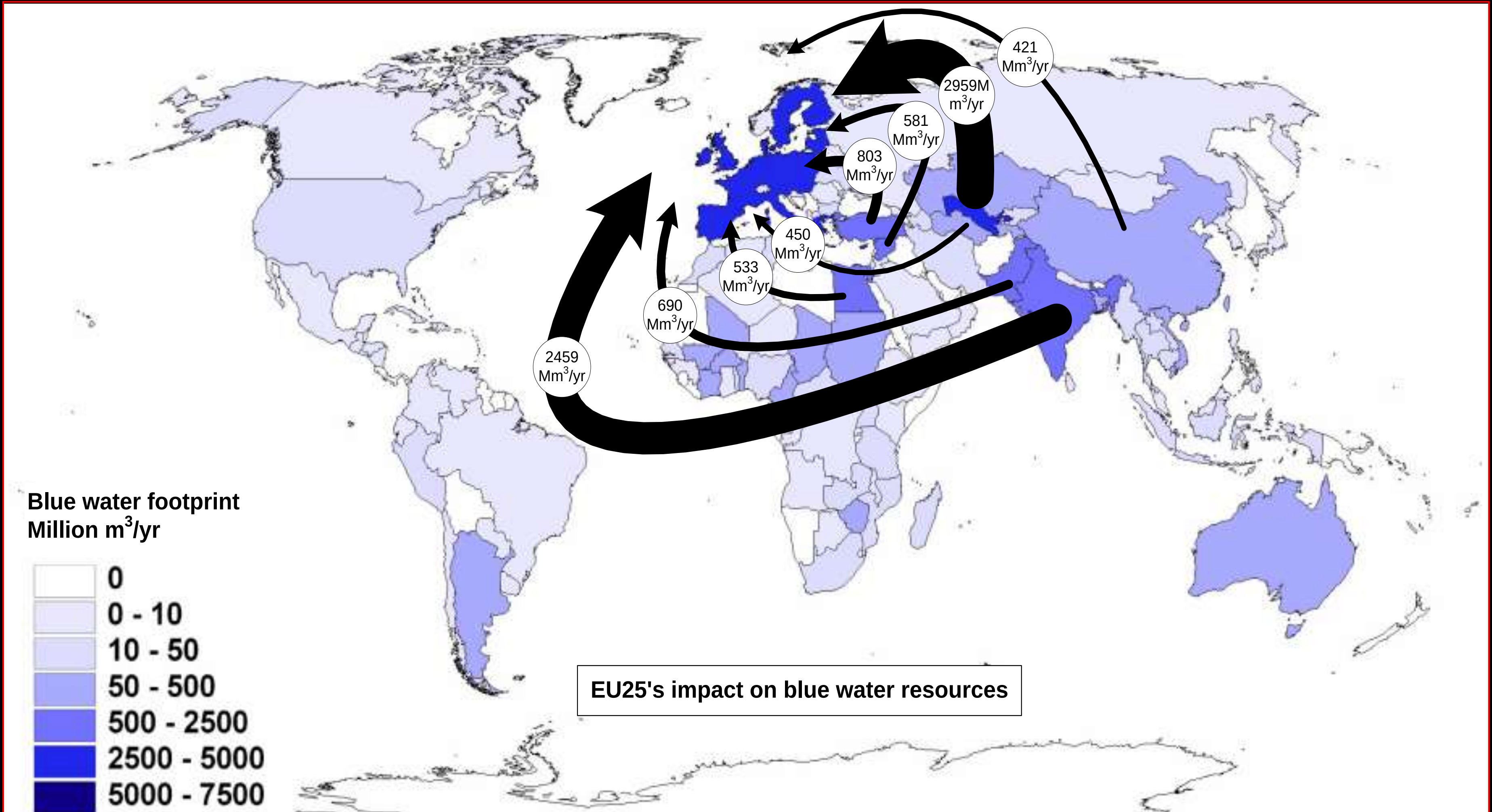
External WF:-

Household = 0.0
Agriculture = 46.4
Industrial = 17.2

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Blue WF of EU Cotton Consumption



SOURCE;Hoekstra & Chapagain, 2008]

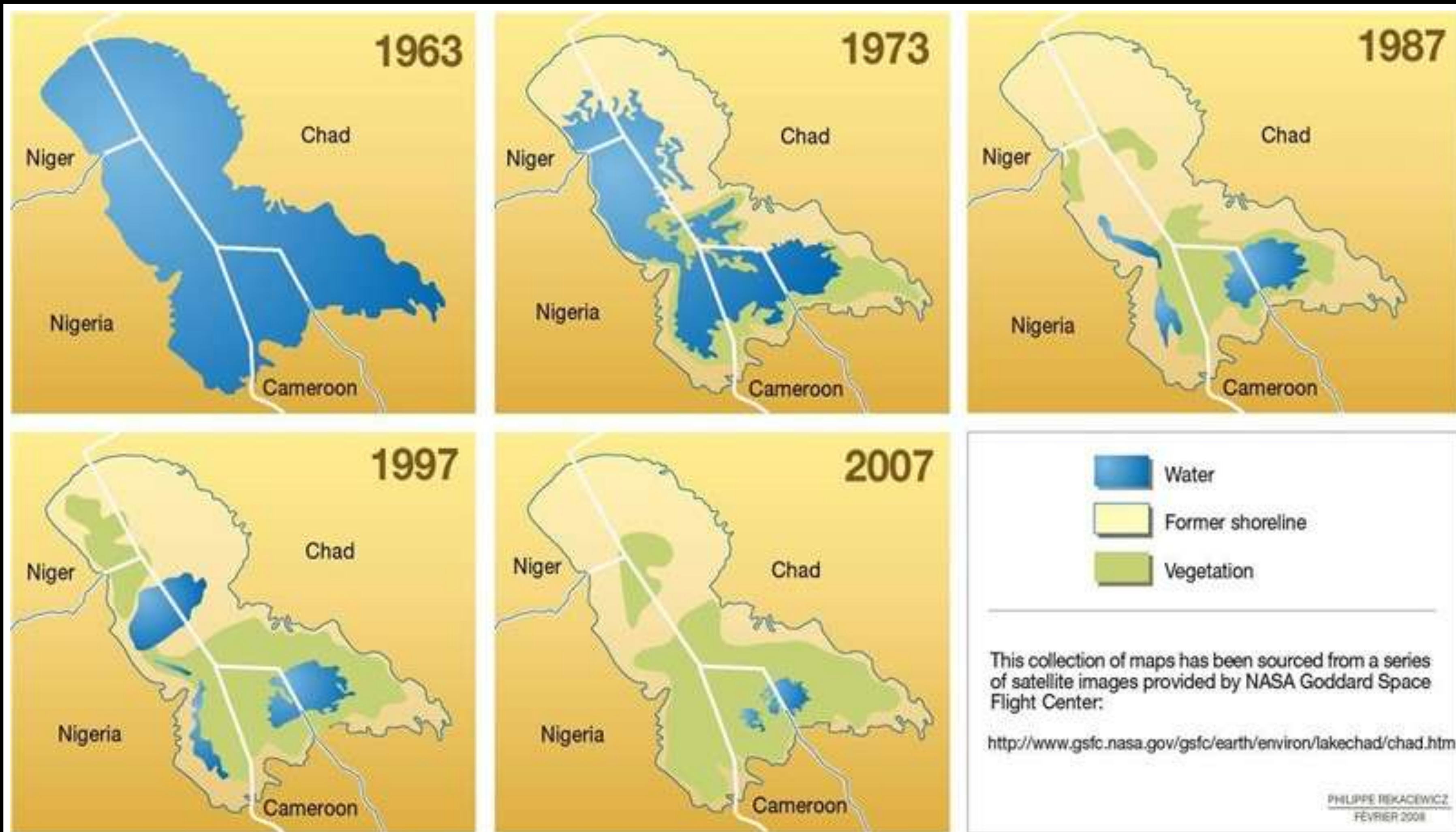
Impacts ⇨ Shrinking Aral Sea

Consumption in one place can impact drastically on water elsewhere

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Impacts ⇨ Shrinking Lake Chad



