Projecting uncertain impacts of climate change on wetlands: a risk-based tool for England and Wales

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Environment Agency · Natural England · English Heritage · The Wildlife Trusts · RSPB · WWT Saving wetlands for wildlife & people · British Geological Survey · UCL · University of Exeter · The Open University · Centre for Ecology & Hydrology

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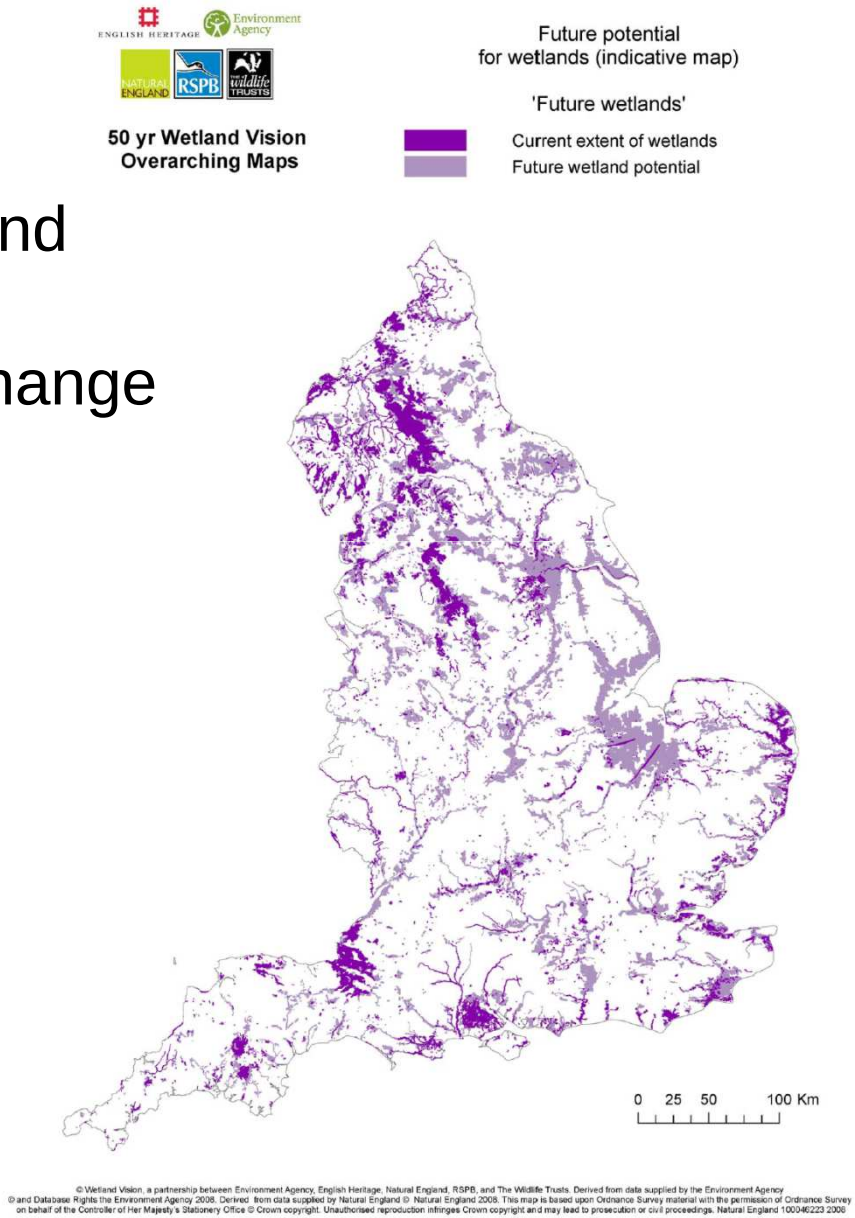
Background

- The Wetland Vision
  - restoration and management of wetlands throughout England over the next 50 years
  - little information on climate change
- www.wetlandvision.org.uk

