UKWIR Technical Note
December 2005

Planning for climate change

UKWIR/Environment Agency Research Project

'Effect of climate change on river flows and groundwater recharge: A practical methodology'

According to the Met Office, all of the 10 warmest years in the instrumental record have occurred since 1990, including every year since 1997. The summer 2003 heat-wave was attributed, at least in part, to human activities and globally, 2005 was another warm year. The water sector, including the Environment Agency and water companies, have been at the forefront of considering the risks of climate change in their long term business plans. By co-funding this project, UK Water Industry Research (UKWIR) and the Environment Agency will ensure that the latest climate change scenarios and hydrological research are used in the next Periodic Review.

Project highlights

The overall aim of the project is to '*produce a robust methodology which water companies can use for climate change impacts assessment and which has the support of the Regulator*'. In its first year, the project has:

- established a strong research partnership between water companies, the Environment Agency and the research contractors - HR Wallingford, Lancaster University, Entec and the Met Office
- built upon existing methods that are used widely in the water sector and developed a strategy that includes the application of innovative modelling techniques to provide a clear picture of the risks and uncertainties related to climate change
- delivered practical outputs, including catchment scale climate change scenarios based on the 2002 UK Climate Impacts Programme (UKCIP02) scenarios, with updates planned as more climate models become available
- reviewed the evidence for trends in UK river flows and groundwater records.

The project, to be completed in 2007, will provide further outputs in 2006.

Forefront of climate impacts research

In 1997 UKWIR and the Environment Agency published a methodology to allow the rapid strategic assessment of the impacts of climate change on river flows and groundwater recharge. The 'Arnell' or 'CL/04' method provided regional factors that could be used to change or 'perturb' observed rainfall, potential evaporation, river flow or recharge sequences in order to determine the impacts of climate change on the yield of water resource zones. The research provided an excellent example of how a complex issue could be addressed using a practical, effective and agreed methodology for climate change impacts assessment.

Since this original work, climate impacts research has developed, with the publication of the United Nations Intergovernmental Panel on Climate Change's (IPCC) Third Assessment Report (www.ipcc.ch) on climate change and at research centres in the UK such as the Met Office Hadley Centre for Climate Prediction and Research (www.metoffice.gov.uk/research/hadleycentre/index.html) and Tyndall Centre (www.tyndall.ac.uk/index.shtml).

UKWIR's own climate change R&D programme has made considerable use of the most recent UKCIP02 climate change scenarios and updated the flow factors in 2003, in advance of AMP4.

This research project aims to develop better practical guidance that takes account of the latest international and UK research on climate change.

Working with stakeholders

Two key requirements of the project are to build upon existing methods and to deliver practical tools for water companies and the Environment Agency. In order to meet these objectives, the project team held three regional project workshops for water company, Environment Agency and SEPA delegates to find out what each stakeholder wanted from the project and to gain an understanding of:-

- the range of techniques that are currently used for analysing climate change
- the tasks that water companies are likely to undertake as part of their future climate change impact assessments and water resource plans
- how climate change uncertainty can be best addressed in water resource planning (from Water Service Provider and Regulator perspectives).

The results of the regional workshops were presented back and debated further with a wider group of stakeholders, including OFWAT, consultants and researchers at a national Technology Transfer Workshop in July, 2005.

The key messages from the workshops were that stakeholders wanted a practical 'tool-kit' with clear guidance that was suitable for different levels of risk assessment. In short; a set of tools that maintained all the practicality of the old method but addressed its weaknesses, in particular, stakeholders wanted the project to:-

- promote a consistent national approach that will be accepted by Regulators and provide justification for investment
- provide a groundwater tool for assessing the impacts of climate change on groundwater levels
- improve their understanding of climate change uncertainties
- provide a better representation of climate variability
- address climate extremes as well as average impacts
- clarify what factors should be applied and where (e.g. in river flow sequences, headroom, on Deployable Output and so on).

In summary, the workshops confirmed that the original project brief largely reflected the needs and aspirations of the water resources 'community'.

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Trends in river flows and groundwater recharge

Given the strong evidence of warming over the last two decades, an early project task was to establish whether there have been discernible changes in river flow and groundwater recharge across the UK. The specific objective was to evaluate trends in river flows for the period 1970 to 2002.

