Department for Environment Food & Rural Affairs

Llywodraeth Cymru
Welsh Government

Cyfoeth Naturiol Cymru
Natural Resources Wales

Environment Agency

delivering benefits through evidence

Understanding the performance of flood forecasting models

Report – SC130006/R

Flood and Coastal Erosion Risk Management Research and Development Programme

We are the Environment Agency. We protect and improve the environment.

Acting to reduce the impacts of a changing climate on people and wildlife is at the heart of everything we do.

We reduce the risks to people, properties and businesses from flooding and coastal erosion.

We protect and improve the quality of water, making sure there is enough for people, businesses, agriculture and the environment. Our work helps to ensure people can enjoy the water environment through angling and navigation.

We look after land quality, promote sustainable land management and help protect and enhance wildlife habitats. And we work closely with businesses to help them comply with environmental regulations.

We can't do this alone. We work with government, local councils, businesses, civil society groups and communities to make our environment a better place for people and wildlife.

Published by:
Environment Agency, Horizon House, Deanery Road, Bristol, BS1 9AH
www.environment-agency.gov.uk

ISBN: 978-1-84911-408-0

Email: fcerm.evidence@environment-agency.gov.uk

Further copies of this report are available from our publications catalogue:
http://www.gov.uk/government/publications

or our National Customer Contact Centre:
T: 03708 506506

Email: enquiries@environment-agency.gov.uk

Author(s):
Robson, A.J., Moore, R.J., Wells, S.C., Rudd, A., Cole, S.J., Mattingley, P.S.

Dissemination Status:
Publically available

Keywords:
Flood Forecasting, Model Performance, Rainfall-Runoff, Distributed, G2G

Research Contractor:
Centre for Ecology and Hydrology, Wallingford, Oxfordshire, OX10 8BB. Project Manager: Robert Moore, 01491 692262

Environment Agency's Project Manager:
Chrissy Mitchell, Evidence Directorate

Theme Manager:
Sue Manson, Incident Management and Modelling

Project Number:
SC130006

Evidence at the Environment Agency

Scientific research and analysis underpins everything the Environment Agency does. It helps us to understand and manage the environment effectively. Our own experts work with leading scientific organisations, universities and other parts of the Defra group to bring the best knowledge to bear on the environmental problems that we face now and in the future. Our scientific work is published as summaries and reports, freely available to all.

This report is the result of research commissioned and funded by the Joint Flood and Coastal Erosion Risk Management Research and Development Programme. The Joint Programme is jointly overseen by Defra, the Environment Agency, Natural Resources Wales and the Welsh Government on behalf of all Risk Management Authorities in England and Wales:
http://evidence.environment-agency.gov.uk/FCERM/en/Default/FCRM.aspx.

You can find out more about our current science programmes at:
https://www.gov.uk/government/organisations/environment-agency/about/research.

If you have any comments or questions about this report or the Environment Agency's other scientific work, please contact research@environment-agency.gov.uk.

Professor Doug Wilson
Director, Research, Analysis and Evaluation

Executive summary

Understanding the performance of flood forecasting models - operated in real-time by the Environment Agency, Natural Resources Wales and the national Flood Forecasting Centre - is crucial to their informed use for flood guidance across England & Wales. It is also essential to guide future strategic investment in flood incident management.

This report presents the results from the first nationwide analysis of flood forecasting model performance across implementations by local centres of the National Flood Forecasting System (NFFS). It considers regional and model-type differences and presents an overview of the current forecasting capability of models in operational use. Previous forecast performance studies of local models were performed on a grouped-catchment or regional basis and not necessarily using a consistent assessment framework. Spatial analysis of flood forecasting model performance in this report is based on Wales and the English geographical regions that align to the old Environment Agency region names.

The report also extends the forecast model performance information available for the Grid-to-Grid (G2G) model, a distributed grid-based hydrological model with rainfall-runoff and flow routing elements. G2G is implemented within the NFFS for the Flood Forecasting Centre as an area-wide national model across England & Wales. The G2G model forecasts are compared with those from the local models which span a variety of model-types: rainfall-runoff models of conceptual and transfer function form, and channel flow routing models of hydrological and hydrodynamic form.

The approach taken to performance assessment has been to gather “raw” data (river flow observations, flow forecasts and historical simulation of flows) from previous local model performance studies. While there are significant regional differences in how these data were gathered and in the methodologies used to generate flood forecast model outputs, collation of the underlying “project” datasets has allowed standardisation of the methods of assessment used here.

This report presents the background to a flood forecasting model “Performance Summary”, as a template for reporting performance at any site from a given model-type, including the underlying performance measures employed. The Performance Summary takes the form of one A4 page for each model at each site, and contains a variety of different performance measures and graphical displays. Just under 1,800 Performance Summary pages have been produced for those working in an operational setting or in strategic planning.

The results contained in the Performance Summary for each site and model combination have been brought together and used as the basis of a national analysis and summary. This constitutes an extensive national evidence base of model performance, stratified by model-type, model-group, geographical region and lead-time. Where there is a choice of model forecast, it also includes information on comparative performance.

Recommendations and important findings

- There is a need for standardisation across local flood forecasting model performance (FFMP) methodologies. For example, models should use the same rainfall scenarios and the model output time-interval should be standardised to 15 minutes.