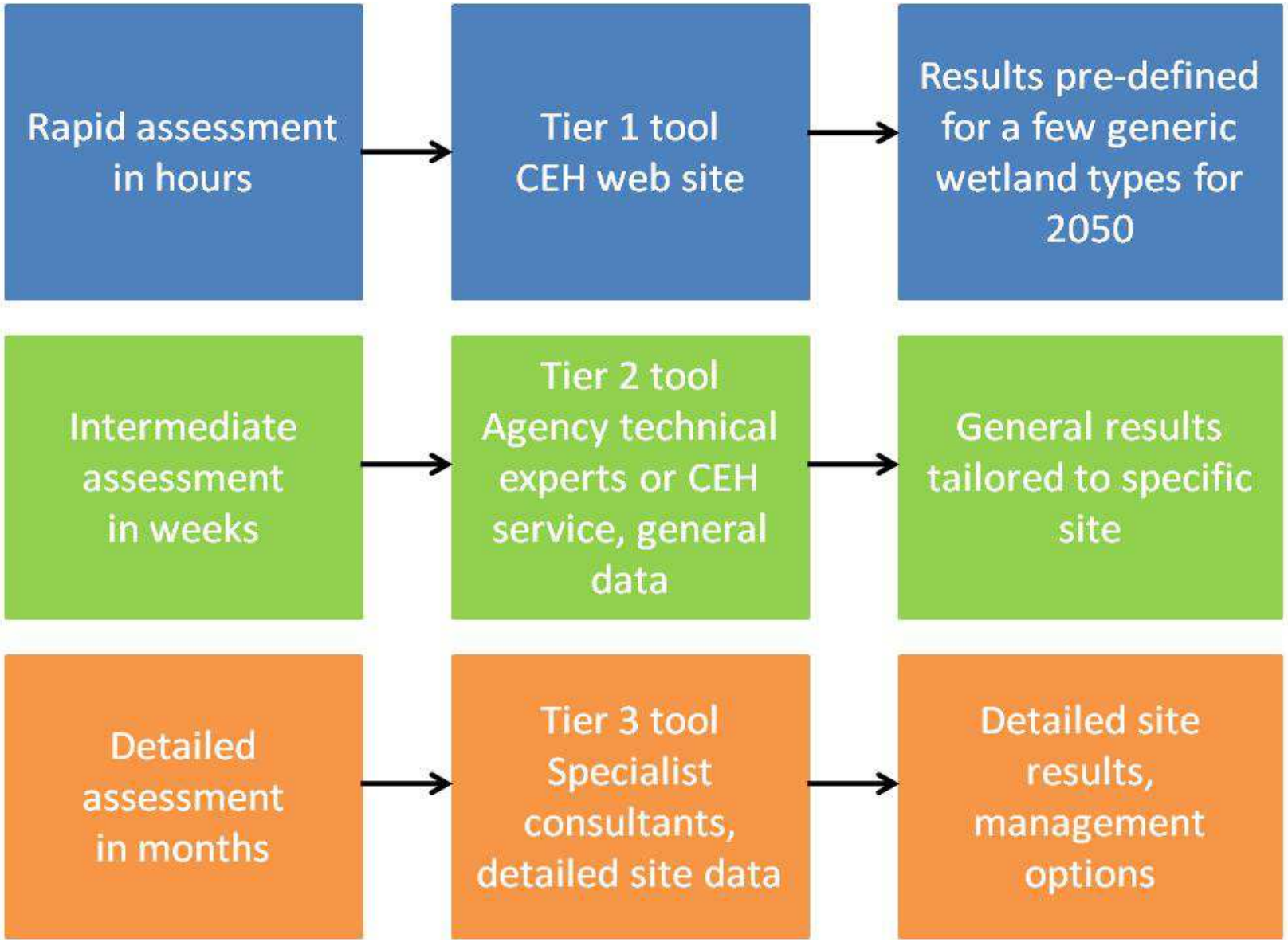


Project aim

- Produce a set of tools to assess impacts of climate change
- Assumption - hydrology is the key characteristic of a wetland that will be directly impacted

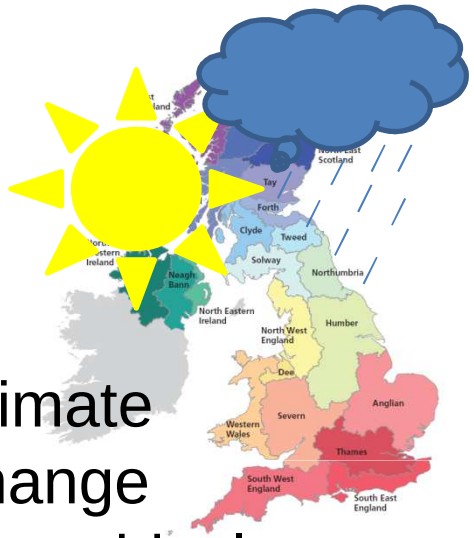
?

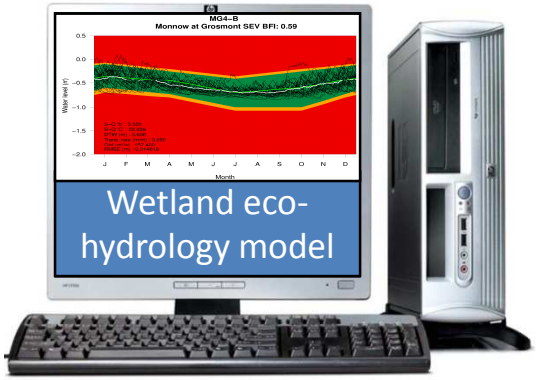
Risk-based tool-kit



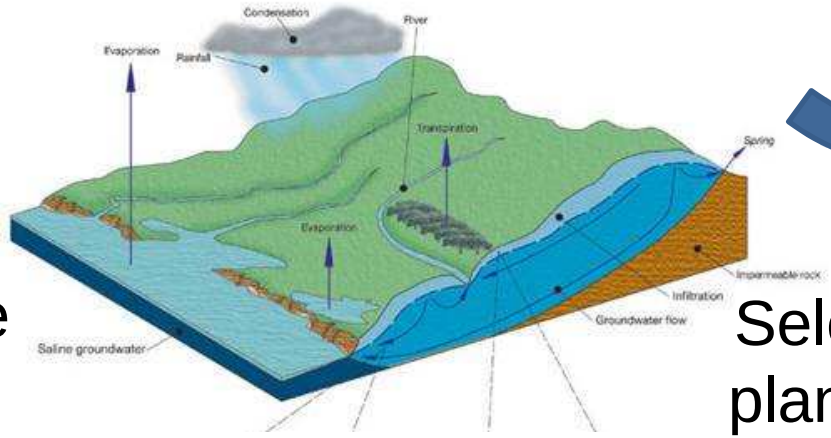
Tier 1 tool approach – regional impacts

Climate change (Geographical location)





Ecosystem sensitivity (Interest feature)



Catchment response (Water source)

