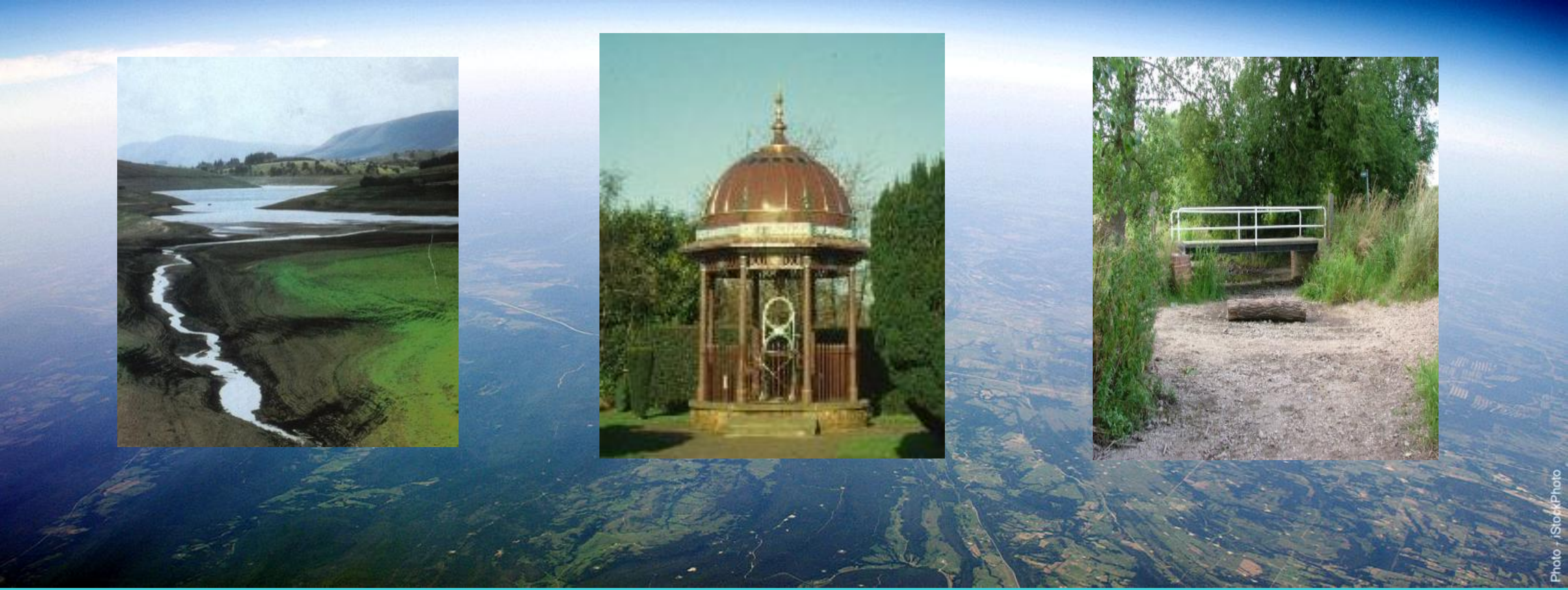

Spatial and temporal relationships between the surface and groundwater manifestations of drought

Terry Marsh
Centre for Ecology & Hydrology

Drought – how resilient are we? BGS Keyworth, June 13th 2012

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Outline

- Background – heterogeneity of the UK
- Examples of temporal contrasts in SW and GW impacts during recent droughts
- Winter rainfall and groundwater stress
- Major contemporary and historical groundwater droughts – focus on the Chalk
- Trends in groundwater recharge and runoff
- Groundwater abstraction and environmental stress
- Water resources management: the SW and GW balance

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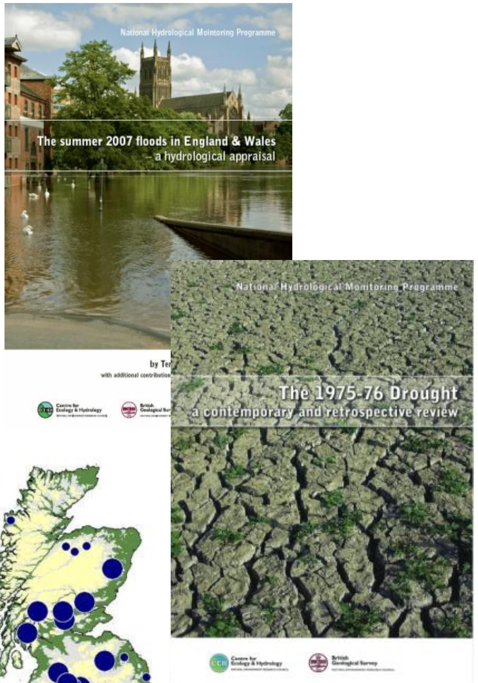
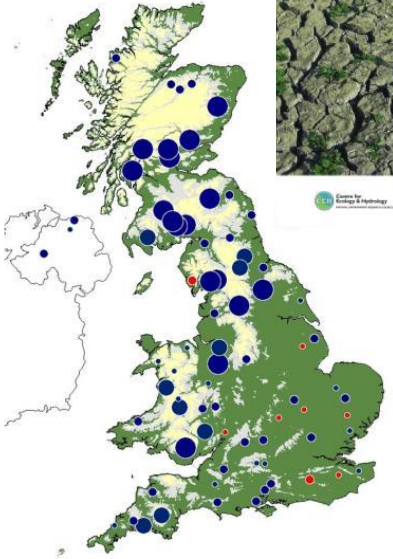
The National Hydrological Monitoring Programme

- Capitalises on the National River Flow Archive (CEH) & National Groundwater Level Archive (BGS)
- In partnership with UK measuring authorities
- Monitor and document hydrological variability across the UK
- Identify and interpret hydrological trends
- Provide guidance and advice to a wide range of stakeholders
- 'Water Watch' Web site: http://www.nwl.ac.uk/ih/nrfa/index.htm