The team applied statistical tests to more than 50 flow and groundwater level time series to detect trends with the following results:

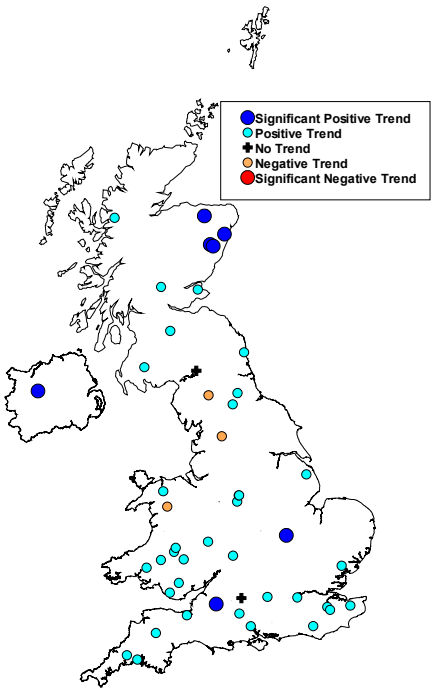
- no trends were found in average summer and spring runoff
- significant upward trends in winter runoff were detected in a small proportion of sites
- significant upward trends in autumn runoff were detected in 15% of sites
- no trends were found in groundwater annual minimum or seasonal average groundwater levels.

The power of the analysis was limited by the short periods considered as well the assumptions of the individual tests. However an innovative approach - Dynamic Harmonic Regression (DHR) - developed by Professor Peter Young at Lancaster University was used to decompose time series data, up to 120 years long but typically from the early 1960s to 2002, into several components including a long term trend, objectively identified from the data.

This analysis placed recent trends in the context of long-term historic changes and showed that recent changes in runoff could not yet be distinguished from long term natural variability. Similar rates of change have occurred in the past.

Wetter winters are one characteristic of future climate scenarios but the research demonstrated that it is too early to state whether the floods in Easter 1998 and Autumn 2000 or the 'low flow' years during the 1990s, 2003 and 2005 are part of a long term trend. In any event, the strongly positive phase of the North Atlantic Oscillation in recent decades probably explains many of the trends in winter river flow.

Figure 1. Trends in average autumn river flows from 1970 to 2002. Mann-Kendall test at 95% confidence level



Output

UKWIR (2005), *Effect of Climate Change on River Flows and Groundwater Recharge, A Practical Methodology: Trends in UK River Flows 1970-2002*. UKWIR Report 05/CL/04/5, 37pp. + annexes. ISBN: 1-84057-387-2.

Using UKCIP02 climate change scenarios for catchment studies

The UKCIP02 climate scenarios provided data on possible changes in precipitation and temperature and were used widely by water companies to assess the impacts of climate change as part of the last Periodic Review. The UKCIP02 scenarios provide data based on the Hadley Centre Global and Regional Climate Models on a 50km grid. For users who want to apply the scenarios for catchment scale water balance studies, there are two tasks:

- to estimate Potential Evapotranspiration as these data were not provided by UKCIP02
- to interpolate or generalise the data from the 50km grid to the catchment scale.

This project has developed an Excel spreadsheet that provides these data at a catchment level, based on Catchment Abstraction Management Strategy (CAMS) areas in England and Wales and Water Framework Directive (WFD) sub-basins in Scotland and Northern Ireland. This is an interim output of the project which will be updated in March 2006 to include outputs of more climate models.

The Excel spreadsheet removes the need for individual studies to interpolate the UKCIP02 50km^2 data to derive catchment specific rainfall and PET factors. It also provides a consistent data set that can be used by WSPs and the Regulator. Several water companies will be reviewing the impact of climate change as part of ongoing work for PR04, and the spreadsheet will provide the appropriate information on UKCIP02 factors at the catchment level.

Output

UKWIR (2005), *Effect of Climate Change on River Flows and Groundwater Recharge, A Practical Methodology: Use of Climate Change Scenario Data at a Catchment Level.* UKWIR Report 05/CL/04/3, 23pp. + annexes. ISBN: 1-84057-373-2.