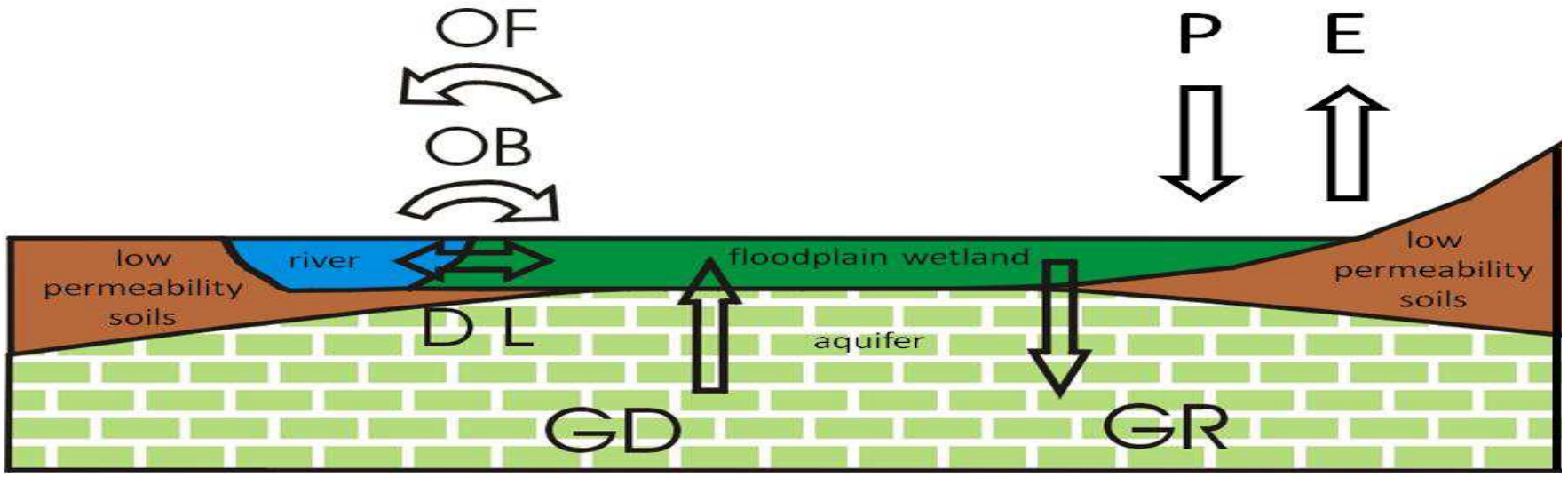
Selected wetland plant communities

Tier 1 climate inputs

- UKCP09 climate projections
- 2050s timeslice (2040-2069)
- ‘Medium’ greenhouse gases and aerosols emissions scenario
- IPCC SRES A1B
- 12 river basin regions for England and Wales
- 10,000 projections per region

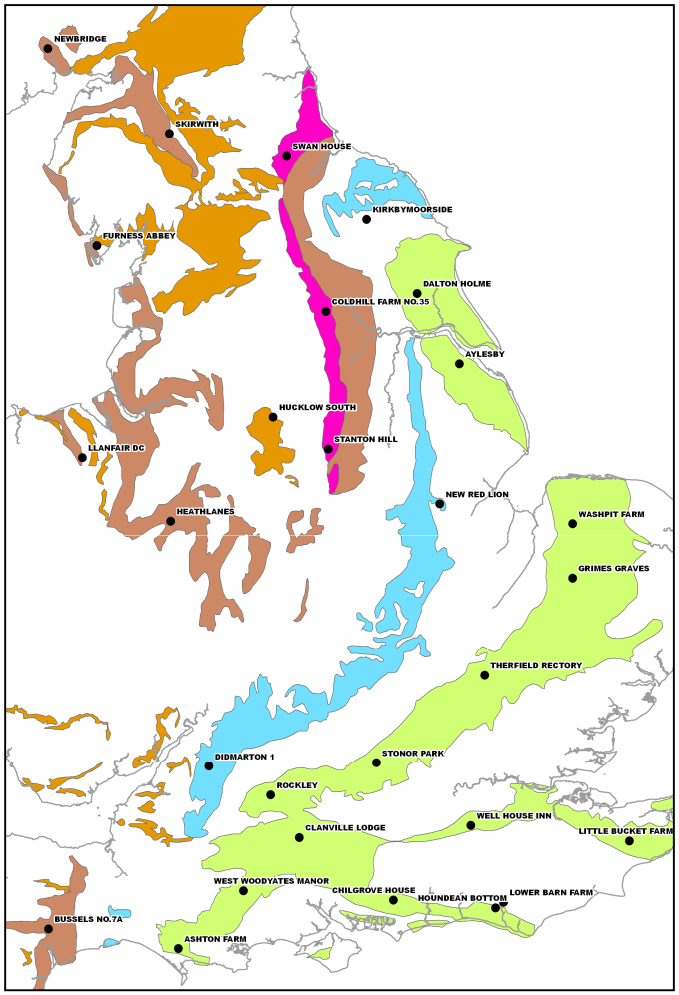
Tier 1 wetland modelling

Water supply mechanism end members		
Rain-fed	River-fed (SW/GW)	Groundwater-fed (various aquifers)
UKCP09 rainfall and temperature	River flows typical catchments (CEH: FFGWL)	Groundwater levels representative boreholes (BGS: FFGWL)



Tier 1 groundwater-fed wetland modelling

- 15 region-aquifer combinations
- 4 vegetation communities
- 600,000 climate change simulations
- Simple (efficient) wetland models
  - applicable at regional scale
- Hypothetical wetlands
  - calibrated to be sustainable under baseline climate conditions
- Approach follows that developed for rain-fed and river-fed wetlands*



*Acreman et. al. (2009) A simple framework for evaluating regional wetland ecohydrological response to climate change, *Ecohydrology*, 2(1), 1-17

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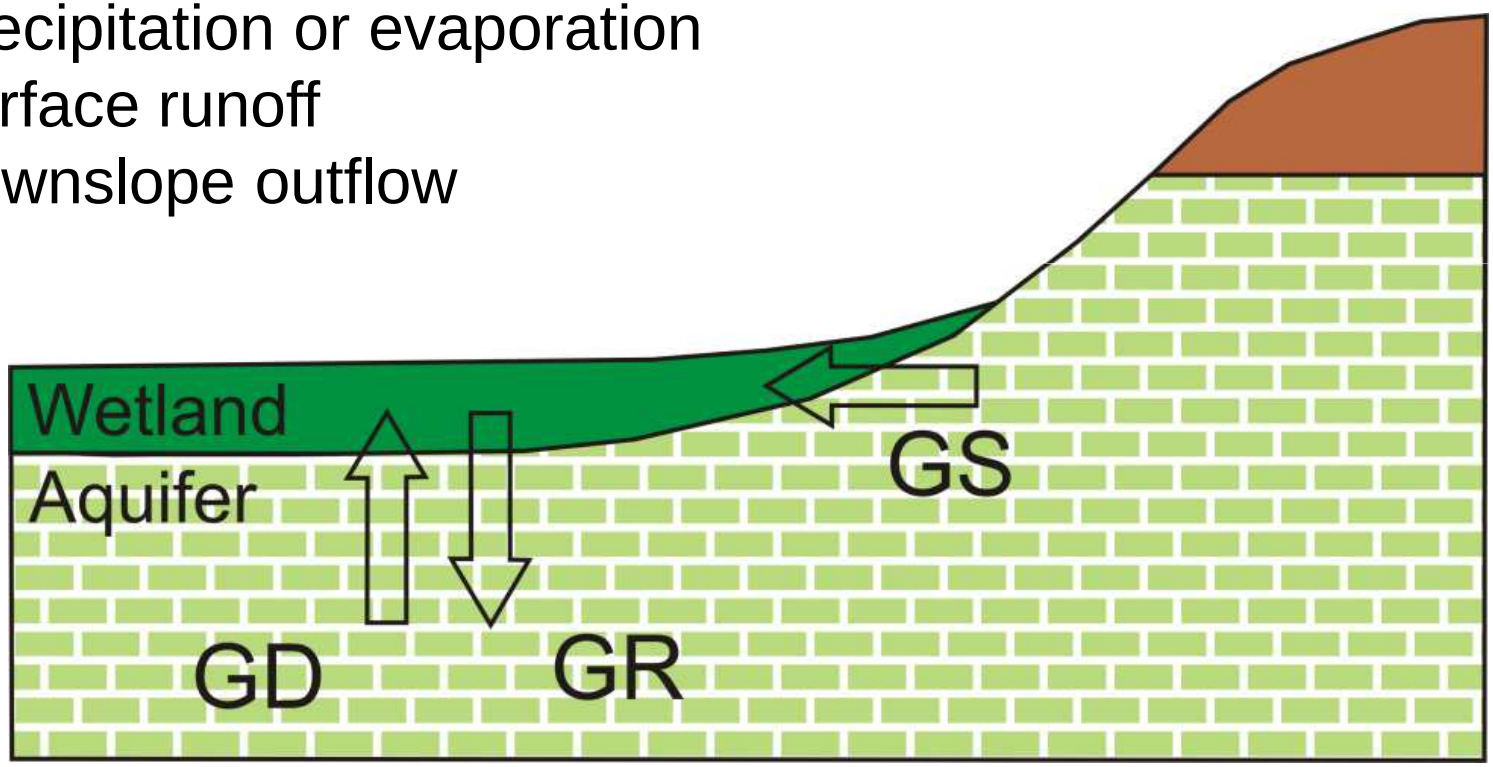
Tier 1 GW-fed modelling approach