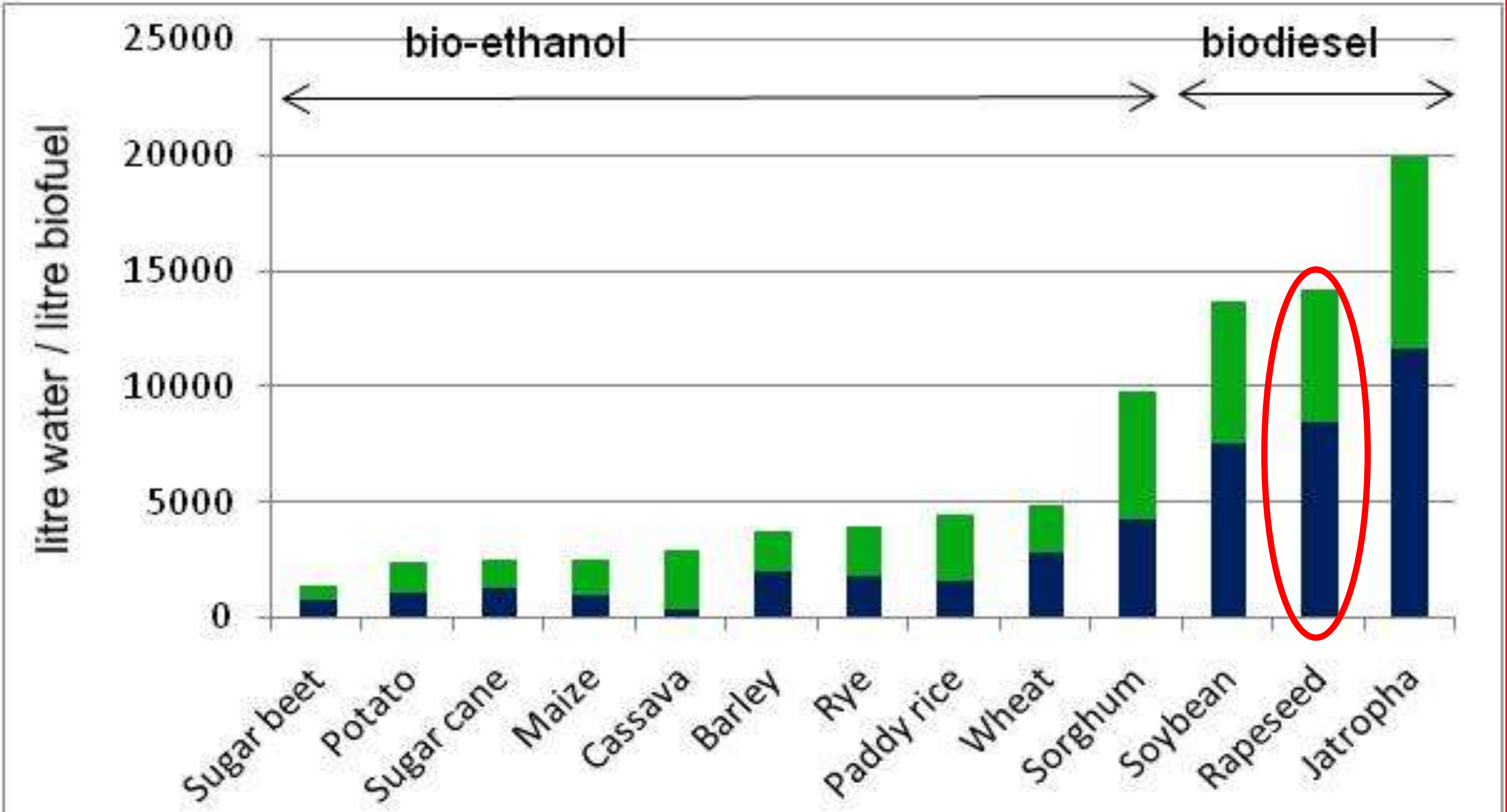
Impacts ⇨ Shrinking Lake Chad

- Large unsustainable irrigation projects
- Local climate change and local deforestation
- Resulting in:-
  - Lake area decreased by 95% since 1963
  - Crop failures
  - Livestock deaths
  - Collapsed fisheries
  - Increased poverty

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Water Footprint of Biofuels



Source: Gerbens-Leenes et al. National Academy of Sciences 2009

Public Education of Water Footprint

A typical football shirt made of Cotton ≈ 2,700 litres of water

Do football clubs need to change their shirt every 1-2 years?

This water could be used to grow food

What Price is Water (e.g. UK)?

$4.6 for 1m^3

(1 person's mean use per week or 150l/d)

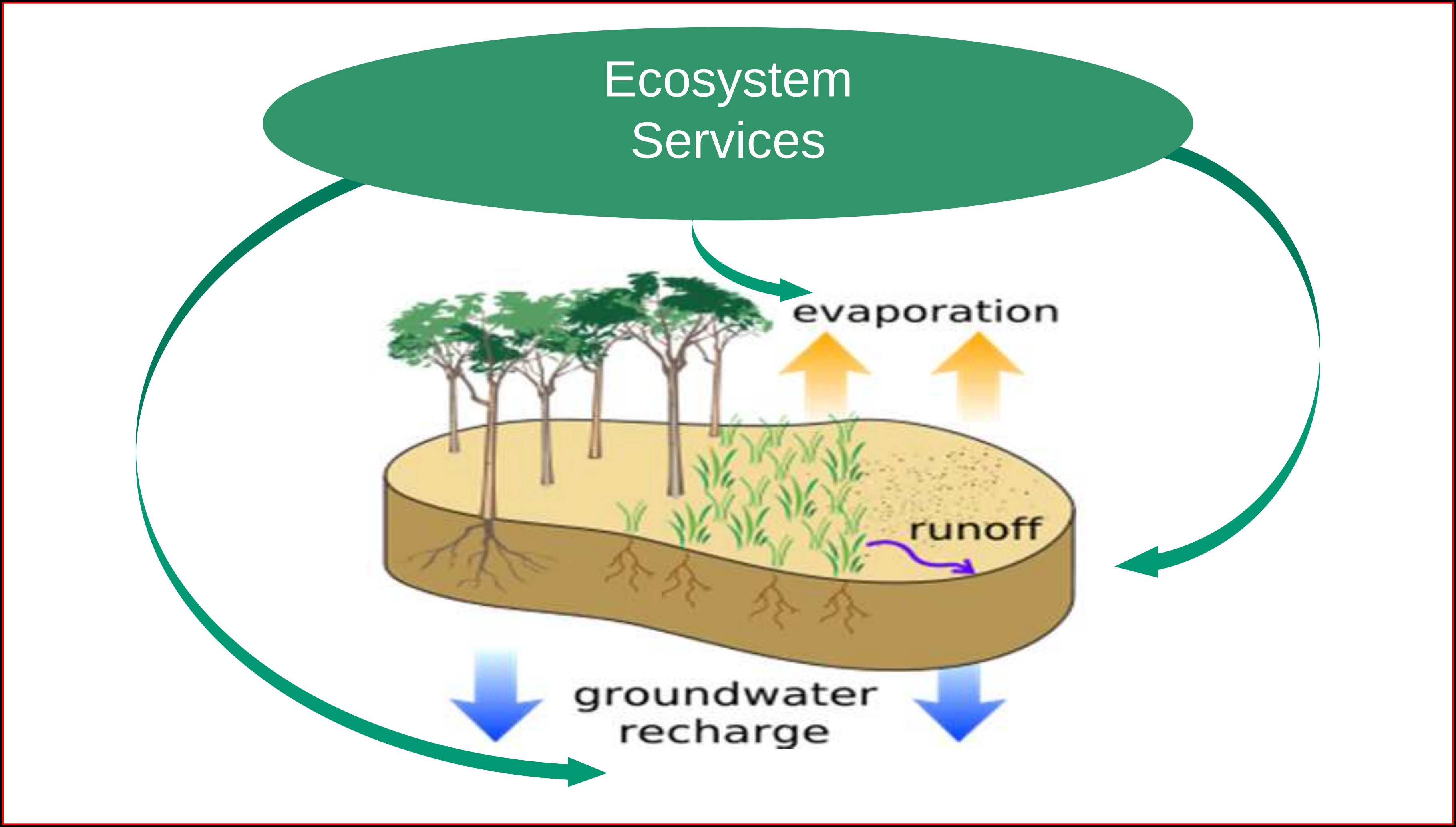
$3.80

$1.50

$3.80

$4.60

Recognising Eco-system Services



Eco-systems Services - Market

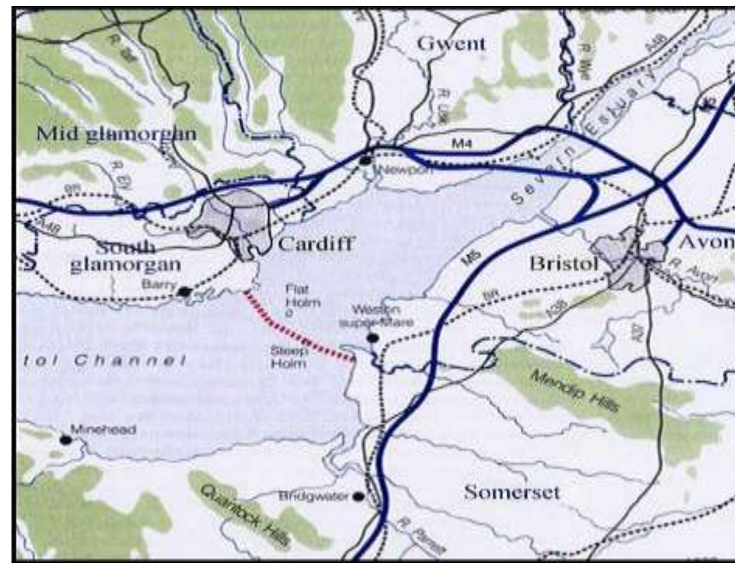
- Provisional services ⇨ controlling water quality and quantity for consumptive use
- Regulatory services ⇨ buffering for flood flows and provision of habitat services
- Cultural services ⇨ recreation and tourism
- Support services ⇨ nutrient cycling and eco-system resilience to adapt for climate change
- Conservation services ⇨ forests reduce GHG emissions significantly ⇨ estimated ≈ $3.7Tr