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Environment Agency

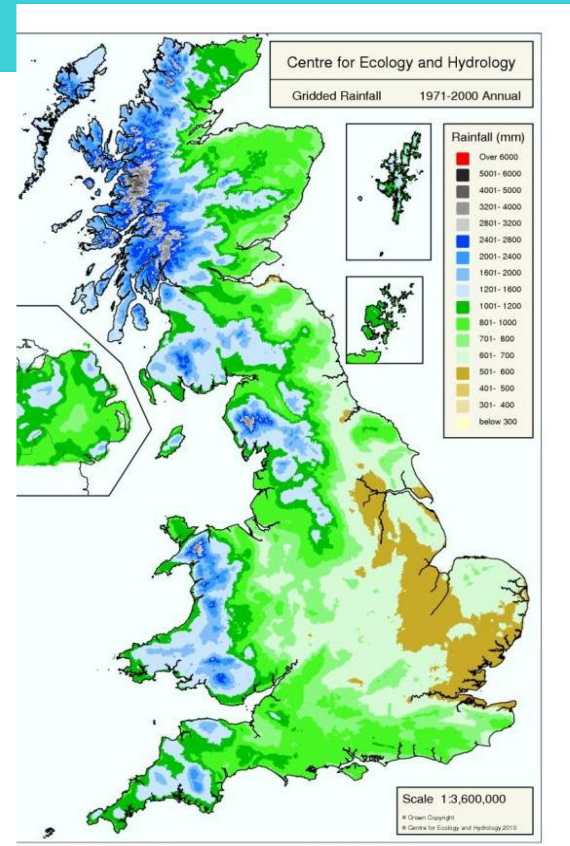
SEPA
Scottish Environment Protection Agency

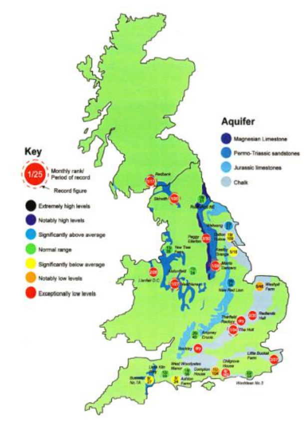
RIVERS Agency

Met Office

Heterogeneity of the UK

- One of the wettest countries in Europe
- Average rainfall varies by an order of magnitude across the UK
- Rainfall is well distributed through the year but evaporation losses, river flows, groundwater levels and reservoir stocks exhibit large seasonal contrasts
- Groundwater is most important in the driest parts of the UK – coincides with the highest water demand
- Major aquifers are mostly in England - minor aquifers are of local importance
- Groundwater sustains river flows and wetlands – increasing ecological and amenity importance





Groundwater levels - October 1997

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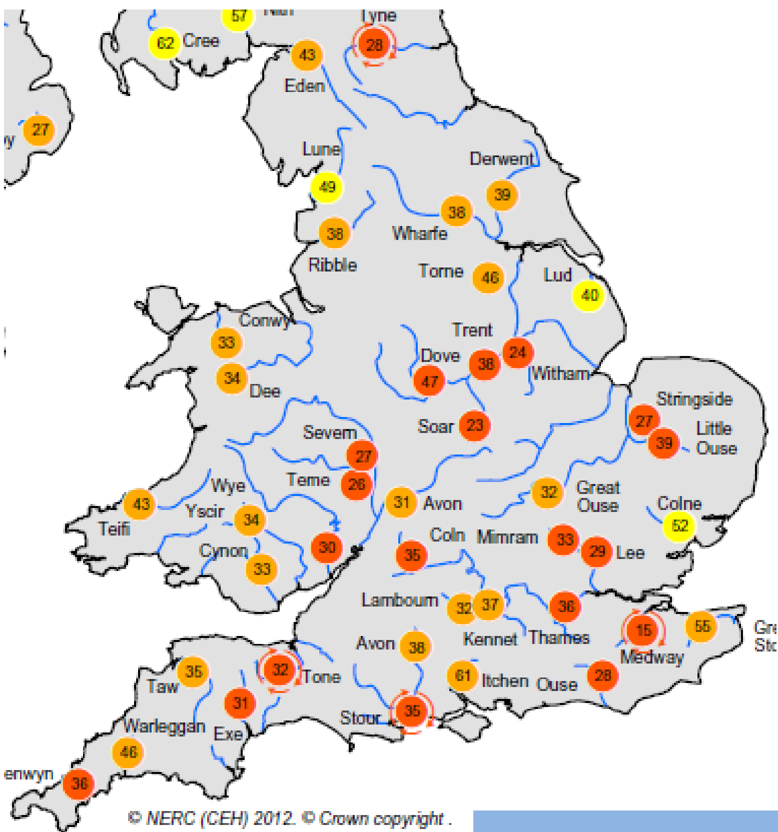
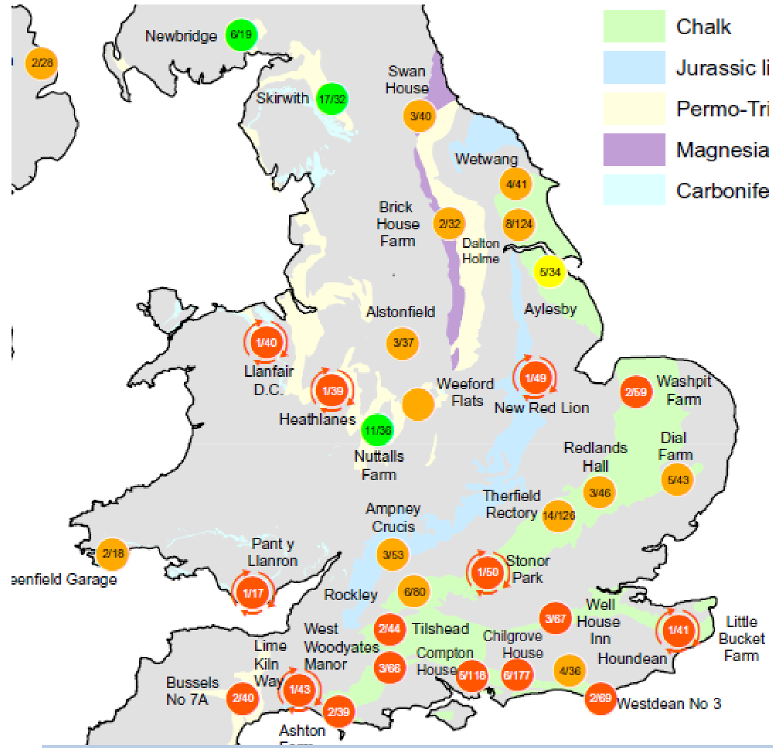
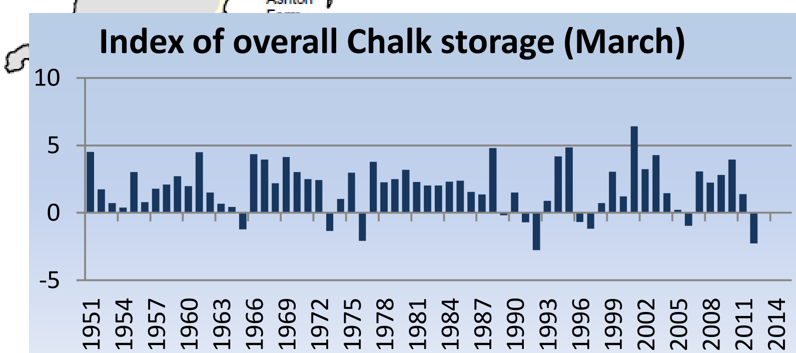
Synchronous runoff & groundwater stress