- Simple conceptual understanding
  - groundwater discharge and recharge
  - lateral groundwater seepage
  - no precipitation or evaporation
  - no surface runoff
  - no downslope outflow



Tier 1 GW-fed model equation

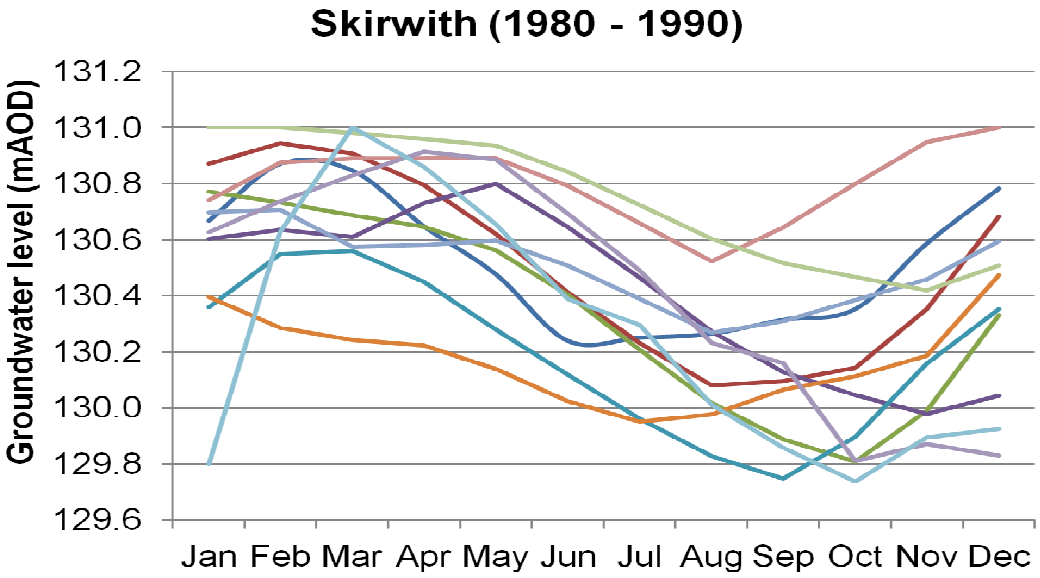
- $WL_{WET,t} = WL_{WET,t-1} + k(WL_{GW,t} – WL_{WET,t-1})$

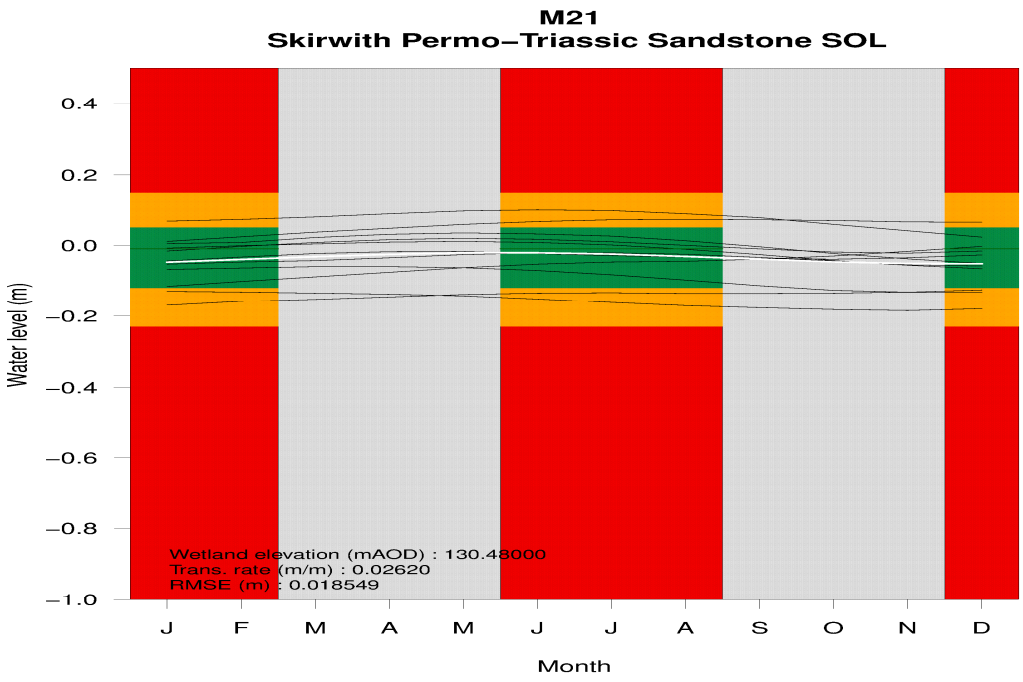
WL	water level / hydraulic head (m)
WET	wetland
GW	groundwater
t	timestep
k	‘hydraulic head transfer rate’ factor (m/m)