- The creation of a national FFMP database, with a well-defined submission format and quality control, is urged. All new FFMP studies should be required to provide the project dataset in this standard format.
- There is also a need for models that perform better at longer lead-times, particularly for the South West and parts of the North West where Physically Realisable Transfer Function (PRTF) models are used.
- On a regional basis, the North East and North West have the strongest forecasting performance. Anglian, Thames and Southern regions do less well. This demarcation is to be expected because of the much more challenging hydrological conditions (flatter catchments, groundwater, river management) in the south and east of England.
- Compounded regional and model differences mean that it is not generally possible to know whether one local model outperforms another. Nevertheless, the best performing models revealed by this study are usually the Probability Distributed Model (PDM), the extended Kinematic Wave (KW) model and the hydrodynamic river model ISIS.
- As would be expected, the national G2G model performs less well than local models at a number of sites. It also performs better than some local models and for some regions especially at longer lead-times.
- Comparison of G2G with local models on a model-by-model basis shows huge variability. For example, on average PDM models outperform G2G, but there are many sites for which the opposite is true.
- Local models require at-site calibration and provide forecasts only for this site when they are of the rainfall-runoff type and for locations along a gauged river reach when of the river model type. G2G provides forecasts everywhere across its model domain (the non-tidal river basins of England and Wales) at a 1km grid resolution. In addition, G2G gives a spatially coherent picture of flood evolution, in contrast to the gauging station specific forecasts produced by local rainfall-runoff models.
- The Performance Summary provides, on a single A4 page, a concise summary of model performance along with hydrometric details for a given site and model. It should be made available to operational users of the NFFS via the tooltip functionality of NFFS map displays.
- An extensive national evidence base of model performance has been created, stratified by model type, model group, geographical region and lead-time. It also includes information on comparative performance where a choice of model forecast exists. This evidence base is seen as of particular value for strategic planning relating to investment in flood forecasting models.
- Accessing, viewing and assessing the wealth of model performance information in appropriate ways is challenging and is dependent on the intended use, for example, in supporting real-time decision-making or in guiding offline strategic investment decisions. Interactive and easily accessible methods of viewing the performance information should be considered, such as that offered by the prototype FFMP web portal being developed by the Centre for Ecology & Hydrology.
- The Performance Summary framework was designed to be readily refreshed to include new datasets from consultants as they become available or are commissioned. Recommendations are made to make this

process more efficient and the model assessments more meaningful and useful, both in incident management and for guiding strategic investment in flood forecasting models.

Acknowledgements

The support and guidance of the Environment Agency members of the Project Board - Chrissy Mitchell, Tim Harrison, Lindsay Ness and David Hill - is gratefully acknowledged. Contributions by Environment Agency and Flood Forecasting Centre staff who attended the Project Planning Workshop on 3 June 2013 are also acknowledged.

Paul Wass and Odell Harrison (JBA Consulting), Clive Powis (Plan B UK) and Murray Dale (CH2M) are thanked for their work in providing datasets on the performance of local forecast models carried out under past contracted work for the Environment Agency and Natural Resources Wales.

Contents

List of figures

List of tables

1 Introduction

1.1 Background

This is the final report for the Joint Defra and Environment Agency FCRM R&D Research Project SC130006 “Understanding the performance of flood forecasting models to guide investment in flood incident management”. The Performance of Flood Forecasting Models project aims to provide the Environment Agency and Natural Resources Wales, for the first time, with a national baseline assessment of the performance of the local flood forecasting models operated within their regional systems. Its findings will also enable a comparison to be made of how the national Grid-to-Grid (G2G) model (Moore et al. 2006, Environment Agency 2007) performs relative to these local models. This evidence can then be used to better direct future investment in real-time modelling, and will provide useful evidence to incident management to help promote a forecast-led service.

The overall aim of the project is an integrated analysis of information from past local model assessments and from the national G2G model. This serves the purpose of providing a performance assessment of both local model and G2G model forecasts and, for sites in common, a comparison of performance.

Spatial analysis of flood forecasting model performance in this report is based on Wales and the English geographical regions that align to the old Environment Agency region names. This geographical analysis of performance is important in relation to:

- how these regions and Wales differ hydrologically in broad terms
- a legacy of local model choice within the old Environment Agency regions

The Environment Agency flood forecasting service now operates from separate centres with responsibilities for these geographical regions and with separate instances of the National Flood Forecasting System (NFFS) configured using networks of local models for each. This geographical region and centre demarcation is as follows:

- Anglian – Peterborough
- Midlands – Solihull
- North East – Leeds
- North West – Warrington
- Southern – Worthing
- South West - Exeter
- Thames – Reading

The service for Wales is now under the authority of Natural Resources Wales with its headquarters in Cardiff.

1.2 Scope of work

When the project began, the broad scope of work was divided into four tasks with a fifth added later as outlined below.

1.2.1 Task 1: Review and understanding

This task reviewed the existing Environment Agency Performance Framework, past performance assessments of local models undertaken by consultants, and the Performance Summary of the G2G model (CEH 2013) prepared by the Centre for Ecology & Hydrology (CEH).

The outcome was an assessment strategy that could draw on the information available in both local model and G2G assessments while recognising the general requirements identified in the Environment Agency Performance Framework.

A critical element was identifying the underlying datasets needed to carry out the assessment in an objective and efficient way.

1.2.2 Task 2: Local model assessments

Previous assessments of local models were identified through a workshop and through interaction with supplier consultants. Arrangements were made to obtain the relevant datasets in a form designed and agreed to be appropriate. Any further supporting datasets, such as warning thresholds and drained areas, were identified and requested from the Environment Agency.

The datasets were managed by CEH to enable it to carry out the performance assessment using suitably chosen and agreed metrics for both local and G2G models, and a performance comparison for sites in common.

From the local model performance datasets provided by supplier consultants, an overview of local model performance across England and Wales was obtained and reported on.

1.2.3 Task 3: G2G model performance comparison

This task used the metrics agreed under Task 2 to carry out a similar performance assessment at gauged sites for the G2G model as implemented across England and Wales for the Flood Forecasting Centre. This drew on the G2G model data holdings recently updated for the 'G2G for Rapid Response Catchments' project (Environment Agency 2014).

The task was implemented so as to allow comparable performance assessments with local models in relation to common sites and periods of assessment.

An overview of the relative performance of G2G and local models was produced and reported on. This evidence was used to make provisional recommendations, with regard to regionally implemented local models and the nationally implemented G2G model, on where future model investment would be best directed.

1.2.4 Task 4: Workshops and project meetings

The inception workshop reviewed the project aims and direction, and helped to guide planning of the way forward.

1.2.5 A dissemination workshop is planned to close the project with reports on its findings and recommendations. Task 5: Project extension to fill gaps in data

After gathering all known project datasets and assimilating the available data, some significant gaps in site coverage across England were identified. An extension to the project was agreed to include analysis of project datasets for these additional sites.

1.3 Structure of the report

Section 1 provides the context for the work described in the report.

Section 2 details planning of the project against existing information and the outcome of an inception workshop where design considerations were determined, helped by advice from regional experts.

Section 3 provides an introduction to the local models and national G2G models featuring in the performance assessment of the flood forecasting models.

An overview of the project datasets from past performance assessment studies collected for the project is presented in Section 4. The location and characteristics of the analysed sites are examined and various underlying differences in the datasets produced for different regions are noted (for example, some regions employ models with a 1-hour time-step rather than 15 minutes).

Section 5 describes the statistical methods chosen for the performance analyses.