March 2012



River Flow





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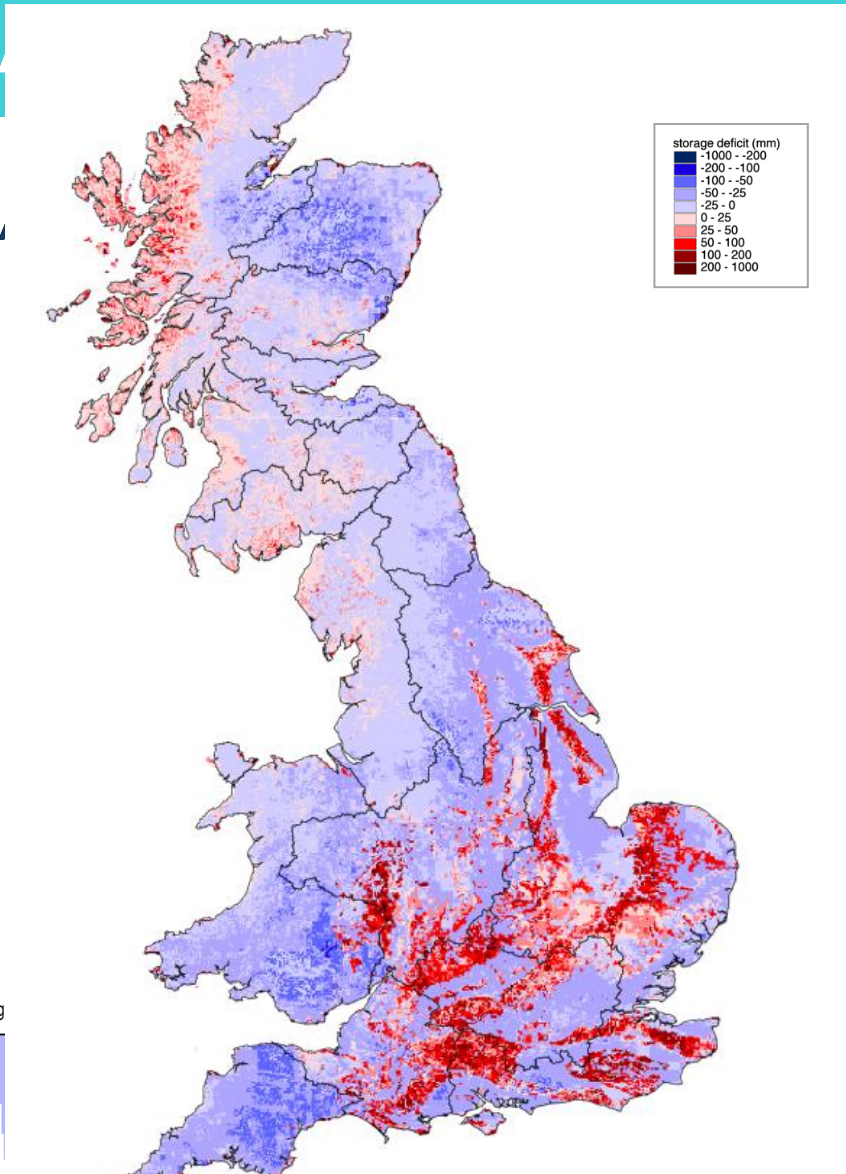
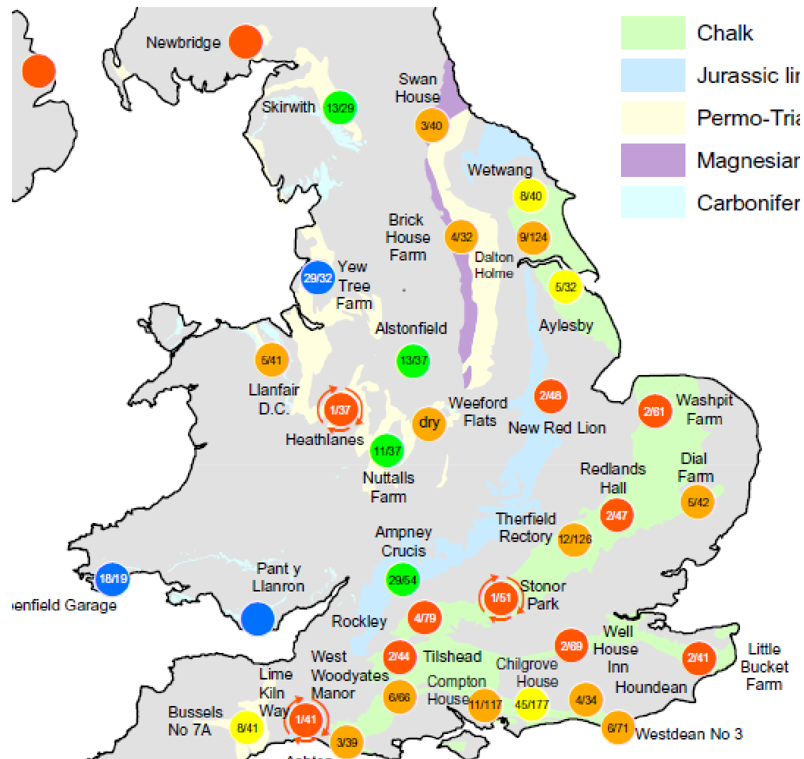
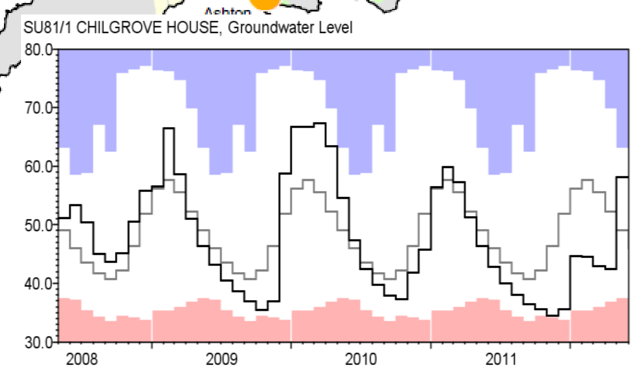