- ‘k’ (basically a scaling factor) combines
  - wetland, aquifer (and any aquitard) permeabilities
  - relative specific yields and scales of wetland and aquifer
- Wetland surface elevation (mAOD) parameter
- No horizontal dimensions – not modelling water volumes
- No lag term – wetland scale minor relative to aquifer

Tier 1 GW-fed model baseline calibration

- Monthly groundwater level data (BGS)
- 1980 – 1990 baseline
- Initial conditions
  - end winter optimum
- 9 month run-in
- Semi-automatic wetland calibration
  - optimise parameters
  - ecohydrological water level requirements
  - deviation consistent between regions





Tier 1 GW-fed model climate change

- We now have 60 calibrated baseline models for each region-aquifer-vegetation community combination...
- ...but we plan to run 10,000 climate change projections for each model...
- ...it isn't practical to store/interpret 600,000 sets of monthly wetland water level data!?

```
 1, -0.006, -0.032,  0.012, -0.060,
 2,  0.006, -0.016,  0.020, -0.056,
 3,  0.018, -0.003,  0.028, -0.047,
 4,  0.030,  0.008,  0.035, -0.038,
 5,  0.036,  0.007,  0.039, -0.036,
 6,  0.035, -0.001,  0.041, -0.041,
 7,  0.028, -0.012,  0.040, -0.052,
 8,  0.021, -0.026,  0.038, -0.068,
 9,  0.009, -0.040,  0.036, -0.086,
10,  0.002, -0.049,  0.033, -0.101,
11,  0.003, -0.043,  0.036, -0.110,
12,  0.010, -0.036,  0.042, -0.109,
13,  0.016, -0.035,  0.048, -0.104,
14,  0.021, -0.036,  0.053, -0.097,
15,  0.029, -0.010,  0.061, -0.087,
16,  0.040,  0.006,  0.070, -0.074,
17,  0.045,  0.012,  0.077, -0.064,
18,  0.054,  0.016,  0.082, -0.054,
19,  0.058,  0.010,  0.084, -0.051,