Eco-systems Services - Tidal Energy

- Methodological Approach (Arup):
  - Current market price for services such as:- Flood Risk Protection, Tourism, Recreation and Regeneration
  - Value:- Habitat Provision

Impoundment Area	116 km2
Potential Energy	1.91 TWh/yr (0-D)

Proposed Clwyd Tidal Impoundment



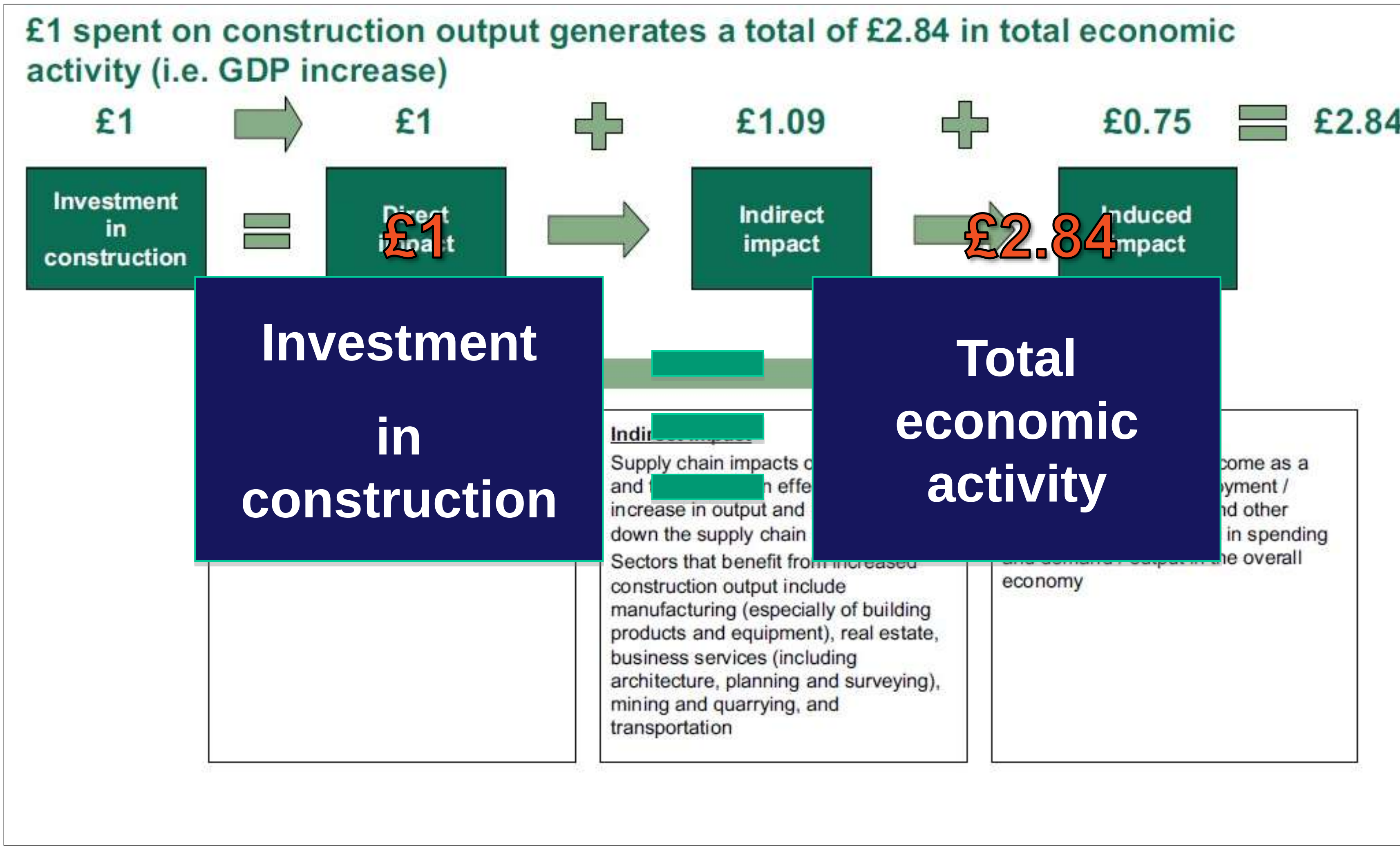
Impounded Area	500 km^2
Potential Energy	17 TWh/yr

Proposed Severn Barrage

PRIFYSGOL CAERDYDD

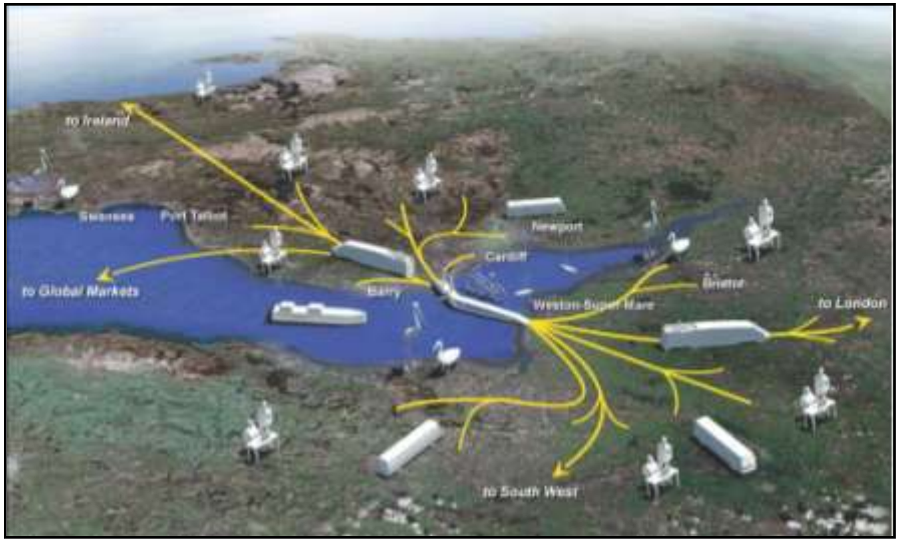
Hydro-environmental Research Centre

Tidal Range - Economic Opportunity



Tidal Range - Economic Evaluation

Tourism and Recreation – Severn Barrage and Clwyd Impoundment



Water sports

Tourism from a new landmark

Properties safeguarded from flooding

Habitats recreation

More secure tourism income and scope for developing

Potential as a dormitory town for North West England realised

Brings more money into area to strengthen and enhance local facilities

Ecosystem Service	Severn Barrage
Flood risk and land drainage	£219m benefit over 100 years
Habitat Provision	£34m-£104m cost over 120 years
Tourism and Recreation	£3m-£27m in annual GVA
Regeneration	£26.0bn capital cost with up to £47.8bn GVA over 8 years' construction period

Ecosystem Service	Clwyd Tidal Impoundment
Flood risk and land drainage	£2.45bn benefit over 100 years
Habitat Provision	Not assessed
Tourism and Recreation	£270m-£670m secured annual tourism spend
Regeneration	£3.5bn capital cost with up to £6.5bn GVA over 5 years' construction period