Grid to Grid sub-surface storage Index – end of April 2012

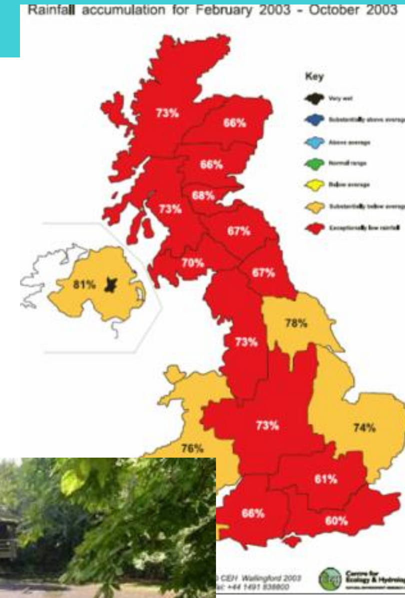
Groundwater

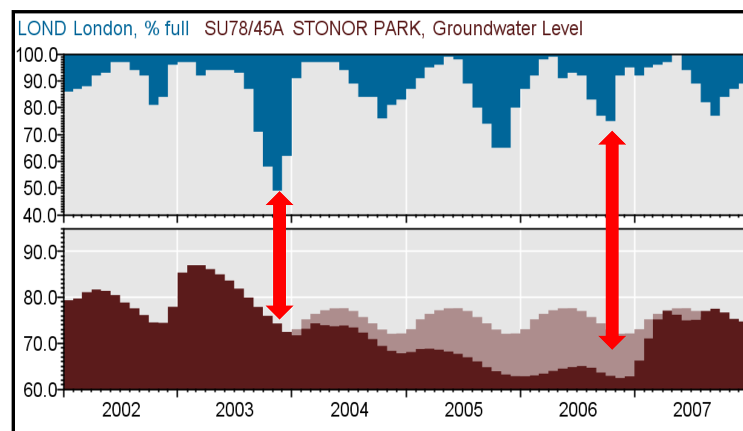




South East England 2003-07

- 2003: 2nd driest Feb-Oct for Thames basin in 128-yr series
- Warmest summer for E&W in a series from 1659 – exceptional evaporative demand
- No water supply restrictions in Thames basin
- But heralded a further drought phase: 2004-06
- 13 million consumers affected by hosepipe bans
- Restrictions on spray irrigation
- Substantial water resources and ecological stress





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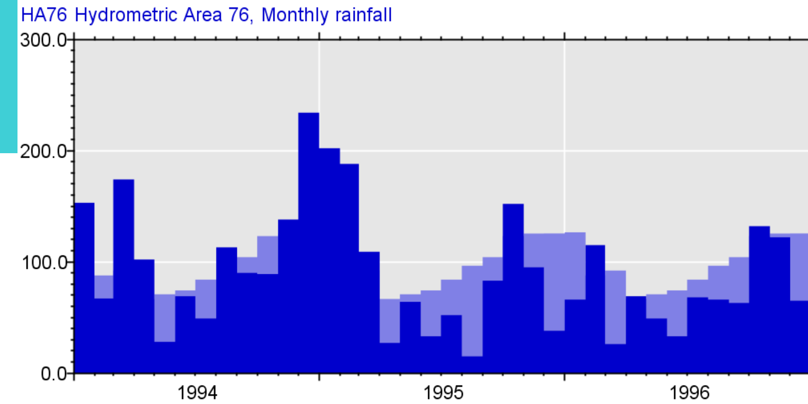
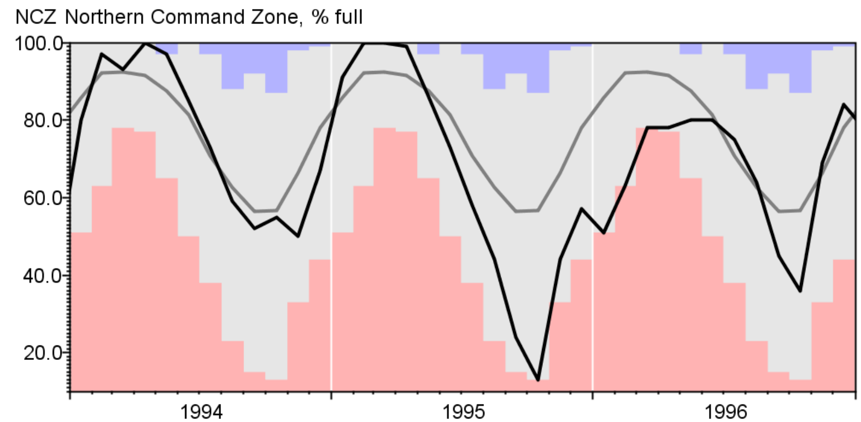
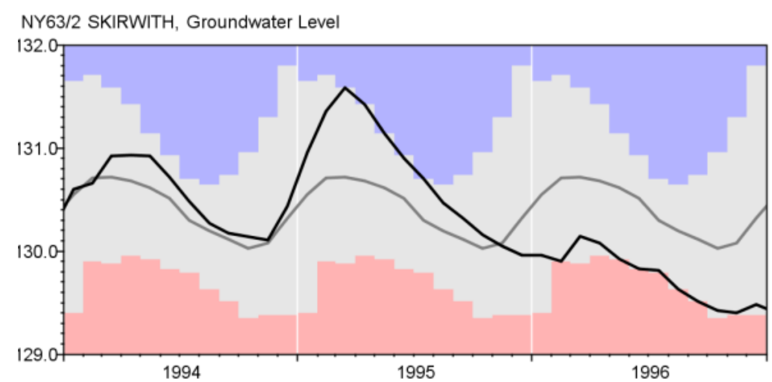
NW England 1995-97