20,  0.055,  0.001,  0.083, -0.057,
21,  0.046, -0.012,  0.080, -0.067,
22,  0.042, -0.017,  0.076, -0.
23,  0.044, -0.019,  0.07
24,  0.053, -0.009,
...
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Tier 1 climate change impact metrics

- Hydrology
  - water levels
  - water balance
- Plant communities
  - ecohydrological water level requirements
- Historic environment
  - soil saturation depths
- Birds
  - flooding in winter and spring

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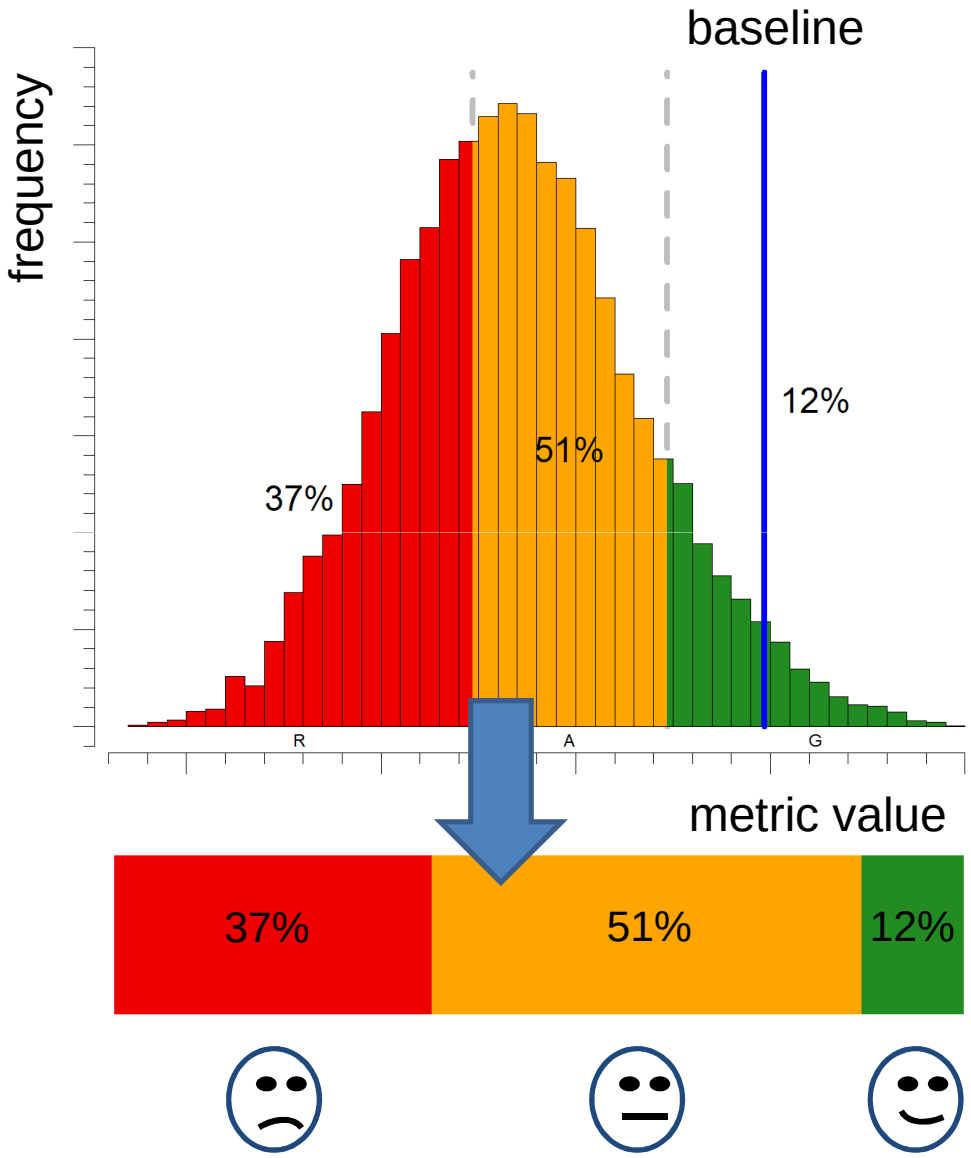
Tier 1 visualising uncertainty

- Impact metric histograms
  - 10,000 projections
  - impact boundaries defined by expert judgement

- Basic block plot



Tier 1 wetlands and climate change tool

- Open access
- Rain-fed and river-fed wetland results currently online
- http://www.ceh.ac.uk/sci_programmes/Water/Wetlands/ClimateChangeAssessmentToolforWetlands.html
- Google ‘CEH wetlands climate change’!
- Revised website and groundwater-fed wetland results online by end March 2013
- A preview of the groundwater-fed Tier 1 tool...

Wetlands and Climate Change

HELP: Step by step guidance for use of this tool (pdf)

Tool for assessing wetland sensitivity to climate change

1. Select region

Anglian	Dee	Humber	Northumbria	North West England	South East England
Severn	Solway	South West England	Thames	Tweed	Western Wales

2. Select water source / National Vegetation Classification

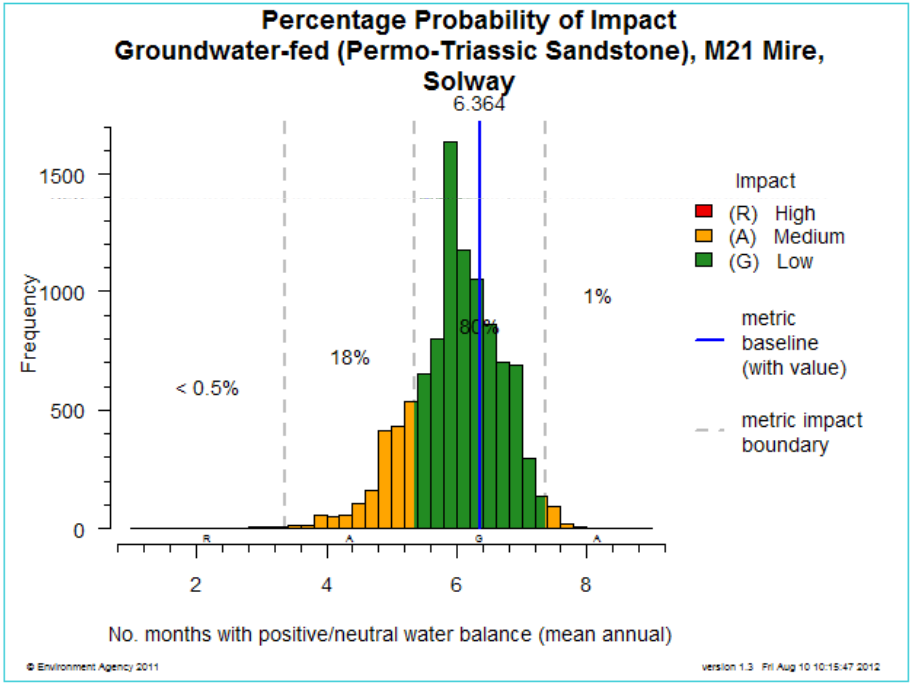
Groundwater-fed | Permo-Triassic Sandstone

National Vegetation Classification
Fen meadow, M24
Tall herb fen, S24
Mire, M13
Mire, M21