Section 6 explains the Flood Forecasting Model Performance Summary developed by this project, which provides a concise summary of performance at each site for a given model.

A national analysis of performance is presented in Section 7 where a range of statistics are examined that measure model performance in a variety of ways. Regional differences and model differences are considered and the performance of local models compared with the national G2G model.

A set of recommendations for improving flood forecasting models and future model performance studies is provided in Section 8 along with the study's conclusions.

Appendices to the report contain additional supporting material of a more detailed nature.

2 Project planning and design

This section summarises some of the planning and design work carried out for this project. It begins with an overview of the inception workshop. This is followed by consideration of the design for implementing the assessment, against the background of:

- the Environment Agency's framework and pro forma for assessment
- local model assessment reports commissioned by the Environment Agency and the availability of datasets from these assessments
- CEH's G2G Performance Summary template

Subsequent sections address the detailed design of the assessment framework and its reporting template. This is followed by its application to datasets from model performance assessments carried out to date to achieve a consistent approach to assessment with coverage across England and Wales.

2.1 Inception workshop

The aim of the inception workshop on 3 June 2013 was to support project planning and engagement. Attendees included representatives from the Environment Agency's Evidence Directorate and flood forecasting regional specialists from the Environment Agency and the Flood Forecasting Centre; a representative from Natural Resources Wales was unable to attend. The project research contractor (CEH) also participated in the workshop, along with a provider of past regional model assessments (JBA Consulting).

A questionnaire for completion by regional specialists (see Box 2.1) was prepared before the workshop to support strategy planning.

Box 2.1: Questions for regional specialists at the inception workshop

1. How many fluvial river gauging sites require forecasting model performance assessment (a) as FWLoS forecast points and (b) as non-FWLoS forecast points (for example, as forecast lateral inflows to a river routing model)? Please provide information on any assessments which will have been completed by November 2013, including the name of the Environment Agency principal contact and that of the consultant (if employed).

2. How many sites do you already have the time-series data used for the calculation of performance assessments/skill scores (for example, observed flow/level, simulated/forecast flow/level)? If not, for how many sites can consultants readily provide them from completed assessments?

3. If model assessment time-series data are available, what format are these in (csv, xls, xml, NFFS exported, other, unknown). Please provide an example or details if possible.

4. If you do not have/cannot access any time-series data, do you have some form of 'database' of performance assessments/skill scores for your sites and in what format are these in (for example, xls, csv, xml, other)? Please provide an example or details if possible.

Note: FWLoS stands for Flood Warning Level of Service and NFFS is the National Flood Forecasting System.

This information was collated and used to scope the work and the approach to be taken prior to the project being contracted to CEH.

The questionnaire responses and workshop discussion identified JBA Consulting as the dominant supplier of local model assessments. Plan B UK were also identified along with

Halcrow (now CH2M) as suppliers. Past collaboration between JBA and Plan B UK resulted in a proposal, subsequently agreed with the Environment Agency, for JBA to be subcontracted to CEH to supply datasets on behalf of both consultants.

At a later stage of the project, supply of CH2M assessment datasets were included in the project as an extension, with CH2M contracted by the Environment Agency to supply directly to CEH.

One action from the workshop was for Environment Agency regional specialists to supply a list of river gauging station locations for which there was a desire for a flood forecasting service where there is currently none. This served to identify sites where there was a potential demand for G2G forecasts from local centre teams. The Environment Agency regional specialists were also asked for the detailed ancillary information required to support the project such as flood warning levels and drained areas for gauged sites. It was also agreed that the scope was to be limited to non-tidal river gauged sites.

The workshop exposed the fact that, in some cases, assessments had been done at an hourly, rather than 15 minute, time-step. Forecasts may also not be made on the hour. G2G would need to be rerun every hour to give a reasonable but not exact match.

It was also agreed that the assessment outputs/reports would be designed to make best use of ideas in past local assessment reports, the G2G Performance Summary and the Environment Agency Performance Framework. However, it was recognised that some of the sophistication in these local assessments was not practical for this project because of its broader scope.

2.2 Design considerations

2.2.1 Environment Agency framework and pro forma

The Environment Agency proposed a draft framework for assessment and an accompanying pro forma for consideration at the inception workshop. The draft was entitled 'Forecasting Model Performance Measurement Framework: Pro Forma for Data Collation to Support Integrated Analysis'. CEH's response to its review of this draft was given in a document entitled 'CEH Initial Review and Recommendation' dated 25 April 2013.

The pro forma took the form of a Microsoft® Word document with entries giving such information as the forecast point, model type, assessment period, thresholds, assessment graphs, commentary information in text form, and contingency table entries and skill scores (POD, the Probability of Detection and FAR, the False Alarm Ratio) in forecast and operational mode.

In its response, CEH advised that the pro forma, while a useful form for summarising performance, did not provide a natural or efficient approach for collating the information required from the local forecast model assessments commissioned by the Environment Agency in the past. The entries were not in a controlled form and, along with the use of Word, not suitable for automated analysis across of the order of a thousand sites and for multiple forms of analysis. It would not be a simple undertaking to transfer the information to a Microsoft® Excel spreadsheet with controlled data entries suitable for automated analysis. Nor would its completion by suppliers of local forecast model assessments.

2.2.2 A forecast model performance database

A fresh approach was clearly needed, though building on the information the pro forma sought to capture. CEH's review suggested a way forward that also took account of the

Environment Agency's strategic requirements for forecasting performance assessment in the longer-term.

For long-term progression, flexibility and sustainability, it was recommended to build a simple database of forecasting model outputs. This database should contain the observed and forecast flows for all periods that are assessed for forecasting model performance. The database could initially be a set of easily read files, for example, in csv format. This would allow rapid conversion to a more formal database in due course. It would be a format that future studies could readily add to.

The form of this database was the subject of subsequent discussion with JBA, aligned to how its performance datasets could be provided in relation to forecast and observed flows/levels and associated ancillary information (catchment, model, forecast type, lead-time, warning level and so on). After some initial attempts, agreement was reached on the broad form of datasets to be provided.

Datasets were received from JBA, CH2M and Plan B UK. JBA's datasets, the largest proportion of the data, represented several phases of forecast model performance work. Later datasets had been produced in a more sophisticated way, while earlier datasets lacked historical simulation data.