- Intense rainfall deficiency in 1995. Driest (by a wide margin) April-Sept in 50 yr 76/7 series
- Severe surface water resources stress
- But groundwater levels above average throughout the year.
- However, groundwater levels depressed throughout1996





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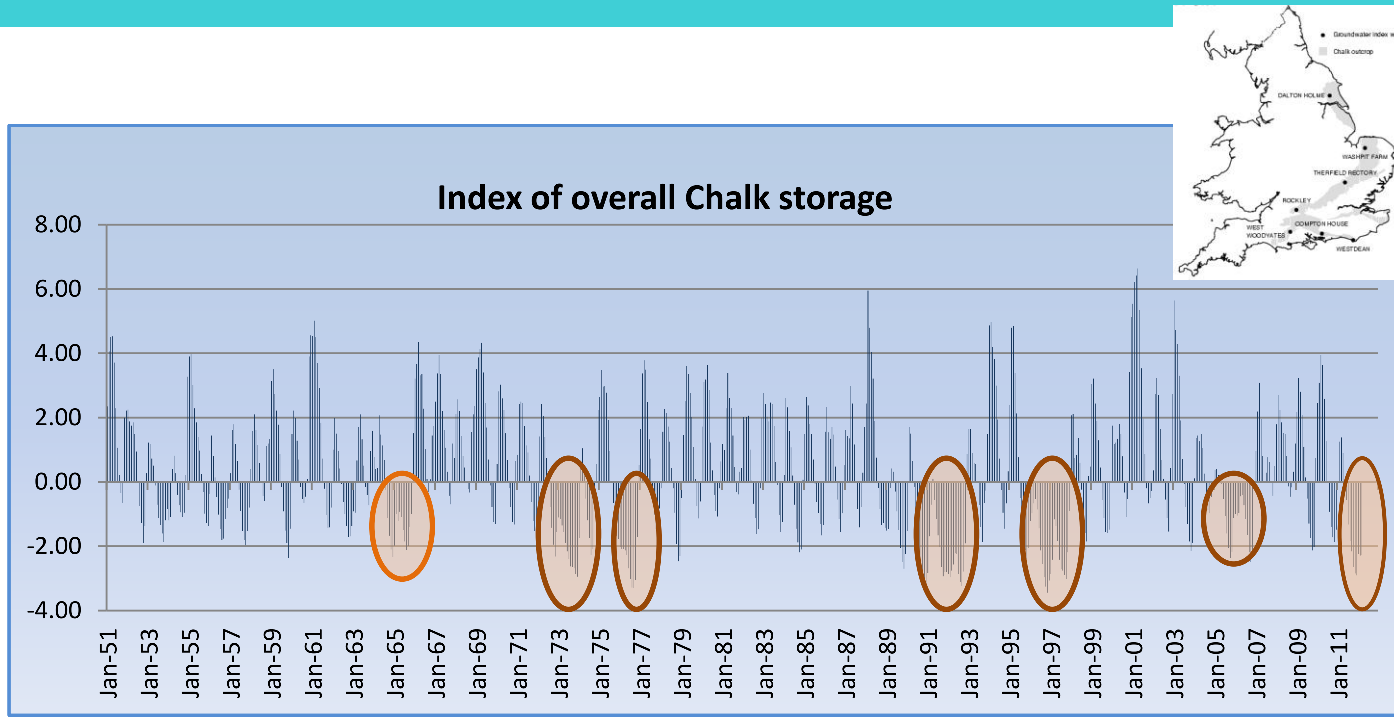
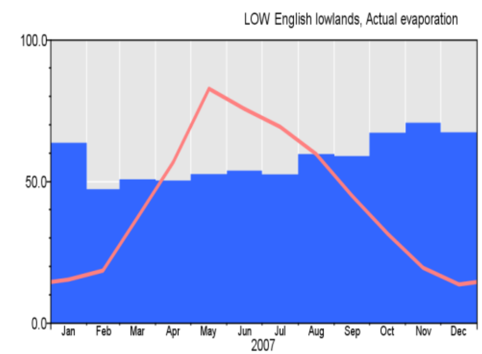
Major groundwater droughts in the Chalk 1951-2012