3. Select feature of interest and metric

Hydrology (water balance)

Metric
No. months with positive/neutral water balance (mean annual)
No. months with positive/neutral water balance (11 yr min)



4. Select result type

Alternative

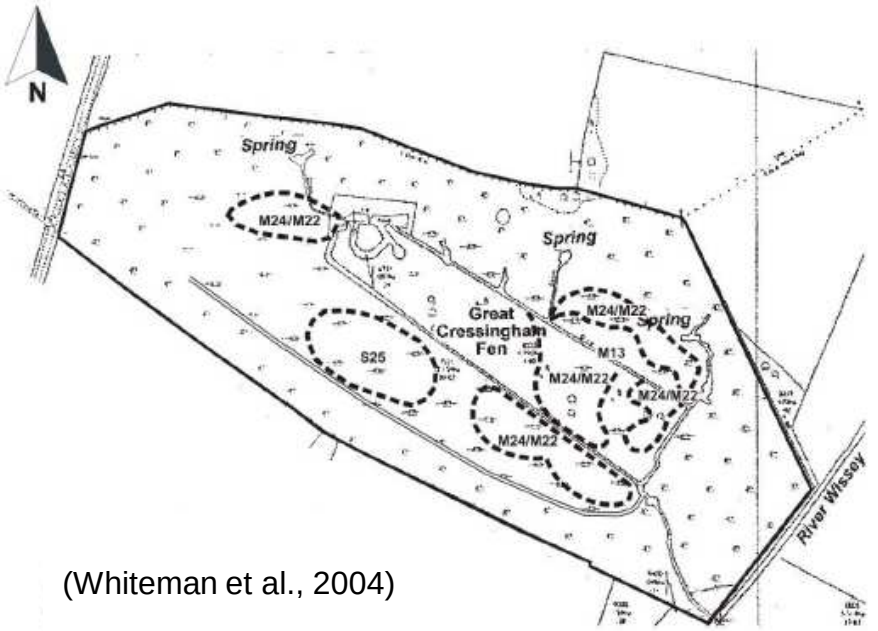
High resolution image for use in documents

Tier 1 tool limitations

- It provides a generalised regional indication of potential impacts suitable for risk screening and investigating uncertainty
- It is not a detailed prediction for a particular wetland
- Other UKCP09 climate change timeslices and emissions scenarios
- Multiple water sources not considered
  - assess separately then consider results in combination using site understanding
- Water quality/nutrients not explicitly considered
  - use site understanding, e.g. increasing chalk groundwater water balance likely to increase base-richness

Tier 3 GW-fed wetland case study

- Testing the Tier 1 tool
- Great Cressingham Fen (GCF), Norfolk
  - calcareous valley-fen
  - groundwater-fed by springs and seepages from the Chalk via granular alluvial deposits
  - surface inputs from rainfall and limited rainfall-runoff
- Existing calibrated Tier 3 model (EA/Entec)



(Whiteman et al., 2004)

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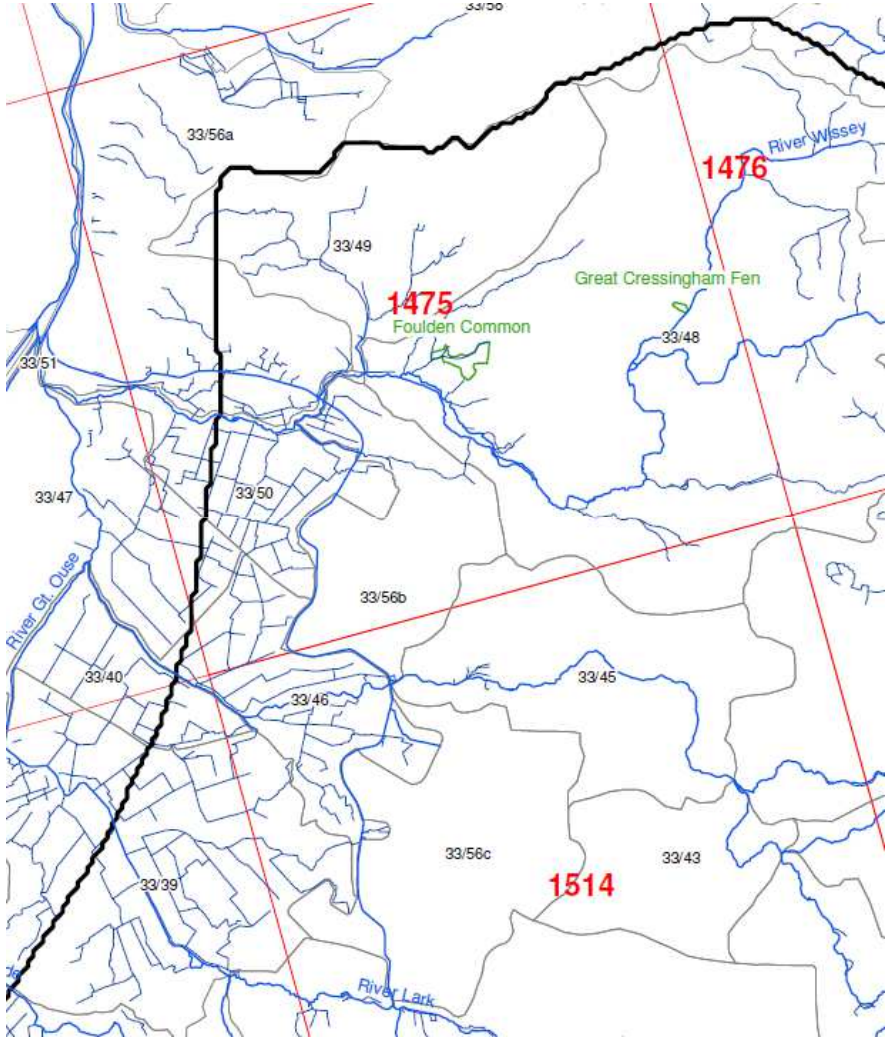
Tier 3 GW-fed wetland case study

- Great Cressingham Fen
  - single 200 x 200 m grid cell
  - 70 x 70 km Ely Ouse regional groundwater model
  - MODFLOW and 4R
- Detailed distributed groundwater modelling by Entec (2011)
  - naturalised GW levels
  - baseline (1961 to 1990)
  - 2050s (2040 to 2069)