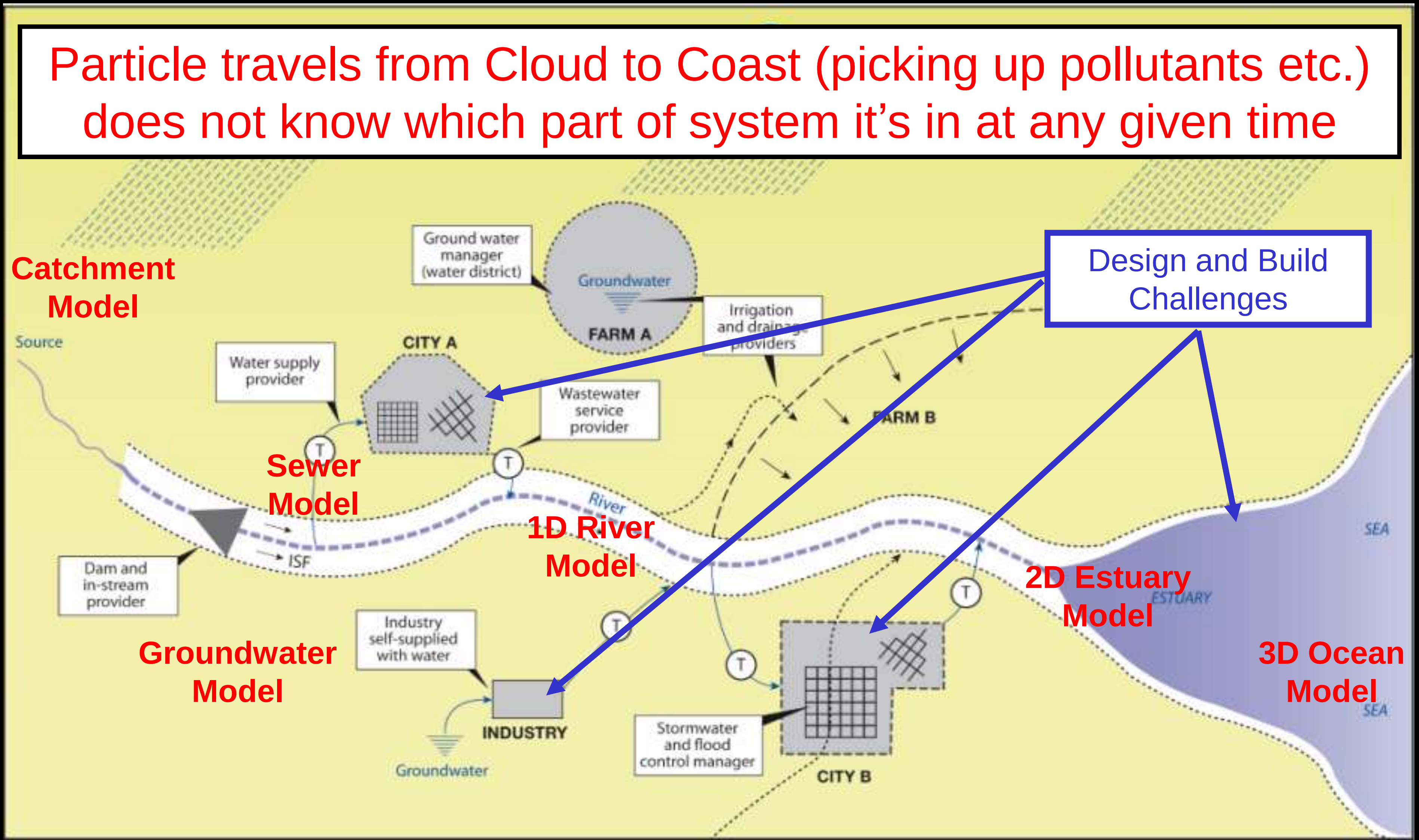
Solutions ⇨ Water Security

- Desalination ⇨ expensive, relatively large carbon footprint and hydro-environmental challenges
- Conservation and water re-use ⇨ to be encouraged but only deals with domestic consumption
- Storage, water transfer & integrated water resources management ⇨ needs more holistic solutions
- Improved water quality in pathways and basins ⇨ pollution exacerbates water security
- Global population growth ⇨ needs addressing

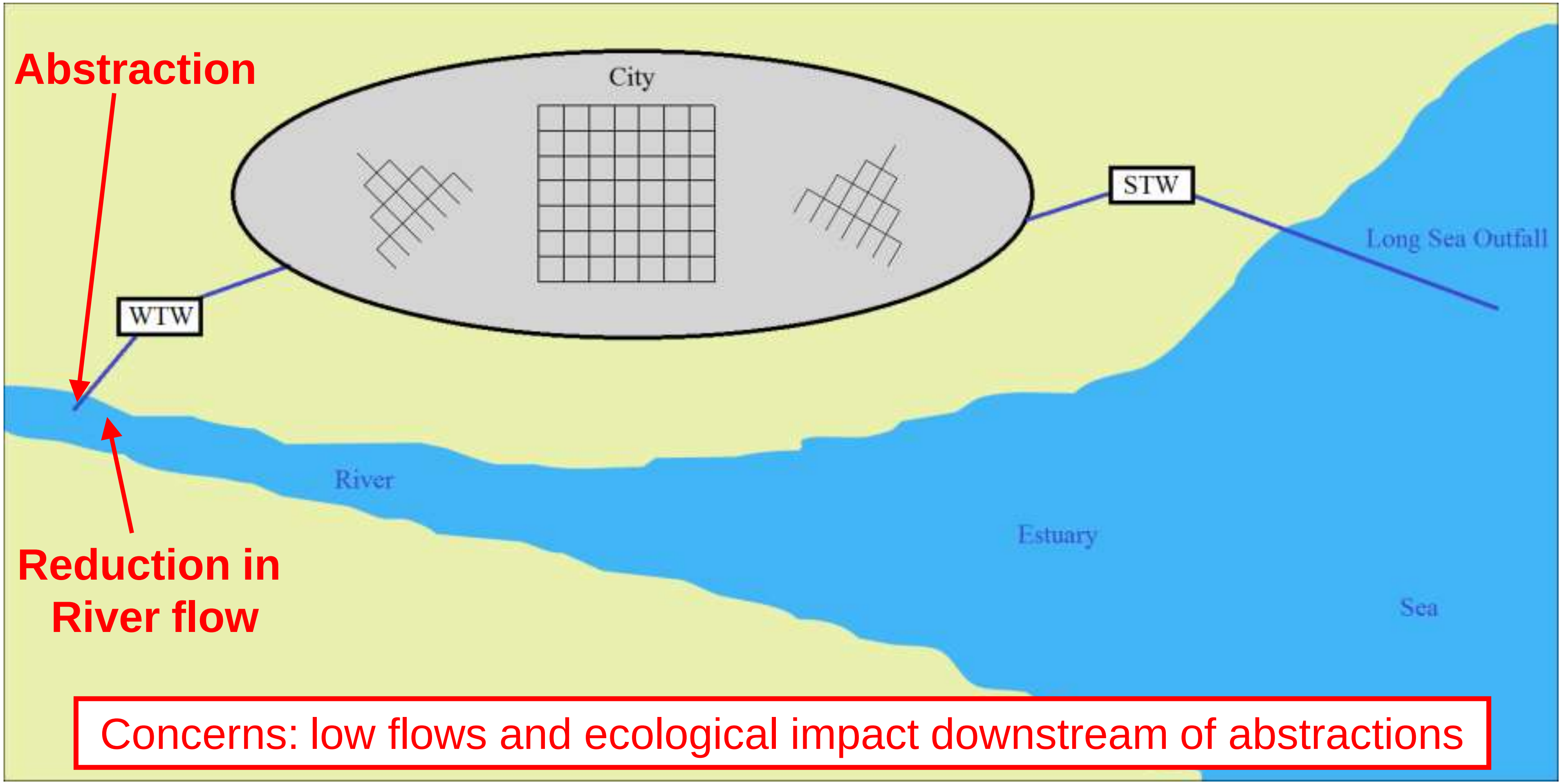
CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Cloud to Coast - IWRM Solutions