2.2.3 Consideration of forms of performance assessment

An important outcome of the planning deliberations was to modify the project approach to collect time-series data of observed and forecast flow/level rather than the measures and other derived outputs on performance. These time-series data can be subject to a consistent performance analysis and reporting procedure, serving both past local assessments and future ones, and be open for future modification and extension.

The Performance of Flood Forecasting Models project was seen as relatively ambitious, aiming both to provide model comparisons and to set up a database that can be used for future comparisons.

Having modified the approach of the project to assimilate the model performance data directly, this meant much more choice over what to include in the Performance Summary. Several discussion documents were produced and several rounds of technical discussions were held. These were instrumental in designing the form of the Flood Forecasting Model Performance Summary and the statistical approach behind it. The results of this process are presented in Sections 5 and 6.

2.3 Using regional expertise

The project benefited enormously from the input of regional experts from the Environment Agency and Natural Resources Wales. This included:

- advice at the project inception stage
- details of forecasting locations
- regional assistance in determining which of the datasets from previous flood forecasting model performance (FFMP) studies should be employed

CEH was also able to send out draft versions of the Flood Forecasting Model Performance Summary to the regional experts and to request feedback on particular issues on a site-by-site basis. The input from the regional experts was most beneficial and allowed for quality control and correction.

3 Models for performance assessment

3.1 Introduction

The models considered in this performance assessment of flood forecasting models are:

- the ‘local’ models used in model networks applied on a regional basis
- the ‘national’ model with England and Wales coverage

The local models consist of:

- rainfall-runoff models of conceptual and transfer function type and, in some cases, having a snowmelt component
- channel flow routing models of hydrological and hydrodynamic type

The national model is the Grid-to-Grid (G2G) distributed hydrological model with area-wide coverage and forecasting river flows on a 1km grid.

The conceptual rainfall-runoff models are:

- Probability Distributed Model (PDM)
- Midlands Catchment Runoff Model (MCRM)
- Thames Catchment Model (TCM)

The transfer function model is the Physically Realisable Transfer Function (PRTF), though this is amenable to conceptual interpretation.

The hydrological routing models are KW (extended kinematic wave) and DODO while the hydrodynamic routing models are ISIS and MIKE 11.

A brief outline of each of these models is given below by way of background. These models have the ability to perform data assimilation of river flow, either through autoregressive moving average (ARMA) error prediction, state updating or direct flow insertion, to obtain updated real-time forecasts. The models may also be operated in simulation mode where model inputs are transformed to outputs without reference to observations of the outputs (except when initialising the model).

The time-step of the model forecasts is normally 15 minutes, aligned to the time interval of river flow data. Exceptions are the local models across the Severn and Trent rivers in the Midlands which have operated at an hourly time-step as standard; use of a 15-minute time-step is an ongoing development (see, for example, Robson and Moore 2009). Some of the PRTF models in the South West also operate at an hourly interval.

When assessing model performance it is important to bear in mind that rainfall-runoff modelling – especially at times of snow – is inherently more uncertain than channel flow routing. This needs to be taken into consideration when comparing across different model groups. The reasons relate to the difficulty of estimating spatial rainfall and the complexity of the processes operating within a catchment; this contrasts with the ability to use observations of upstream and lateral river flows in channel flow routing, helping to get the flow volumes right.

3.2 Rainfall-runoff models

3.2.1 Conceptual (PDM, TCM, MCRM)

PDM

The Probability Distributed Model, PDM, is a fairly general conceptual rainfall-runoff model which transforms rainfall and potential evaporation data to river flow at the catchment outlet (Moore 1985, Moore 1999, Moore 2007, CEH 2012a). It was designed more as a toolkit of model components than a fixed model construct. A number of options are available in the overall model formulation, allowing a broad range of hydrological behaviours to be represented.

Runoff production at a point in the catchment is controlled by the absorption capacity of the soil to take up water: this can be conceptualised as a simple store with a given storage capacity. Given that different points in a catchment have differing storage capacities and that the spatial variation of capacity can be described by a probability distribution, it is possible to formulate a simple runoff production model which integrates the point runoffs to yield the catchment surface runoff into surface storage.

The standard form of PDM employs a Pareto distribution of store capacities, with a shape parameter controlling the form of variation between minimum and maximum values of the storage capacity across the catchment. Drainage from the probability-distributed moisture store passes into subsurface storage as recharge. The rate of drainage is in proportion to the water in store in excess of a tension water storage threshold.

The subsurface storage, representing translation along slow pathways to the basin outlet, is commonly chosen to be of cubic form, with outflow proportional to the cube of the water in store. An extended subsurface storage component (Moore and Bell 2002, Cole et al*.* 2009) can be used to represent pumped abstractions from groundwater; losses to underflow and external springs can also be accommodated.

Runoff generated from the saturated probability-distributed moisture stores contributes to the surface storage, representing the fast pathways to the basin outlet. This is most normally modelled by a cascade of 2 linear reservoirs cast as an equivalent transfer function model (O’Connor 1982). The outflow from surface and subsurface storages, together with any fixed flow representing, say, compensation releases from reservoirs or constant abstractions, forms the model output.

PDM can be used in combination with CEH’s PACK model to represent snowmelt conditions (Moore 1999).

For real-time use, data assimilation of river flows can be invoked using either state updating or ARMA error prediction to obtain updated forecasts of river flow.

MCRM

The Midlands Catchment Runoff Model, MCRM, is a classical conceptual rainfall-runoff model based on water storage accounting principles applied to soil- and ground-water and river channels (Bailey and Dobson 1981, Wallingford Water 1995, Robson and Moore 2009). It employs an interception store, a soil moisture store and a groundwater store in sequence. Rapid runoff is generated from the soil moisture store, with the fraction of the input to the store becoming runoff increasing exponentially with decreasing soil moisture deficit. ‘Percolation’ to the groundwater store occurs when the soil is supersaturated, increasing as a linear function of the negative deficit. When supersaturation exceeds a critical value, ‘rapid drainage’ also occurs as a power function of the negative deficit in excess of the critical value – the so-called excess water. This rapid drainage along with rapid runoff forms the soil store runoff. Evaporation occurs preferentially from the interception store at a rate which is a fixed proportion of the catchment potential evaporation. A proportion of any residual evaporation demand is then met by water in the soil store, the proportion varying as a function of the soil moisture deficit. Drainage of the groundwater store to baseflow varies as a power function (with exponent 1.5) of water in storage.