  - three RCM representations



(Entec, 2011)

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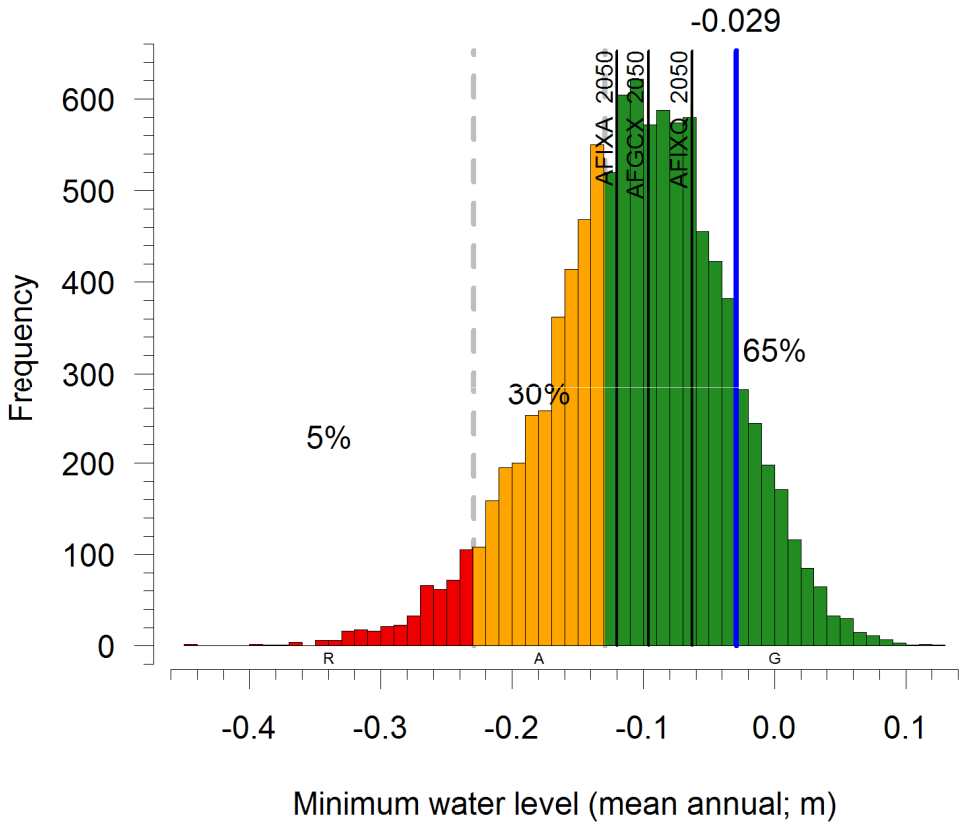
Tier 3 GW-fed wetland case study

- Calculated impact metrics for Tier 3 wetland water levels
- Standardised results to Tier 1 baseline (as Tier 3 RCM is a simulated baseline climate, Tier 1 uses observed climate)
- M13 *Schoenus nigricans-Juncus subnodulosus* mire



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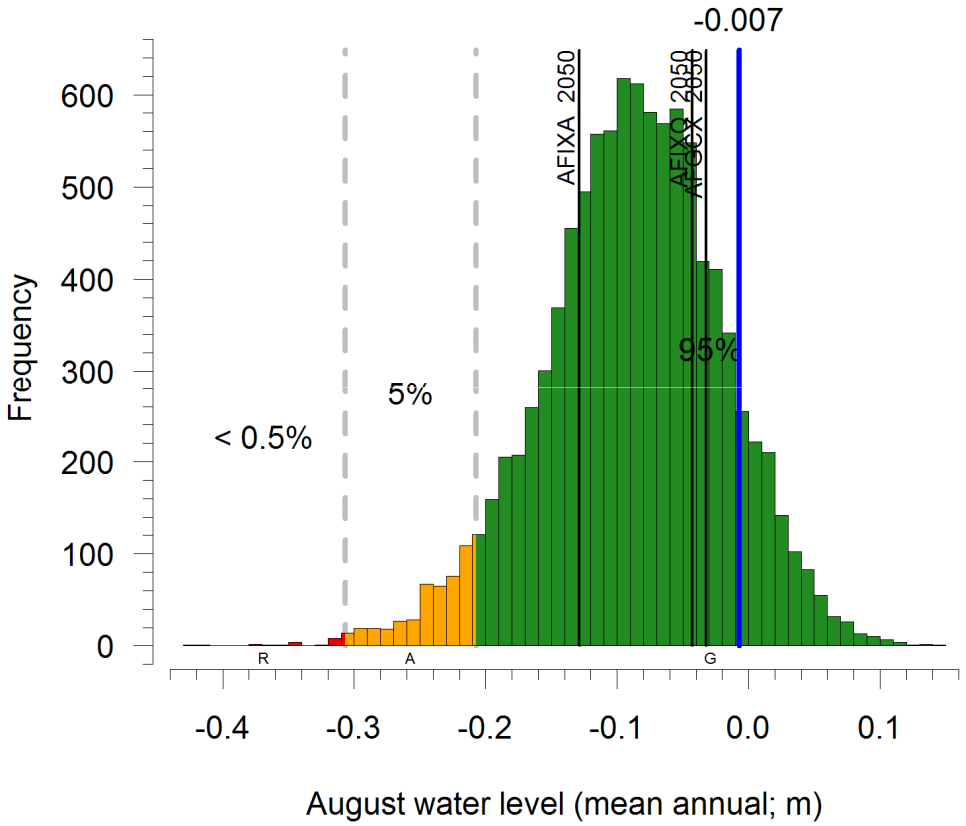
Tier 3 GW-fed wetland case study

- Some consistency between the Tier 1 and Tier 3 models
- Caveats
  - different baseline climate data
  - Tier 3 GCF grid cell groundwater levels represent several vegetation communities therefore average response
  - natural vs naturalisation



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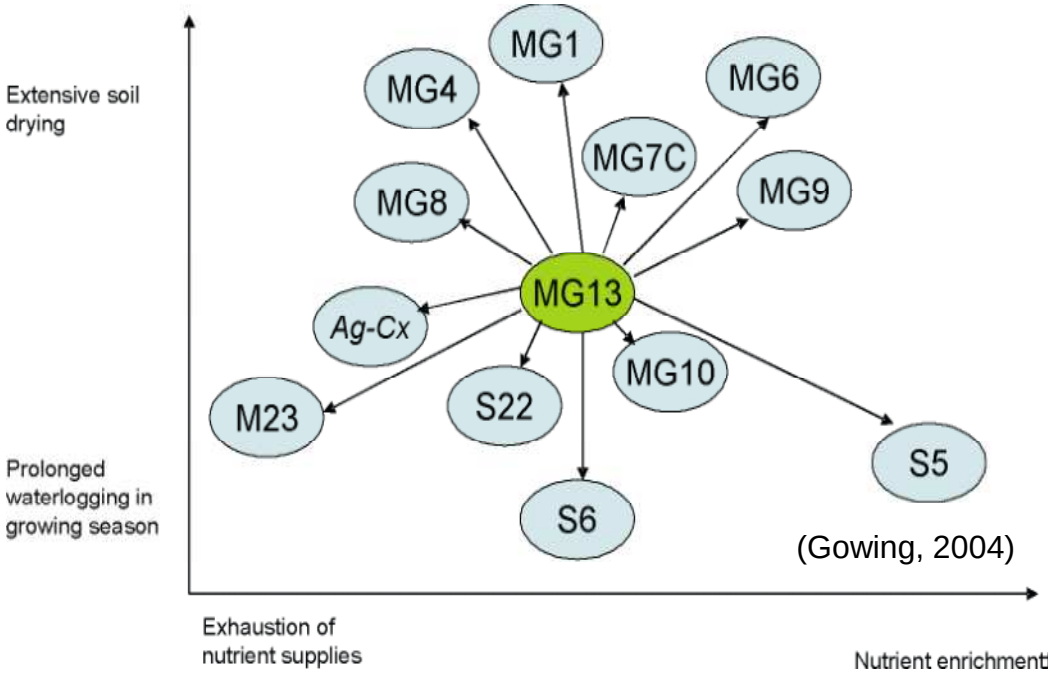
Tier 2 tool

- Simple Tier 1 models
- Groundwater levels
  for a specific wetland
  - other FFGWL project results
  - generate climate change results
    from an existing groundwater model
  - develop a new model
    (baseline and climate change)

Future developments

- Modelling wetland water levels and nutrients under climate change
  - linking Tier 1 river-fed wetlands and INCA river models
- Considering model uncertainty as well as climate uncertainty
  - improved calibration objective function
  - parameter equifinality
- Other UKCP09 timeslices and emissions scenarios?



(Gowing, 2004)

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Thank you

Any questions / discussion welcome

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