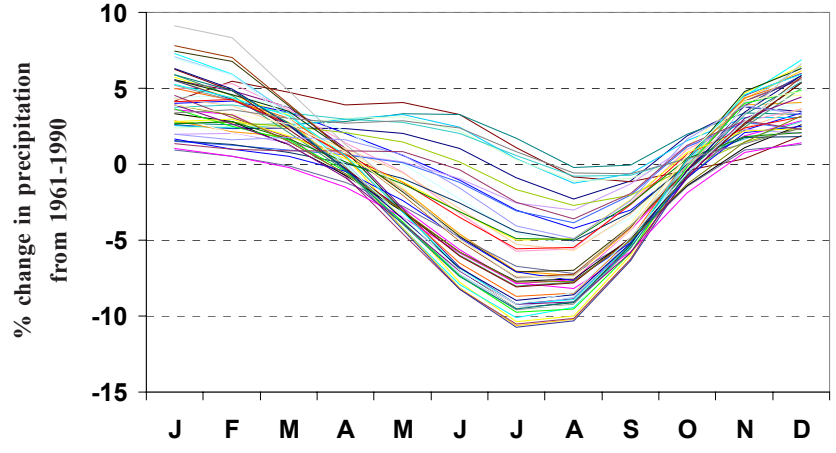
Dealing with uncertainties

The challenge of developing a *'set of tools that maintained all the practicality of the old method but addressed its weaknesses'* including the need to consider climate change uncertainties is addressed in the project report 05/CL/04/6. This report:

- describes the team's proposed approach to uncertainty in the subsequent stages of the research project
- develops the concept of a practical framework and 'tool-kit' for evaluating climate change uncertainties in future water resource studies.

In both cases, the starting point is a fuller understanding of the full 'cascade of uncertainties' (see box on page 3).

Figure 2. An example of catchment specific rainfall factors for the 2020s that have replaced regional factors. Each coloured line represents monthly factors for a different Scottish catchment



The project team are developing ways for dealing with these uncertainties including:

- making use of several GCMs from research centres in the US, Australia, Japan and Germany as well as the UK's Hadley Centre for Climate Change Prediction and Research.
- testing how well these models reproduce the observed climate of the UK (see Box 3), specifically precipitation and potential evaporation, to develop weights.
- ways of correcting errors or 'bias' in the GCMs so that they can be used more effectively for hydrological modelling.
- methods for disaggregating data to a 5km grid and catchment scale for use by water companies

For water resource planners the idea of weighting climate impacts is not new because UKWIR's headroom methodology already includes a component that allows for uncertainty due to climate change. However, to date, the challenge has been to assign uncertainty to different scenarios (e.g. high, medium or low) that have the same theoretical probability.

The framework proposed in this project allows the weighting of climate change scenarios based on better scientific understanding. It will also be possible to apply uncertainty within different parts of the analysis, depending upon the detail of the study.

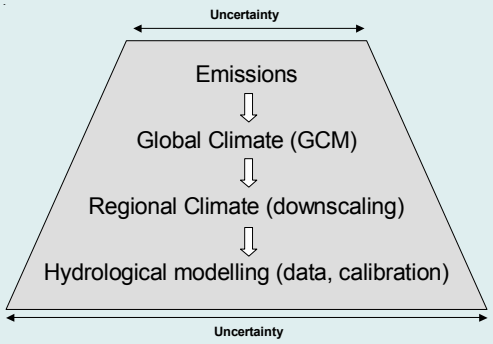
For example, a simple study may consider climate change factors based on three GCMs, assess the potential impact on resource zone yield and then apply a weight or probability to the reductions in yield in headroom analysis.

Alternatively, a more complex study may weight the climate change inputs so that the uncertainty related to climate change can be considered alongside hydrological modelling uncertainties and natural variability to determine a range of yields. For future water resources studies a framework of tools and guidance is proposed that includes:

- simple methods of factoring, based on the original CL/04 methodology (UKWIR, 1997) but including a wider range of climate change uncertainties
- intermediate methods that include the use of data from several GCMs and a form of re-sampling to represent natural variability when very long records are not available
- advanced methods that deal with the full 'uncertainty cascade' and involve a mix of regional climate models and statistical downscaling methods to produce catchment specific information.

The output from this project will provide water resource planners with flow-chart based guidance on the most appropriate methods for climate change analysis. The choice of method (i.e. simple to advanced) will depend on a number of factors, including the type of hydrological and water resource models companies use, the available data, and the sensitivity of resource zone supply-demand balance to climate change. The project team are undertaking a pilot study over the next few months to test this framework in a range of water resource planning circumstances.