The total output, made up of baseflow and soil store runoff, is then lagged and spread evenly over a specified duration to represent the effect of translation of water from the ground to the catchment outlet. Finally, the flow is smoothed using 2 nonlinear storage functions, one for routing in-bank flow and the other out-of-bank flow; the 2 components are summed to give the catchment model outflow.

MCRM also has components representing snowmelt (see the reviews by Harding and Moore 1988, Moore et al. 1996), reservoir routing and, for use in real-time, river flow data assimilation via a form of error prediction called the 'Error Forecast Model'. The latter examines the difference between observed and simulated outflows over the last 6 hours of the hindcast period. A judgement is made on how predictable future errors are and forecast outflows are adjusted accordingly. These components are documented by Robson and Moore (2009), which also describe the extension of MCRM to run at a 15-minute time-step rather than the hourly time-step currently in use operationally.

TCM (and TCM ARMA)

The structure of the Thames Catchment Model, or TCM (Greenfield 1984, Wilby et al. 1994, Environment Agency 2001a, CEH 2012b), is based on a spatial subdivision of a basin into different response zones representing, for example, runoff from aquifer, clay, riparian and paved areas and sewage effluent sources. Within each zone the same vertical conceptualisation of water movement is used, the different characteristic responses from the zonal areas being achieved through an appropriate choice of parameter set, some negating the effect of a particular component used in the vertical conceptualisation. The zonal flows are summed, passed through a simple routing model (optional) and go to make up the total flow at the catchment outlet.

The same conceptual representation of a hydrological response zone is used for all types of response zone, but with differing nomenclature; for example, percolation is better described as rainfall excess for zones other than aquifer. Within a given zone, water movement in the soil is controlled by the classical Penman storage configuration (Penman 1950). This has a near-surface storage of depth related to the rooting depth of the associated vegetation and to the soil moisture retention characteristics of the soil (the root constant depth). It drains only when full into a lower storage of notional infinite depth. Evaporation occurs at the Penman potential rate while the upper store contains water and at a lower rate when only water from the lower store is available. The Penman stores are replenished by rainfall, but a fraction (typically 0.15, and usually only relevant to aquifer zones) is bypassed to contribute directly as percolation to a lower 'unsaturated storage'. Percolation occurs from the Penman stores only when the total soil moisture deficit has been made up.

The total percolation forms the input to the unsaturated storage. This behaves as a linear reservoir, releasing water in proportion to the water stored at a rate controlled by the reservoir time constant. This outflow represents 'recharge' to a further storage representing storage of water below the phreatic surface in an aquifer. Withdrawals are allowed from this storage to allow pumped groundwater abstractions to be represented. A quadratic storage representation is used, with outflow proportional to the square of the water in store and controlled by the nonlinear storage constant.

Total basin runoff derives from the sum of the flows from the quadratic store of each zonal component of the model delayed by a delay time parameter. Provision is also made to include a constant contribution from an effluent zone if required. An extension of the original TCM passes the combined flows through an additional channel flow routing component if required. This extension derives from the KW channel flow routing model developed by CEH (Moore and Jones 1978, Jones and Moore 1980) which, in its basic form, takes the kinematic wave speed as fixed. The model employs a finite difference approximation to the kinematic wave model with lateral inflow. The delay and attenuation of the flood wave are controlled by the spatial discretisation used and a dimensionless wave speed parameter.

For real-time use, river flow data assimilation by the TCM through state updating or ARMA error prediction can be invoked to obtain updated forecasts of river flow. Where a model is referred to as TCM ARMA, this indicates that a recursive updating of the ARMA model parameters is invoked (as provided by Deltares) as opposed to the fixed ARMA parameter form (as provided by CEH).

3.2.2 Transfer function

PRTF

Transfer function models are a class of time-series models popularised by Box and Jenkins (1970). They are linear models where an output variable can be forecast as a linear weighted combination of past outputs and inputs. In a rainfall-runoff context, the output is usually flow (or baseflow-separated flow) and the input rainfall (or effective rainfall). Any residual model error can be represented through a noise model which is normally of ARMA form. The overall model is termed a transfer function noise (TFN) model.

The Physically Realisable Transfer Function or PRTF model (Han 1991, Yang and Han 2006) is a form of transfer function model. The basic idea in formulating the PRTF model is to choose a parameterisation which constrains the impulse response function to have a physically realistic form in a hydrological context. Primarily, this means that it should be positive and not exhibit oscillatory behaviour (that is, it is stable). This is achieved by replacing the set of autoregressive parameters by a single, related parameter. Provided the parameter is greater than unity, this ‘equal root’ parameterisation gives a stable impulse response function, though this results in a more restricted form of transfer function model. To make the parameter more physically intuitive it is recast as a time-to-peak parameter.

Han (1991) recognised that the PRTF model, with its fixed impulse response function, would not provide an adequate representation of the rainfall-runoff process which is both nonlinear and time variant. He chose to address this problem by adjusting the form of the impulse response function to reflect each flood situation as it is encountered in real-time. To ease this task, Han introduced 3 types of adjustment factor designed to alter the volume, shape and time response of the transfer function model.

Practitioners can encounter difficulties in implementing such simple adjustments, especially for fast responding catchments and where forecasts from many catchments may be required. The PRTF model was originally used in the North West and South West regions in a form that required manual adjustment of the 3 factors controlling the volume, shape and time response of the model as the flood developed to gain better agreement between past observed and forecast flows. This approach is not automatic or objective.

The PRTF model is normally used in real-time with data assimilation of river flow data. Full state correction is usually applied. This correction essentially exploits the transfer function form, with (autoregressive) dependence on past flows, allowing direct insertion of observed flows in the model as they are received.

Model gain updating can be applied to control the proportion of rainfall that becomes runoff (or baseflow-separated runoff). A time-varying model gain parameter has been used in the past; see Cluckie and Owens (1987) and Environment Agency (2001a) for details.

Introducing model dependence on catchment state is the variant of the PRTF now used in operational practice. Current operational use of the PRTF model in the NFFS by the Environment Agency is restricted to the South West and parts of the North West.

Different PRTF models are available depending on the catchment state, as defined by the Catchment Wetness Index (CWI). In the South West, an automatic selection procedure is invoked to choose between usually 2 pre-calibrated PRTF models (Pollard and Han 2012). In the North West, a default PRTF model is used, irrespective of catchment wetness (generally the 'wet' model); the Flood Duty Officer is able to decide to run other versions, though this rarely happens.