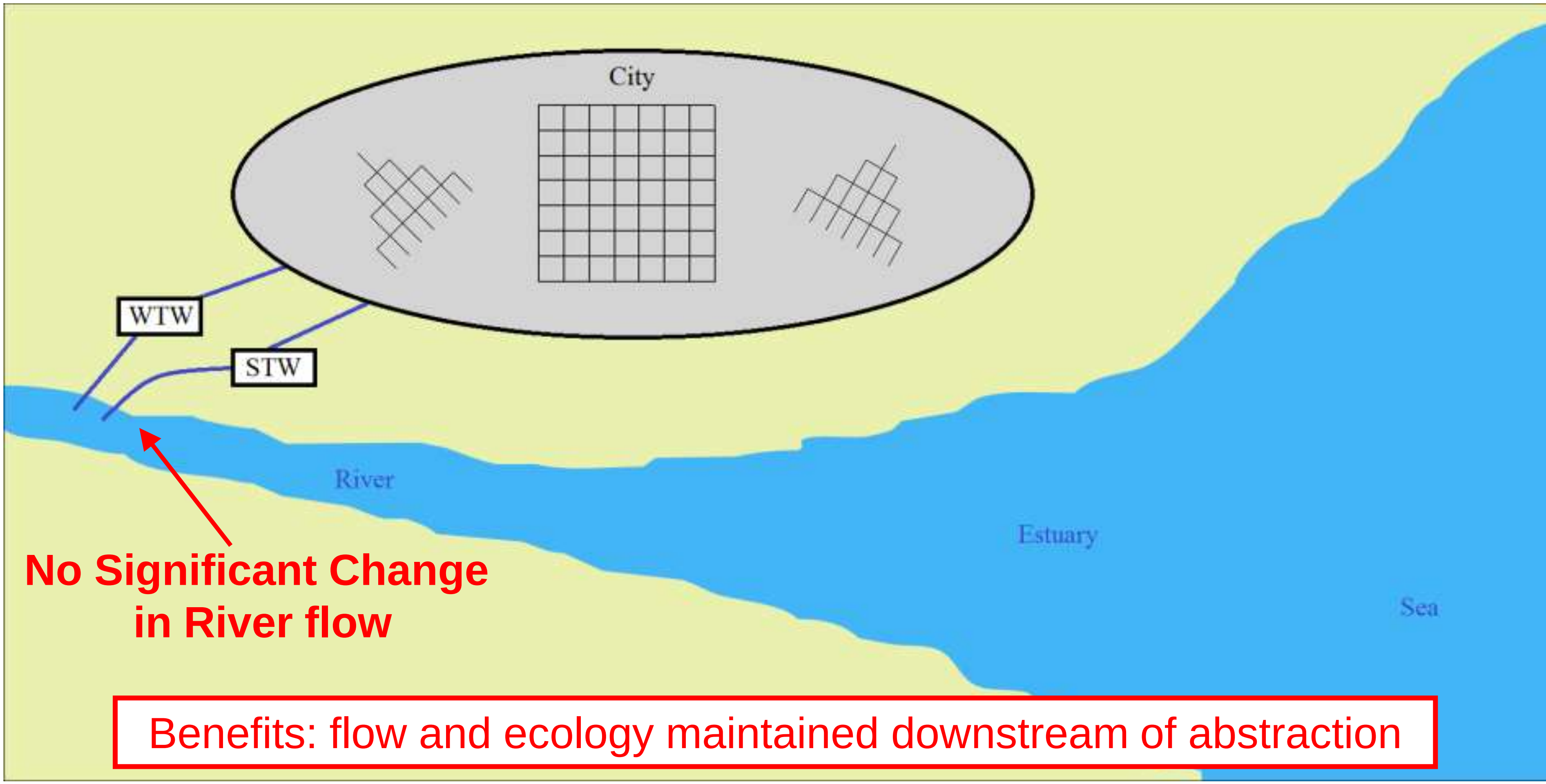


Traditional System Layout



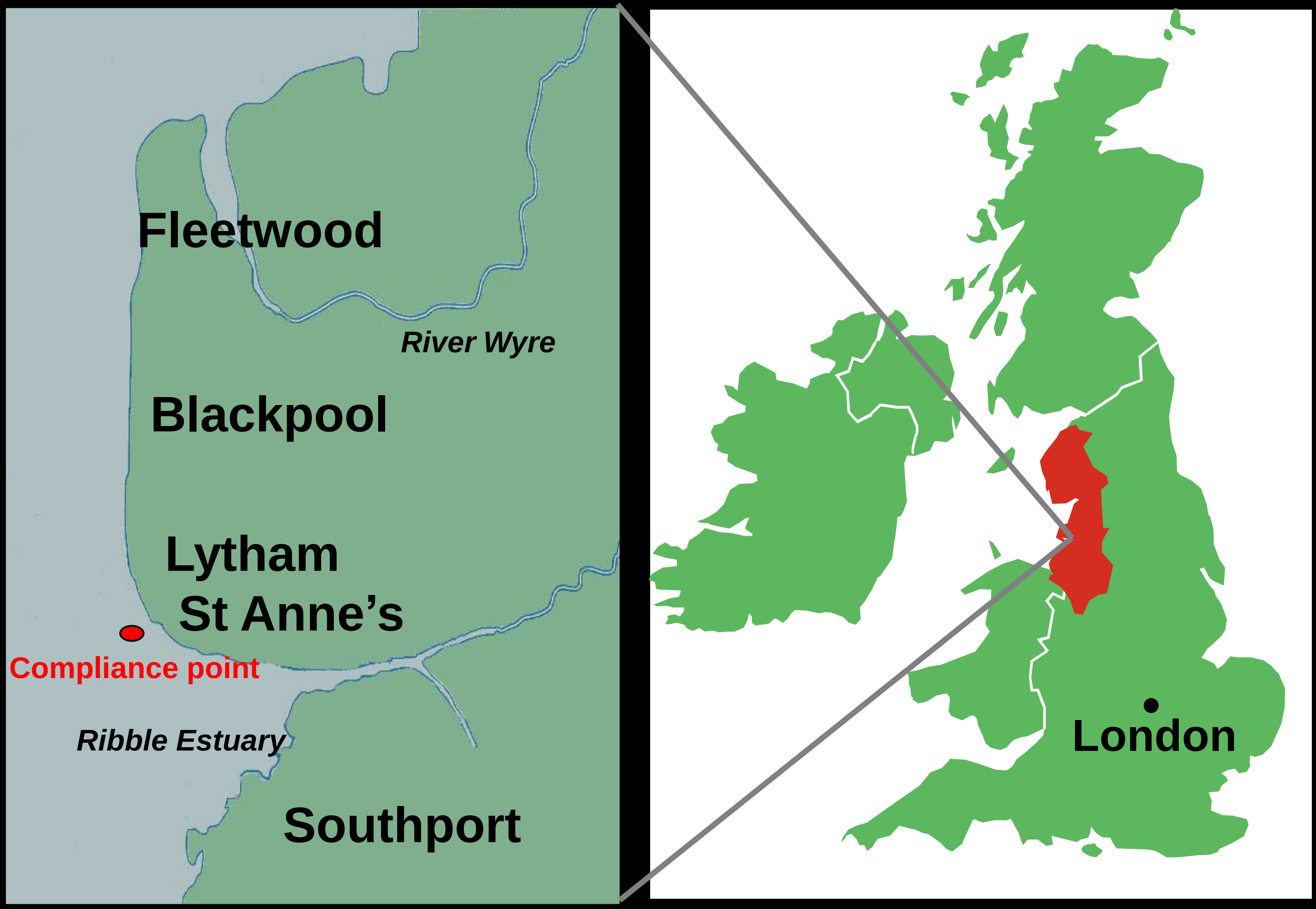
Concerns: low flows and ecological impact downstream of abstractions

Preferred System Layout



Benefits: flow and ecology maintained downstream of abstraction

Fylde Coast - Ribble Estuary, U.K.

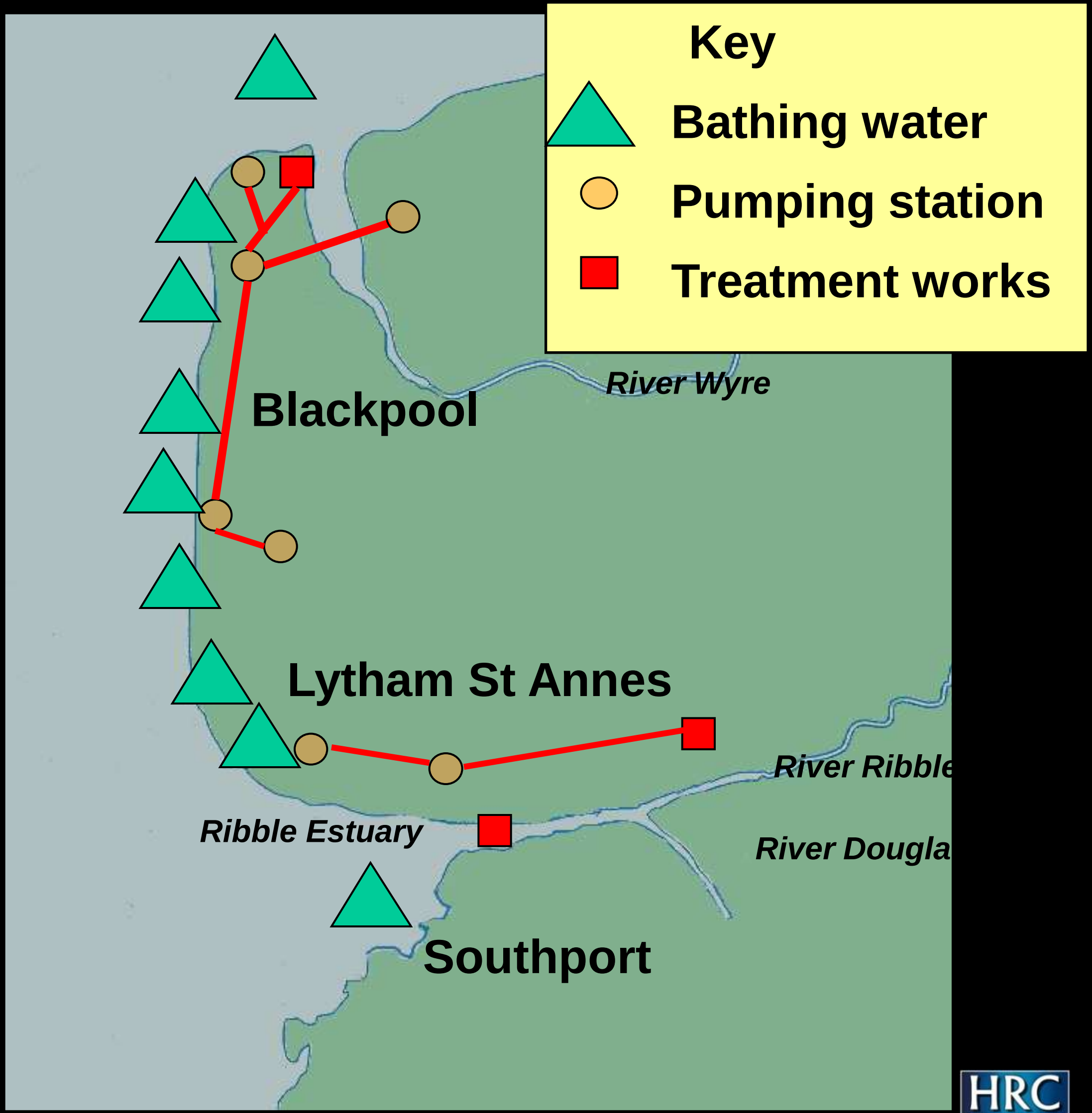


Background

- Failure to meet EU Bathing Water standards
- Storm sewers and sewage works discharging along coast thought to be main problem
- Combined storm water and sewer overflows discharge into water courses and rivers
- Field surveys undertaken to establish inputs and failure levels at compliance points
  - Surveys unable to provide definitive conclusions
  - Data could not allow for impact of future proposed capital improvements to works to be assessed

Water Assets

- $800 million invested from 1993 – 1996
- 3 major sewage treatment works
- 5 pumping stations with storm outfalls along coast