The 'cascade of uncertainties' relevant to an impacts assessment on hydrological systems

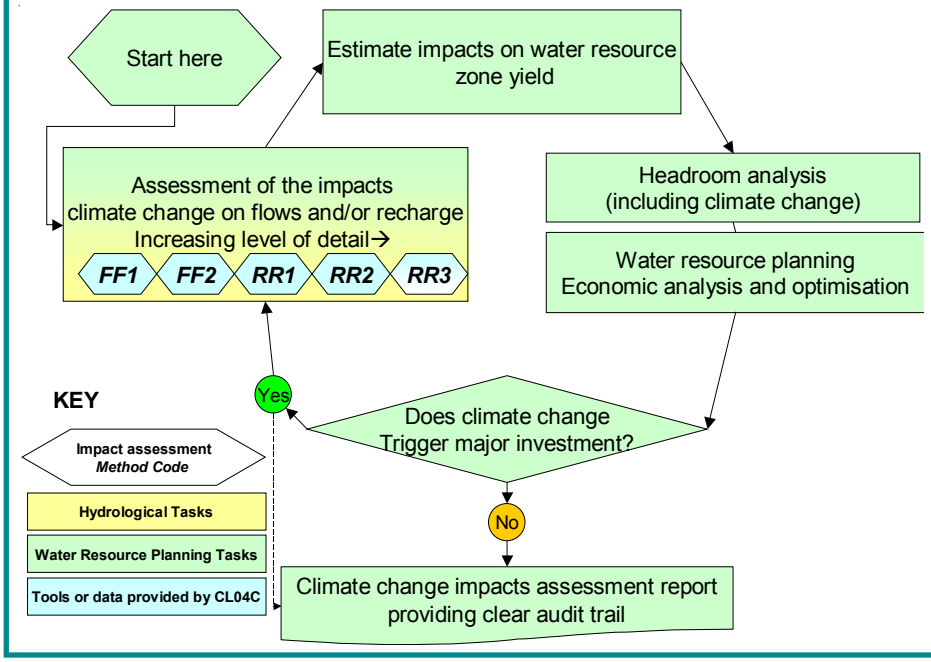


The complementary research project (see report 05/CL/04/4) found that the greatest uncertainties affecting future water resources relate to:

- the outputs from different Global Climate Models (GCMs)
- the effect of different 'downscaling techniques' on how GCM outputs are translated to the catchment scale
- current and future climate variability
- emissions scenarios (for studies that consider the 2050s and beyond)
- the uncertainty inherent to hydrological models at catchment scales.

Reference: UKWIR, 2005. Climate change uncertainty in water resources planning – final report. UKWIR Report 05/CL/04/4, in press.

Figure 3. Part of the proposed new CL/04 framework for dealing with climate change uncertainties. There will be simpler methods for flow factoring (FF) as well as more sophisticated hydrological or rainfall-runoff (RR) modelling



Output

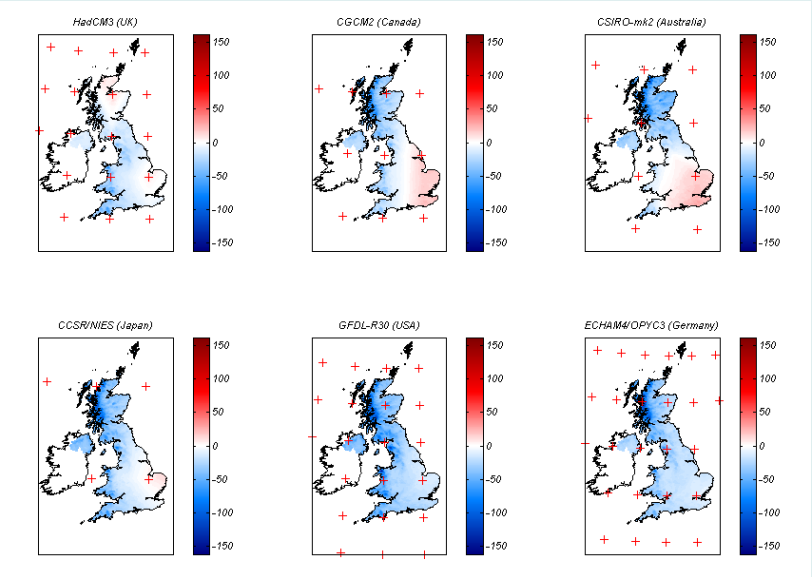
UKWIR (2005), *Effect of Climate Change on River Flows and Groundwater Recharge, A Practical Methodology and A Strategy for Evaluating Uncertainty in Assessing the Impacts of Climate Change on Water Resources*. UKWIR Report 05/CL/04/6, to be issued.