The PRTF within the NFFS runs as a 'cold start' model and is automatically initialised on a stable baseflow before the onset of an event. In the South West, the older models employ total rainfall as input and employ a CWI to define catchment state. The most recent models employ 'effective rainfall' as input, defined as a product of rainfall and the Soil Moisture Index, SMI, as used in IHACRES (a rainfall-runoff model employing a unit hydrograph in transfer function model form). SMI is a measure of catchment state, calculated from past rainfalls.

Two PRTF models are calibrated offline, one for events with a saturated initial catchment state (based on CWI). The PRTF module in the NFFS automatically chooses which PRTF model to use based on the CWI at the start of the event to be forecast. It is this model, with direct flow insertion of observed flows, which is identified here as the 'simulation mode' PRTF modelled flow. The 'forecast mode' PRTF modelled flows are obtained using an error prediction scheme that is autoregressive of order 1 with a fixed parameter of 0.95 used for a 1 hour time-step model. The PRTF simulation mode flow is added to the predicted error to give the forecast mode flow. The model is run to produce 15 minute flow forecasts in the North West and a mixture of 15 minute and hourly forecasts in the South West.

3.3 River flow routing models

3.3.1 Hydrological routing models (KW, DODO)

KW

Developed by CEH, the extended Kinematic Wave model provides a simple way of routing flow from upstream to downstream river gauging stations. Once flow from an upstream catchment has been estimated using a rainfall-runoff model, the KW model can be used to:

- route the flow downstream
- incorporate inflows along the way from other tributary streams

Through its use of empirical functions, the KW model is especially suited to situations where auxiliary information, such as channel survey data, is unavailable.

The KW model is based on a finite difference approximation to the kinematic wave model, but has been extended to include the following functions:

- a choice of relations linking wave speed to discharge including cubic, linear-exponential and piecewise-linear functions
- threshold storage functions representing channel overspill onto floodplains, with the option to enforce mass balance of returned flows to the channel
- estimation of ungauged lateral inflows

- incorporation of stage–discharge relations within the model to permit calibration at sites where no rating exists
- model calibration by automatic optimisation and by interactive visualisation
- forecast updating, using error prediction, for real-time applications

The KW model cannot be used for channels experiencing significant backwater effects due to tides, confluences and river control structures.

Further details are given in Moore (1999) and CEH (2012c).

DODO

The hydrological channel flow routing model used in the Midlands across the Severn and Trent basins is called DODO (Douglas and Dobson 1987). This is based on the Muskingum storage function, which relates the volume of water stored in a river reach at a given time to the reach inflow and reach outflow. Thus channel storage is considered to be the sum of 2 components:

- the prism storage – proportional to the outflow
- the wedge storage – proportional to the inflow less the outflow.

The effect of wedge storage is to increase the total storage on the rising limb and decrease it when falling, leading to a hysteresis loop in the relation between reach outflow and storage.

In the DODO model, the reach input is the input delayed by a pure time delay, which is allowed to vary as a function of discharge. This extension to the basic Muskingum model, along with a way of representing static storage and flow on floodplains, are the main features of DODO.

The component of reach inflow above the bankfull discharge is routed through a parallel, second Muskingum storage, after accounting for an initial contribution to static floodplain storage. On the flood recession, water in static storage drains out of the reach, initially slowly, but then freely below a critical return bankfull storage; this threshold is a power function of the volume of water in static floodplain storage. This allows the model to mimic the behaviour of submerged flapped outfalls from washlands. Lateral inflows to the reach are divided equally between the reach inflow and the reach outflow; a downstream input can also be added to the routed outflow to give the final reach outflow.

For real-time flood forecasting, a form of error prediction called the ‘Error Forecast Model’ is used to obtain updated forecasts of river flow from DODO. This is discussed in Section 3.2.1 in the section on the MCRM model, which also employs this approach.

Detailed documentation of the DODO model is given in Wallingford Water (1995).

3.3.2 Hydrodynamic routing models (ISIS, MIKE 11)

ISIS

ISIS is a classical one-dimensional (1D) hydrodynamic river flow model now maintained via CH2M. It employs the Preissmann Box implicit scheme to solve the equations for free surface flow, based on the Saint-Venant equations for flow in open channels. It can represent water flow involving open channels, floodplains, embankments, complex structures and operating rules.

MIKE 11

MIKE 11 supports a classical 1D hydrodynamic river flow model developed and maintained by the Danish Hydraulics Institute. It uses the Abbott-Ionescu 6-point implicit, finite difference scheme for the computation of unsteady flows in rivers and estuaries. It can represent water flow involving open channels, floodplains, embankments, complex structures and operating rules.

Both ISIS and MIKE 11 have simplified routing schemes available as options, such as the variable parameter Muskingum–Cunge scheme. Extensive use is made in the North East of ISIS in this form.

3.4 Area-wide distributed hydrological models

G2G

The Grid-to-Grid Model, or G2G, is a physical–conceptual distributed hydrological model developed by CEH Wallingford (Moore et al. 2006, Environment Agency 2007, Bell et al. 2009, Environment Agency 2010, Environment Agency 2014). G2G is formulated to represent spatial variability in catchment response and to make full use of spatially distributed rainfall data derived from networks of radars and raingauges. The model employed operationally is configured to run on a 1km grid and for a time-step of 15 minutes. Spatial datasets (for example, terrain, soil/geology, land cover) are used to support its configuration and parameterisation.

G2G is in operational use as a countrywide flood forecasting system at both the Flood Forecasting Centre across England and Wales (Price et al. 2012) and the Scottish Flood Forecasting Service across Scotland (Cranston et al. 2012). Five day outlook forecasts from G2G are used in preparing the Flood Guidance Statements issued by these operational bodies. The value of G2G in forecasting for rapid response catchments has been demonstrated in a research phase (Environment Agency 2014) and operational use is in planning.

Through adopting an area-wide formulation, in contrast to a catchment-based one, the G2G model is well suited to support forecasting at any set of locations within a defined area. As a consequence, G2G can be calibrated to groups of gauged locations over the model domain and forecasts extracted for any ungauged location within the same area. It can also support modelling of nested and parallel catchments. Consequently, the G2G model provides a flexible and natural approach to a range of gauged and ungauged flood forecasting problems.