- 7 notable episodes

- 2010-12
- 2004-06
- 1995-97
- 1990-92
- 1975-76
- 1972-74
- 1963-65



Most groundwater droughts are associated with two or more successive dry winters



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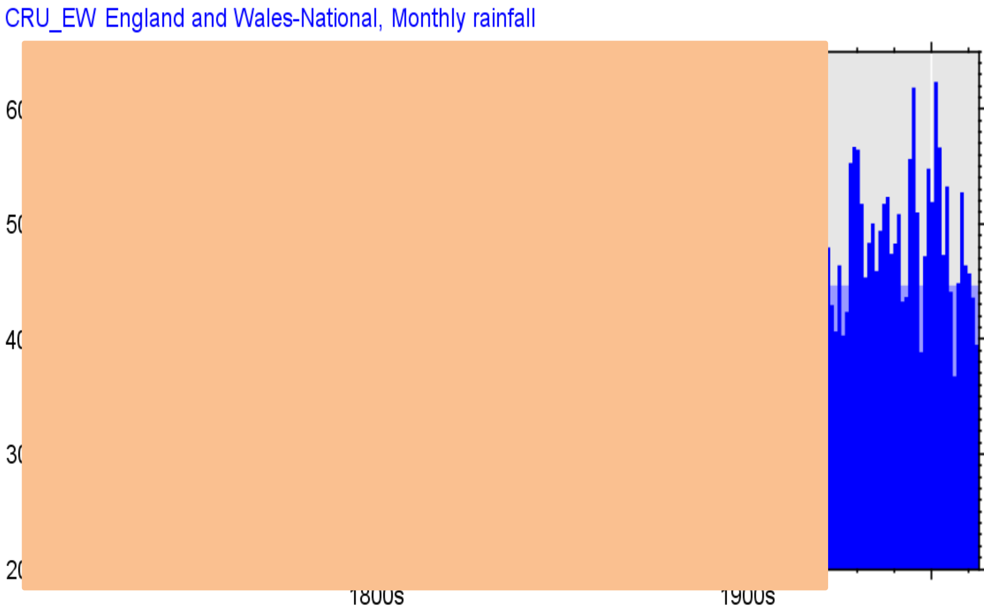
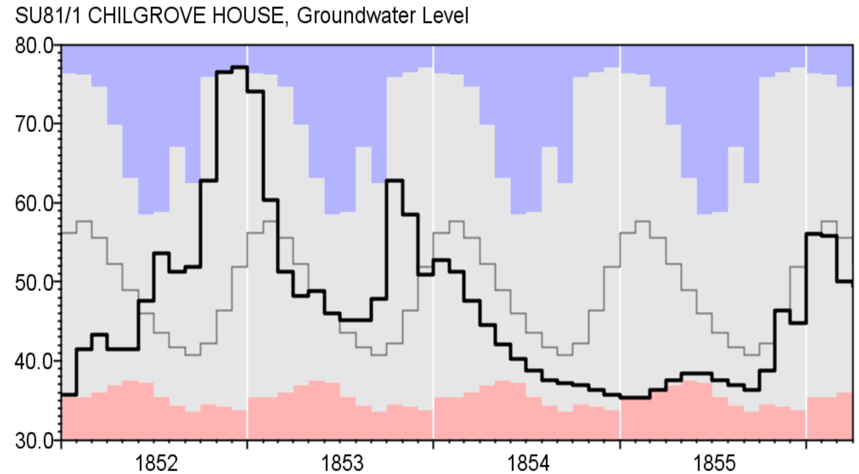
A longer historical perspective

- Does the recent cluster (2012, 2006, 1997, 1992) imply an increasing frequency of severe GW droughts?
- Approx. 50 2-yr Nov-Apr periods with lower ‘rainfall’ than 2010-2012
- Several extended groundwater droughts in the 19th century
- Long term trend towards increasingly wet winters – but observational record may exaggerate the trend





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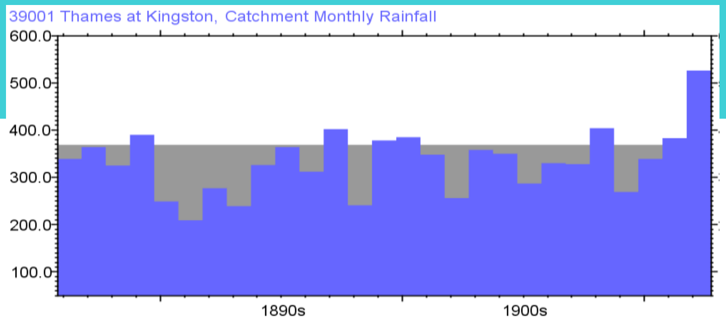
The 'Long Drought'

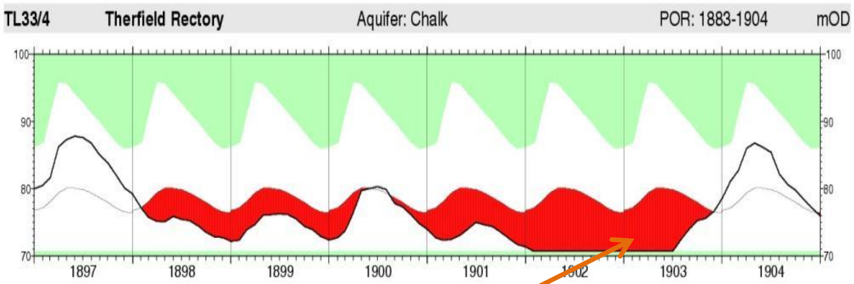


- Circa1890-1910

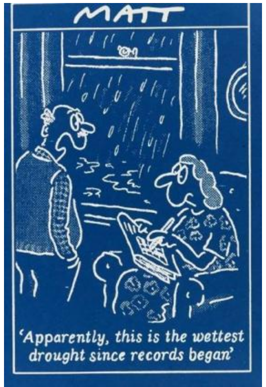
- 1893 spring drought – famine and water riots (74 dry days)

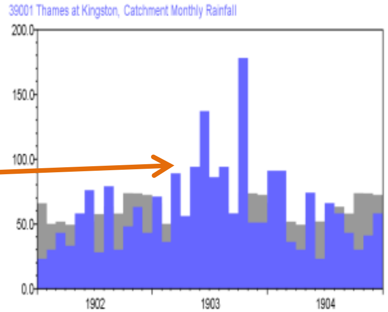
- Thames basin: 17 out of 21 Nov-April rainfall totals below average

- Limited direct groundwater level evidence



- But severe and sustained impacts on the environment with associated ecological stress





- 'Wettest drought on record'