Making use of several Global Climate Models (GCMs)

HR Wallingford is reviewing six GCMs from research centres in Japan, Australia, Canada, the US, Germany and the UK. They are developing a range of techniques for the research project including methods for correcting prediction and scaling errors or 'bias' in GCMs and weighting models according to how well they reproduce the 1961-1990 climate in terms of precipitation and potential evapotranspiration (see figure 4, overleaf)

This research will provide a new set of rainfall and PET factors based on several GCMs that can be used by water companies and the Environment Agency in their own modelling studies.

Figure 4. Differences between average August rainfall from different GCMs (disaggregated to a 5km grid using 'spatial-pattern' scaling) for the 1961-1990 and corresponding observed average. White shows a good fit, red indicates an overestimate of rainfall and blue indicates an underestimate of rainfall



Future consultation as part of this project

The project will be holding further workshops in 2006 and March 2007

The objectives of the next project workshops are:-

- to present outputs from the pilot study of the modelling framework. This will include examples of how the framework is applied to a range of water resource planning situations and detail how the outputs from this project will address uncertainty due to climate change in different ways, depending on specific resource zone circumstances
- to present draft tools and guidance for assessing the impacts of climate change on groundwater levels
- to provide 'hands-on' practical guidance to resource planners within water companies and regulators on the application of the methods and guidance coming out of this project, ahead of the next Periodic Review.

UKCIPNext

In 2005, UKWIR hosted a presentation from the Hadley Centre on the next generation of UKCIP climate change scenarios. The 'UKCIPnext' scenarios will present rainfall and PET data in probabilistic form – something that water resource engineers, familiar with dealing with probability and risk, have wanted for many years.

Therefore, it is important that the current project is able to accommodate the UKCIPnext scenarios. To this end, the project team (with the help of Claire Barnett from the Met Office) will develop a method that is 'primed' for use with the next generation of scenarios.

Work in progress

The project work programme is structured around 10 tasks, three of which are substantially complete, five tasks are ongoing and the final two tasks are programmed towards the end of the study in Winter 2006/7.

No	Task Name		Comments
1.	Develop climate change scenarios for the 2020s	✓	To release a final CD Rom that includes data from several GCMs
2.	Develop a more rigorous approach to uncertainty	✓	Draft methodology complete but more work required to develop practical guidance.
3.	Examine the relationship between flow factors and characteristics	⇨	In progress. Based on developing rainfall-runoff models catchment for 70 catchments
4.	Re-calculate factors, taking account of the 'regionalisation work'	⇨	
5.	Effects of climate change on groundwater recharge	⇨	In progress
6.	Probabilistic interpretation of likely changes in river flows and recharge	⇨	Presentation of outputs of tasks 3 to 5
7.	Trend analysis on UK gauged river flows over the period 1970-2002	☑	Complete
8.	'Reverse impact study'	☞	A study to test whether hydrological models can reproduce flow series 'perturbed' by flow factors for the 2020s
9 .	Year to year variability	☞	Tools and guidance for handling changes in the year to year variation of future climate
10	User workshops & seminars	⇨	Further workshops planned in March 2006

⇨ *In progress,* ✓ *Complete in draft,* ☑ *Complete,* ☞ *Scheduled for later in project programme*

Project partners and further information

Project Sponsors: UKWIR and Environment Agency

Contractors: HR Wallingford (project manager, Steven Wade), supported by Entec, Met Office and University of Lancaster

Project Management: UKWIR (client manager Dave Cook, project manager Richard Kirby)

Project Steering Group: Anglian Water, Environment Agency, Scottish Water, Southern Water, South-West Water, Thames Water, United Utilities, Veolia Water, Yorkshire Water

For queries concerning the project contact r.kirby@ntlworld.com. All report outputs are available directly from UKWIR – www.ukwir.org.uk. Information on the project, including newsletters and related publications from the project team, are available on www.futuredrought.org.uk.