The model employs a simple **runoff production scheme** to derive surface and subsurface runoffs from gridded rainfall and potential evaporation inputs. The water holding capacity of each model grid square controls runoff production and is specified using soil property and terrain slope data. Variation of this capacity from point to point within a grid square is represented in a probability distributed way. The processes of lateral and vertical drainage through the soil are represented and specified through soil property data. Land cover data are used to modify runoff response in areas of urban and suburban development. Soil percolation (recharge) varying with soil moisture content drains as subsurface runoff from the grid-square for subsequent subsurface flow routing.

G2G's **water routing component** offers a choice of nonlinear and linear kinematic wave formulations. Surface and subsurface runoffs are routed via parallel fast and slow response pathways linked by a return flow component representing stream–soil–aquifer interactions. Water is routed from grid cell to grid cell, with the terrain-following flow paths being configured using a digital terrain model. The nonlinear storage routing formulation, allowing conveyance to be related to channel properties (slope, width, length and roughness) through use of Manning's equation, is invoked for river reaches; it is also used for groundwater routing of subsurface runoff. The simple linear formulation, equivalent in conceptualisation to a network cascade of linear reservoirs, is currently used for hillslope routing of surface runoff. Floodplain storage is not explicitly represented at present. However, its effects on river flow can in part be invoked through the conveyance formulation, most readily through automated local calibration for gauged river reaches (see below).

In contrast to more complex physics-based distributed hydrological models, the physical–conceptual form of the G2G model employs simple depth-integrated formulations of runoff production and flow routing. This means that it is computationally efficient and therefore fast to run for nationwide real-time flood forecasting on a 1km model grid. Because the model formulation allows model properties to be linked directly to spatial datasets on terrain, soil/geology and land cover, only a few parameters need to be calibrated across the model domain. It is possible to **locally calibrate parameters** affecting channel flow routing (flow conductance) and return flow fraction for gauged river reaches.

Direct flow insertion allows observed flows, available up to the time the G2G model is run ('time-now'), to be used instead of modelled flows to improve forecast performance at locations downstream of river gauging stations. A simple **empirical state correction scheme** for the G2G model is provided for forecast updating in real-time. This scheme adjusts the model states, using observed river flows up to the time of the forecast creation ('time-now'), as a way of improving the accuracy of the flood forecasts. Model simulation errors up to time now can be used to forecast future errors using an ARMA error predictor and in turn produce an internally updated flow forecast for each gauged river location.

To accommodate the effects of **artificial influences,** such as river abstractions/discharges and reservoirs/lakes, simple functionality is provided to:

- set a constant flow value (negative or positive)
- apply an annual profile of monthly flows
- represent a damped response using a conceptual storage with a rate-constant parameter

Direct insertion of flow up to time-now can be used for a gauging station that measures the outflow from a reservoir or lake; future flows can be set to the last observed flow or the functionality above invoked.

The **G2G Snow Hydrology component** uses screen-level air temperature and precipitation from a weather model as additional inputs. It is used to simulate snowpack formation, melt, storage, and drainage release to the land surface within each G2G model grid square. Important features include:

- handling of rain-on-snow
- elevation-dependent rain/snow discrimination and rate of melting
- pack 'ripening' controlling the rate of release of water

At present, this component operates only over Scotland; a weather model estimate of snowmelt is used over England and Wales.

The G2G model has evolved as a **toolkit of modelling components** representing the runoff production and flow routing processes. Different options are available to represent a range of hydrological behaviours. A modular design allows new formulations to be added with relative ease.

4 Datasets for performance analyses

4.1 Background

An important component of this study was the collation of FFMP datasets from past performance assessment projects carried out at a catchment or regional level. For this study, existing project datasets were collected as flows/levels and not as pre-calculated performance measures. This allowed the assessment methods to be applied to the datasets as consistently as possible. The approach also allowed additional statistics to be calculated and, in the future, means it will be possible to add to or amend the performance measures employed.

An additional part of the study was the collation of information on a regional basis of:

- what performance datasets are available
- the location of flood warning sites and local models

4.1.1 Flood warning and modelling sites

Regional experts in the Environment Agency and Natural Resources Wales were tasked with identifying flood forecasting locations in England and Wales. Their responses are summarised in Figure 4.1, which shows the extent of locations available for inclusion in a study of flood forecasting model performance. However, it was not possible to include a small number of these locations. Note that the existence of a model at a given location does not mean it is directly required for flood forecasting at this location and may, for example, represent reservoir behaviour required to make forecasts for a flood warning site downstream.

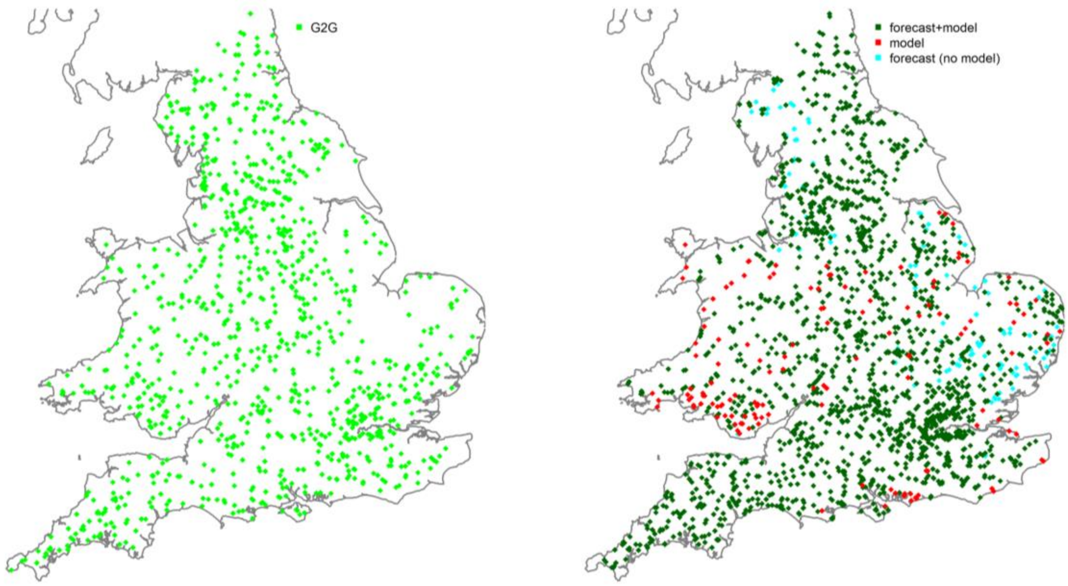


Figure 4.1 Sites with data for performance analyses

Notes: Maps are based on the returns from regional experts. They show the locations for which models exist and/or are used as forecast locations. A few have not been analysed. Local models have data as forecasts, historical simulations ('model') or both.