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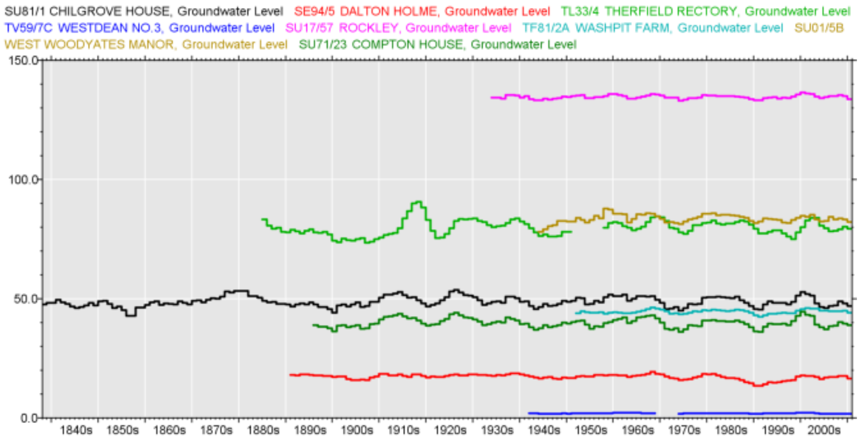
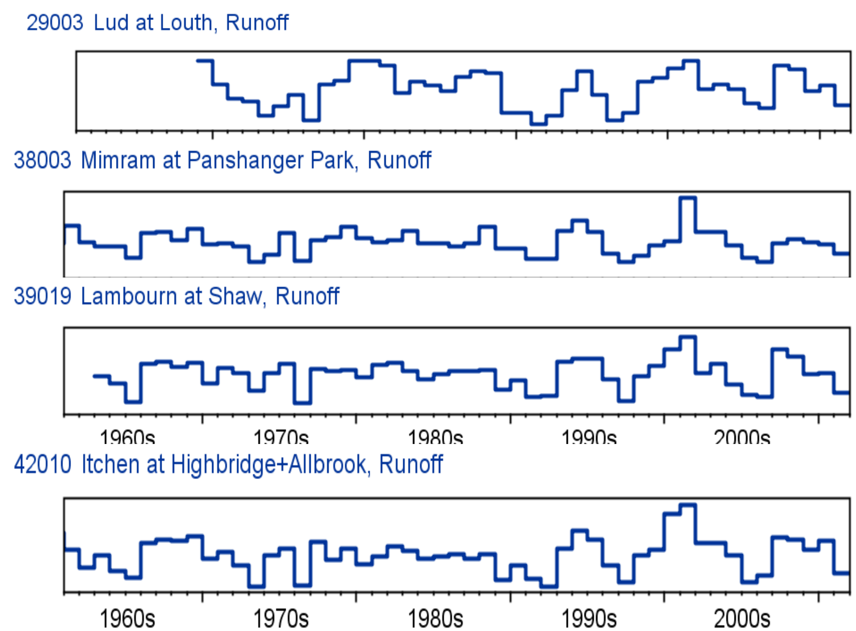
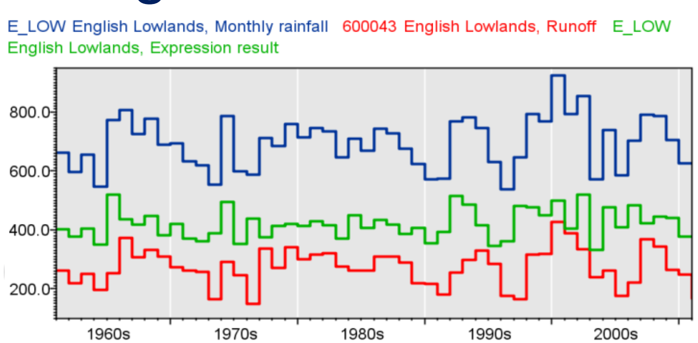
Recharge and runoff trends – the Chalk

- No clear long-term trend in groundwater levels (where abstraction is not an influential factor)
- No compelling post-1960 trend in runoff from Chalk catchments
- Potential evaporation totals increasing but little trend in catchment losses for the English Lowlands



Annual runoff totals

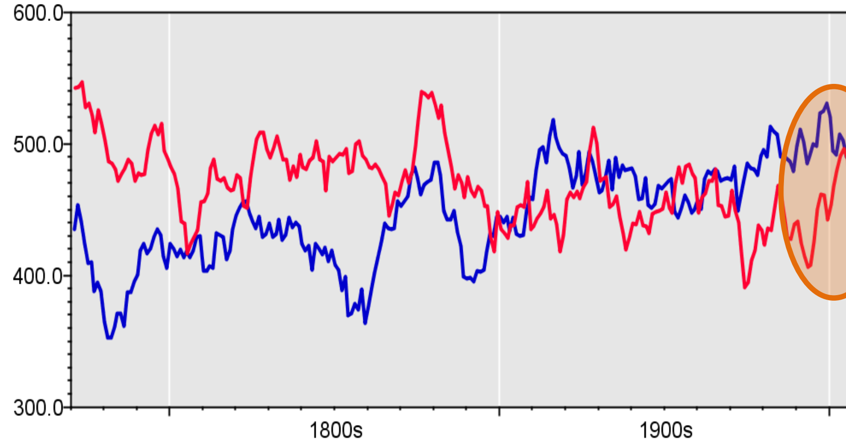


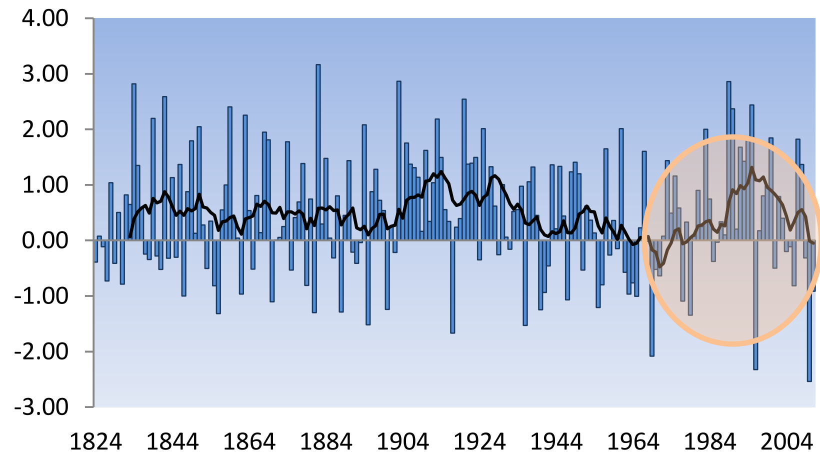


Encouraging - but....