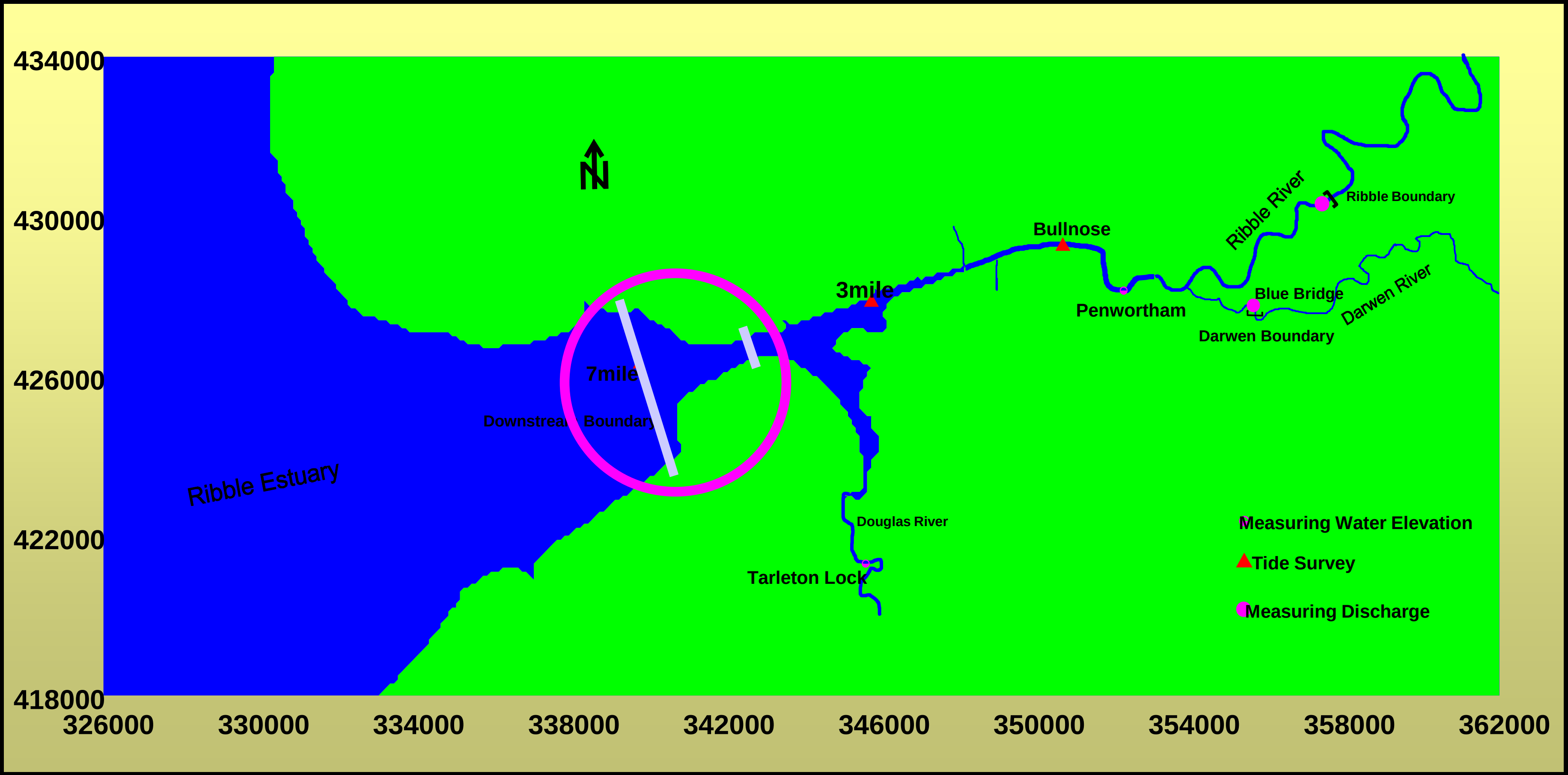
Objectives

- Refine HRC hydro-environmental modelling tools
- Quantify impact of sewage inputs into Ribble basin on coastal bathing water quality
- Investigate influence of various parameters such as wind, tidal range, river discharge, etc
- Allow for continuous and intermittent inputs
- Incorporate land use changes and diffuse source inputs as boundary fluxes when data available
- Propose management strategies for basin