- Little change in mean annual rainfall but trends in seasonal partitioning have tended to favour groundwater recharge
- Climate variability may be at least as important as climate change
- Most UK hydrometric data have been collected during a positive phase of the NAO
- Impact of NAO and other tele-connections is uncertain but the recent past may be atypical

CRU_EW England and Wales-National, Monthly rainfall





NAO (DJFM) source: http://www.cru.uea.ac.uk/~timo/datapages/naoi.htm

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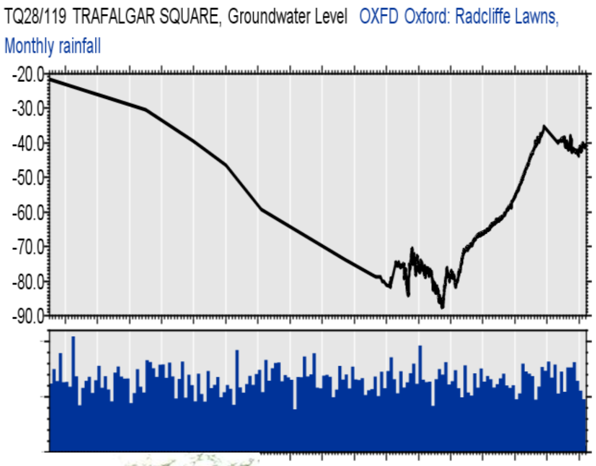
Drought and groundwater abstraction

- Conjunctive use, low flow augmentation and better abstraction management has moderated GW drought impacts
- GW abstraction can have major impacts and result in spatially very variable manifestations of drought stress
- The environmental and ecological dimension of GW droughts is attracting much greater public and political attention



1845 - 2011

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Water management and drought

- Integration of SW and GW resources has increased resilience to drought
- But demand pressures, particularly in the driest parts of the country may well rise
- Rich water resources legacy bequeathed by the Water Resources Board
- SW-GW balance: dearth of major reservoir construction in the last 25 years
- Increasing public and political expectations in relation to the environmental, ecological and amenity impacts of drought
- Time for a new National Plan?

Reservoirs	
Derwent	1964
Balderhead	1965
Celyn	1965
Washburn	1964
Grafham	1965
Farmoor I	1966
Stithians	1967
Clwyedog	1967
Cow Green	1971
Wraysbury	1972
Brianne	1972
Rutland	1976
Brenig	1976
Farmoor II	1976
Queen Mary	1977
Bewl	1978
Ardingly	1978
Wimbleball	1979
Colliford	1983
Keilder	1983
Roadford	1989

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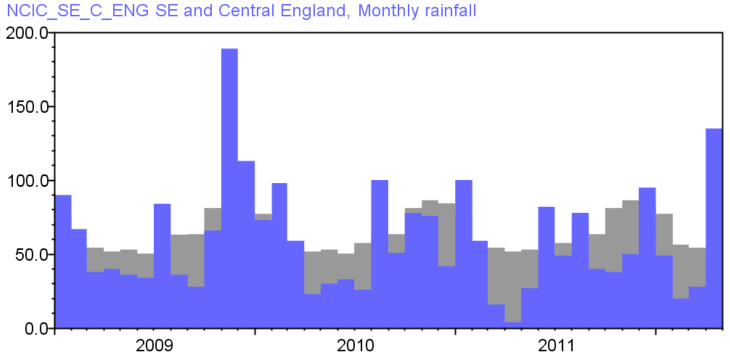
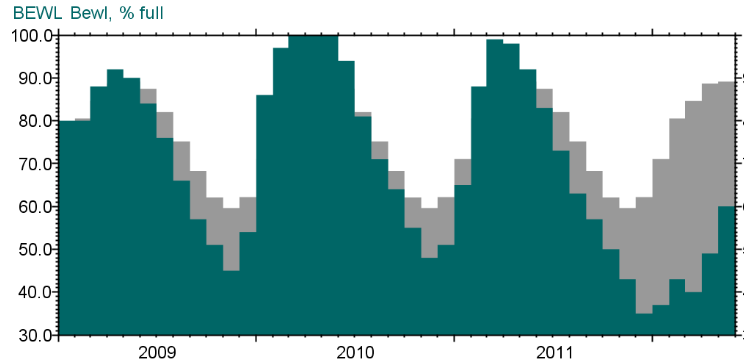
Conclusions

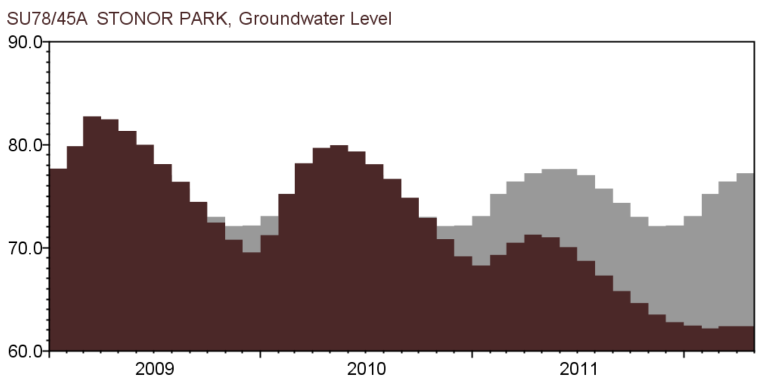
- Spatial and temporal relationships between SW and GW droughts are complex – reflecting regional and local differences in artificial and natural storage capacities
- Drought is too complex to characterise by single portmanteau indices
- Flooding can co-exist with very depressed groundwater levels
- The cluster of recent groundwater droughts is not historically exceptional
- No compelling evidence for significant decline in aquifer recharge or a change in the frequency of groundwater droughts
- Ecological, environmental and amenity impacts of depressed GW levels have assumed a much greater importance
- The need to capture and quantify hydrological and hydrogeological trends remains an imperative

2010-12 Drought – temporal footprints

- Soil moisture deficiencies during the growing season produced agricultural stress in the dry springs of 2011 and 2012
- Successive dry winters generated concern for water resources outlook
- Contrasts between onset, duration, and termination of different drought categories







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A look at the Chalk

- Average variation – 10m
- Land use and management influential (but barely shows)
- Outcrop area of 21500 km2
- Effective thickness of 50m and specific yield of 2% - thus total available storage is about 2x10$_{10\ m3}$
- Total vol is around 2.4 x 1012 – only a small prportion is drainable
- Vol released during a water level drop from max to min is between 0.4 and 1.0 x 109 (Keilder: 2 X 108fro
- Equivalent to 4 years average recharge or about 17 yrs average abstraction (may not have changed much due to CAMS and decline in industrial abstractions)
- But it is an overestimate because little of the upper 50m of the saturated Chalk could be drained without major impact on rivers
- Typically average seasonal variation: 10m
- Onset and cessation of recharge may be changing but wetter winters.
- Dangerous patchy impact on rivers and wetlands

BGS report to NRA GEW storage in Brit Aquifers: Chalk NRA 1993 Report: 128/8/A

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