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

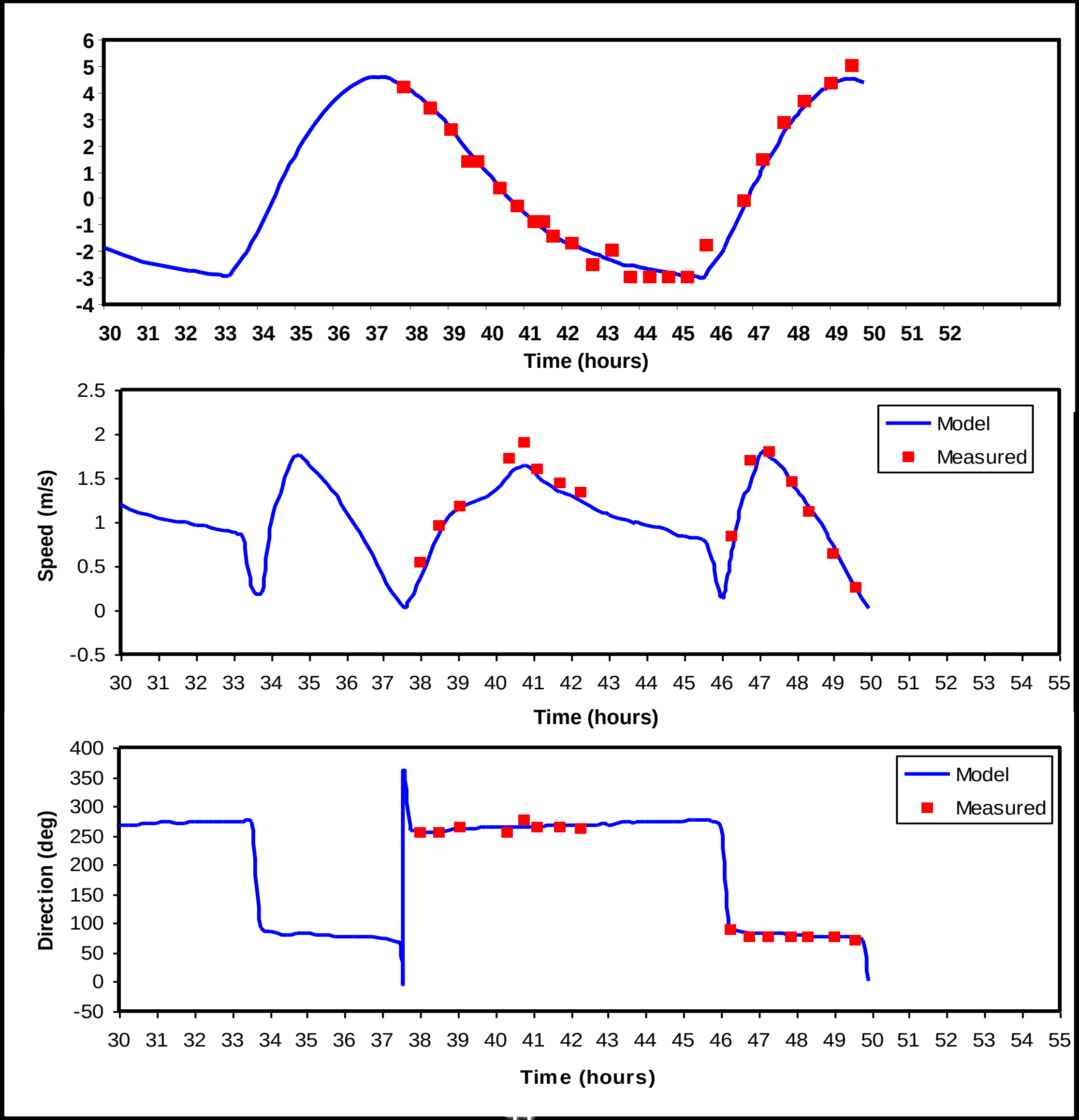
Linked 2-D and 1-D Models



Current Calibration

11 Milepost

3/12/98



E_{max}=4.7%

E_{min}=1.9%

E_{max}=13.0%

E_{min}=9.7%

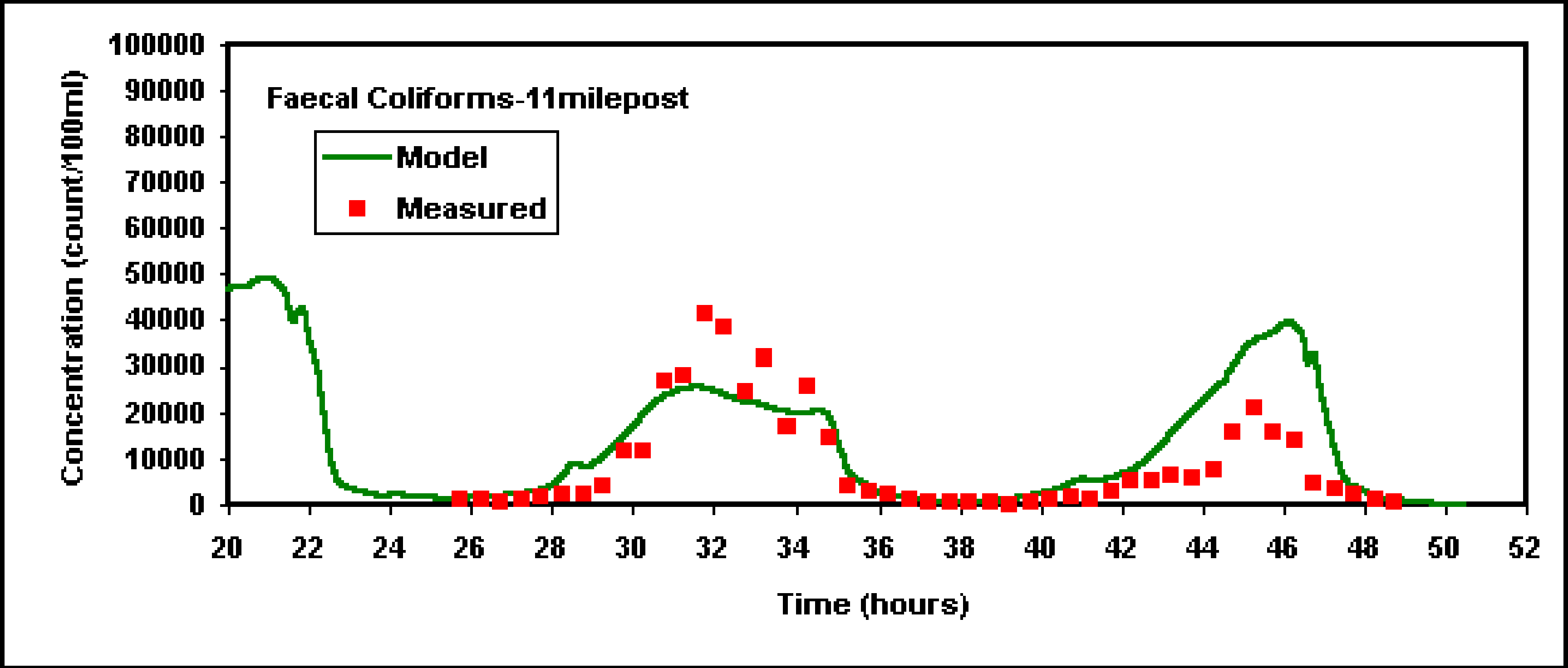
E_{min}=2.2%

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Ribble Estuary

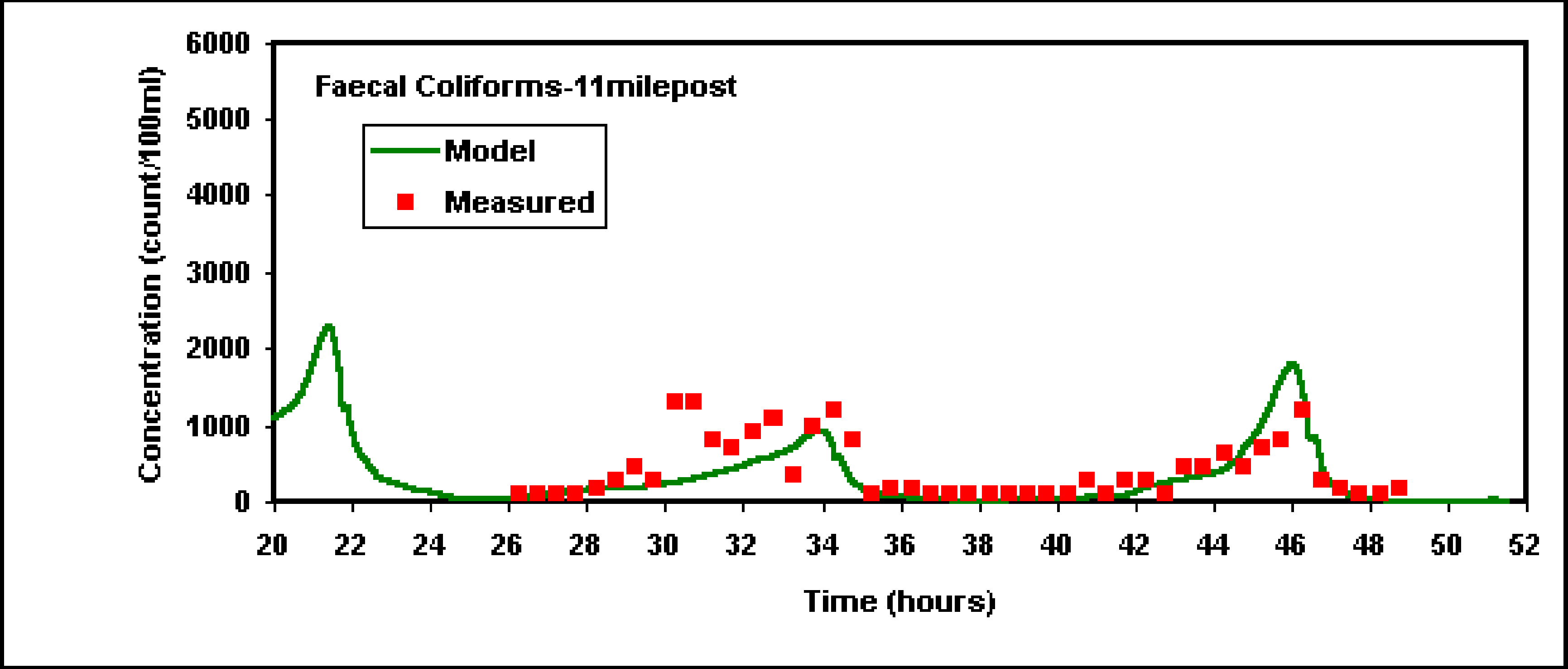
Model Calibration
11 milepost



11 May 1999 Wet Weather Neap Tide

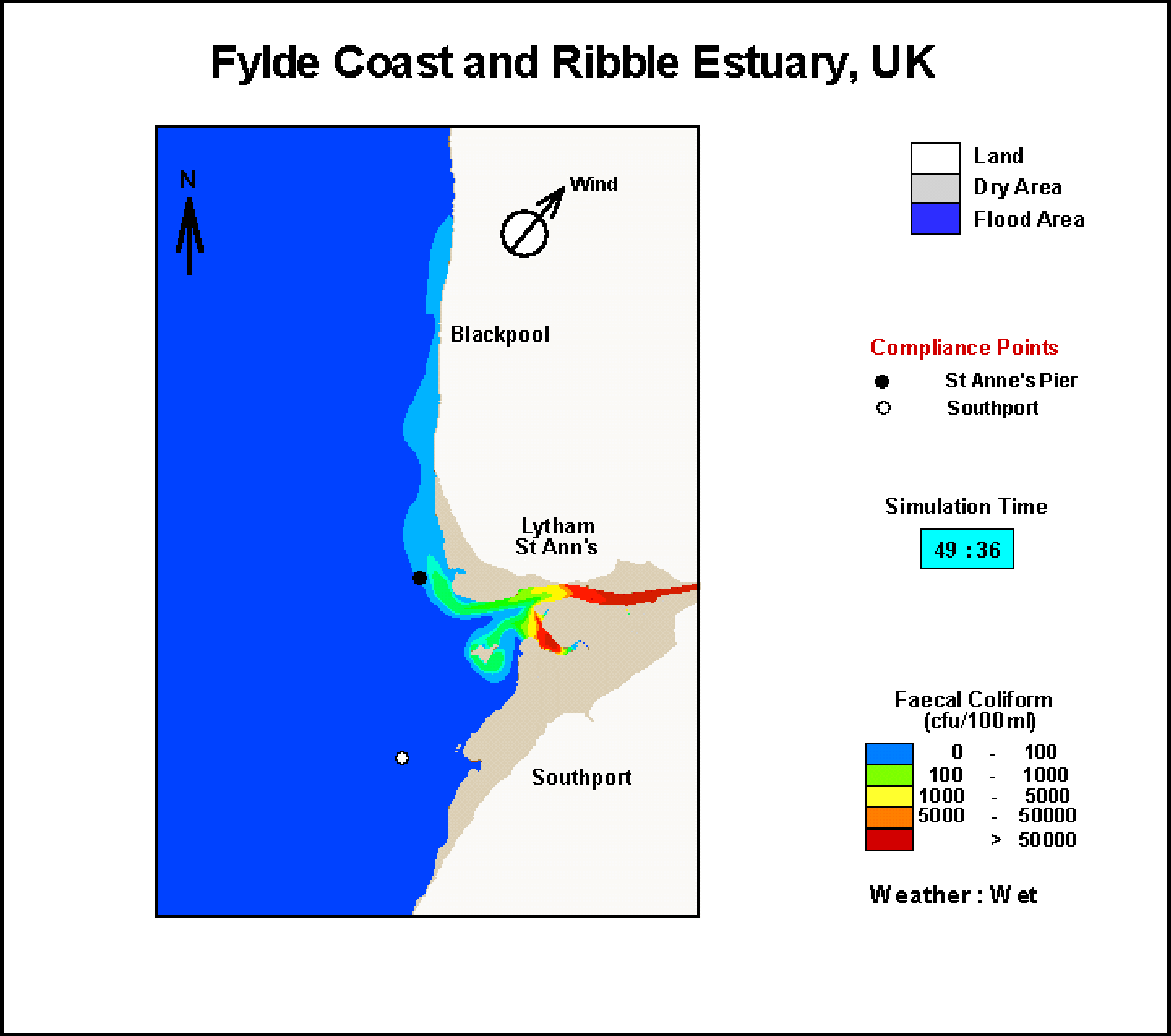
Ribble Estuary

Model Calibration
11 milepost



19 May 1999 Dry Weather Spring Tide

Coliform Predictions

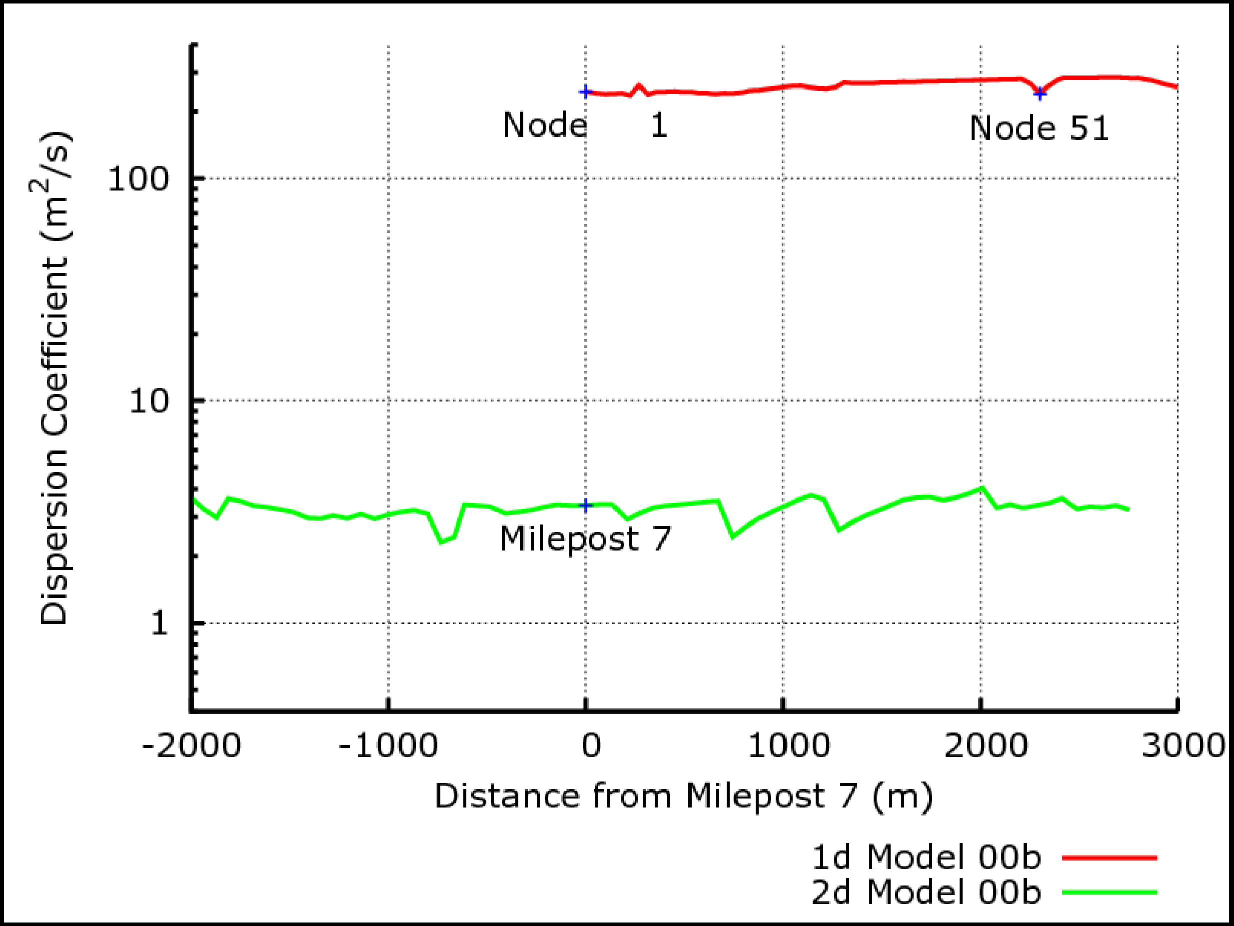


Review of Previous Study

- Previous study undertaken at HRC Cardiff gave good calibration agreement separately for 1-D and 2-D models before linking, but needed:
  - Different values of decay rates
  - Different values of dispersion coefficients
  - Different flow area representations over linked region
  - Different values and formulations for roughness coefficients in 1-D (k_s) and 2-D (n) models
  - Simplified treatment of kinetic decay and source inputs for stochastic inputs from discharges

Overview of Previous Study

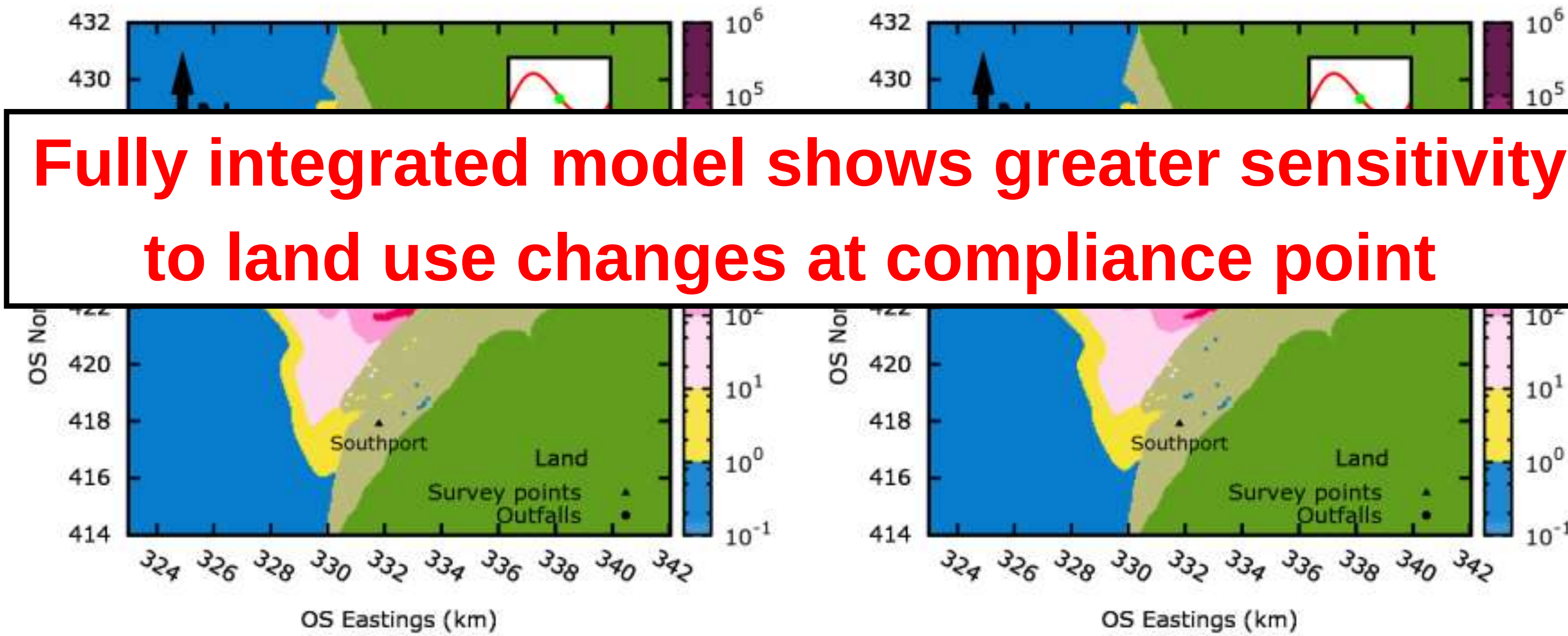
- Observations made between 1-D & 2-D parts of linked model ➪ Different dispersion coefficients



C2C: Common Dispersion

- 1-D / 2-D longitudinal dispersion (Preston 1985):

Distribution FIO Levels at Mid Ebb Tide



Fully integrated model shows greater sensitivity to land use changes at compliance point

(a) Old Model　　**(b) Common Dispersion**

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

General Challenges

- Security of clean water supply will become an increasing challenge over next 30-50 years
- Increasing concern about water quality in rivers, estuaries and coastal basins world-wide
- Traditionally water engineers and scientists have focused emphasis on flow and gross water quality
- Increasing emphasis now needs to be focused on improving bio-geochemistry and health risk in hydro-epidemiological impact assessment tools

Conclusions ⇨ General

- Intensify debate around fundamental role of water
- Better understand levers to close supply-demand gap
- Government, private sector and communities must better harmonise their aspirations for water use
- Correlate countries hydrologically best suited to grow food for 9 bn people by addressing trade barriers, price supports and other subsidies
- Water professionals need to stand up and be counted and get out of the box

Conclusions ⇨ Hydroscience

- Need better tools for weather modelling, precipitation prediction and better data to understand processes
- Need new tools for improved process representation in design of water supply and treatment works
- Need better monitoring strategies for highly episodic events, both for flow and epidemiological data etc.
- Need new hydroinformatics tools for more efficient use of water for agriculture ⇨ more ‘crop per drop’
- Hydroscience tools ⇨ driver for global water security

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

HRC Hydro-environmental Research Centre

Thank You

Professor Roger A. Falconer
Email: FalconerRA@cf.ac.uk