4.2 Sites used in the this study

A map of local model locations is given in Figure 4.2. Locations marked in purple are sites that are included and analysed in this report. The map also shows sites from other studies that are known to be underway or about to complete. Grey points indicate locations where a model exists but no performance study is known of at present.

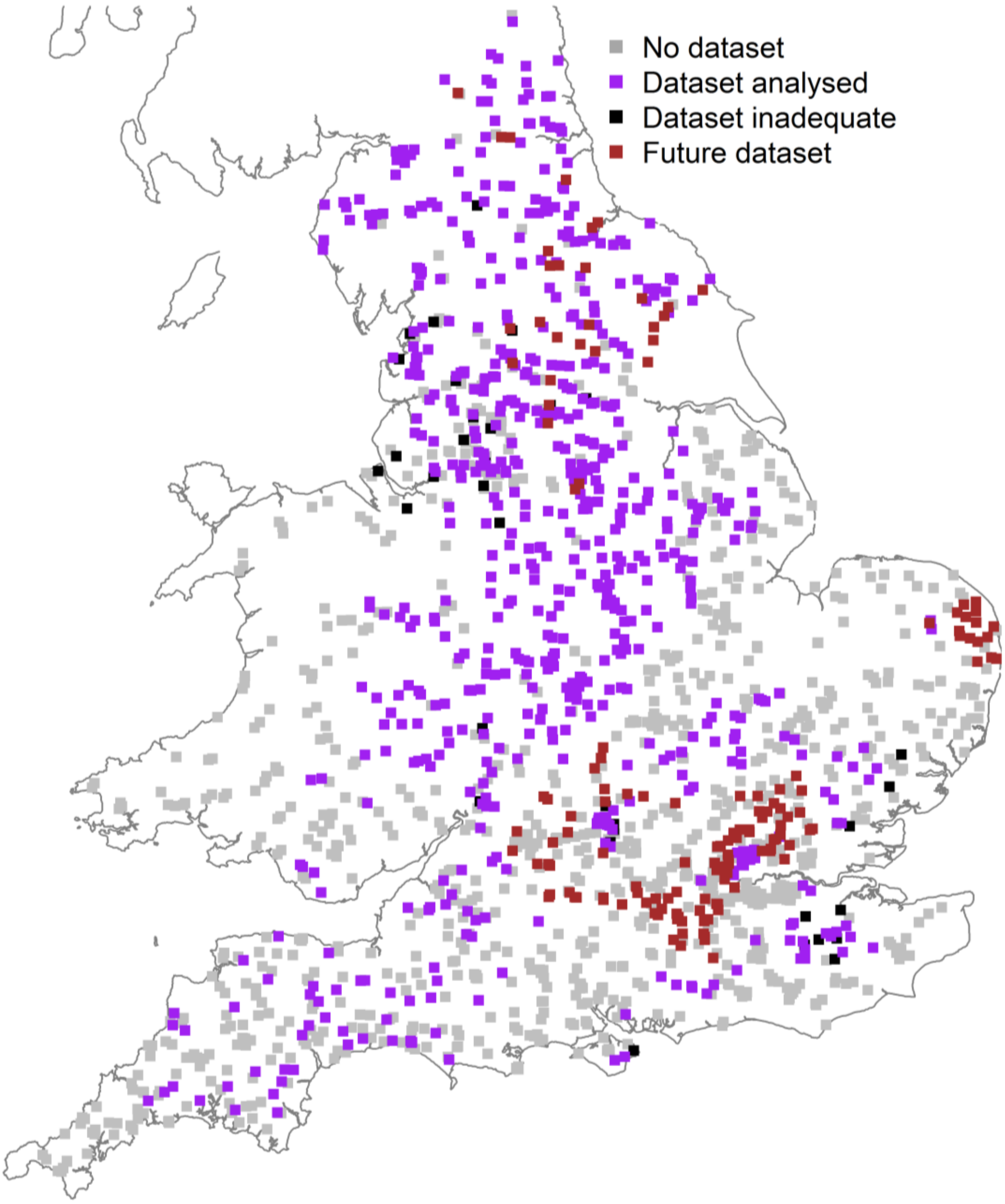


Figure 4.2 Local model locations showing availability of FFMP datasets

Notes: Sites for which performance data have been analysed are marked in purple. Points in grey show locations where performance analyses are not known to exist.

4.2.1 Distribution of study sites by model and region

Table 4.1 provides a summary of the local model performance datasets by model and region. Data for 676 forecast sites are suitable for analysis and 8 model types across 8 regions are involved. In instances where there is more than one local model for a site, the number of sites analysed in the region will be fewer than the total number of models. The spatial distribution of the local models is shown in Figure 4.3, which reveals marked regional differences and preferences for models.

Outputs from the G2G model have been produced for 1036 gauged sites in England and Wales (Table 4.2**Error! Reference source not found.**). This coverage can be compared with the local model locations in Figure 4.3. A total of 829 were suitable for analysis, with 207 previously judged unsuitable on account of artificial influences affecting the hydrograph or problems with flow gauging. Because G2G has the capability to provide flows everywhere across its model domain on a 1km grid, forecasts are available in practice for any ungauged or gauged location.

Table 4.1 Local model types by region

		Number analysed		Number of models by type								
Region	**No. of models**	**Sites**	**Models**	**PDM**	**MCRM**	**TCM**	**TCM ARMA**	**PRTF**	**KW**	**DODO**	**ISIS**	**MIKE 11**
Anglian	51	43	46	15					4		15	12
Midlands	182	165	179		65					88	26	
North East	191	183	183	64					67		52	
North West	216	103	142	72				4			66	
South West	66	65	66	2				64				
Southern	36	24	24	18			1				5	
Thames	40	30	30	4		6					20	
Wales	6	6	6	6								
Total	**788**	**619**	**676**	**181**	**65**	**6**	**1**	**68**	**71**	**88**	**184**	**12**

Table 4.2 Number of G2G sites by region

Region	**Number of G2G sites**	**Number of sites analysed**
Anglian	105	67
Midlands	156	131
North East	161	144
North West	123	96
South West	159	122
Southern	85	51
Thames	134	127
Wales	113	91
Total	1036	829

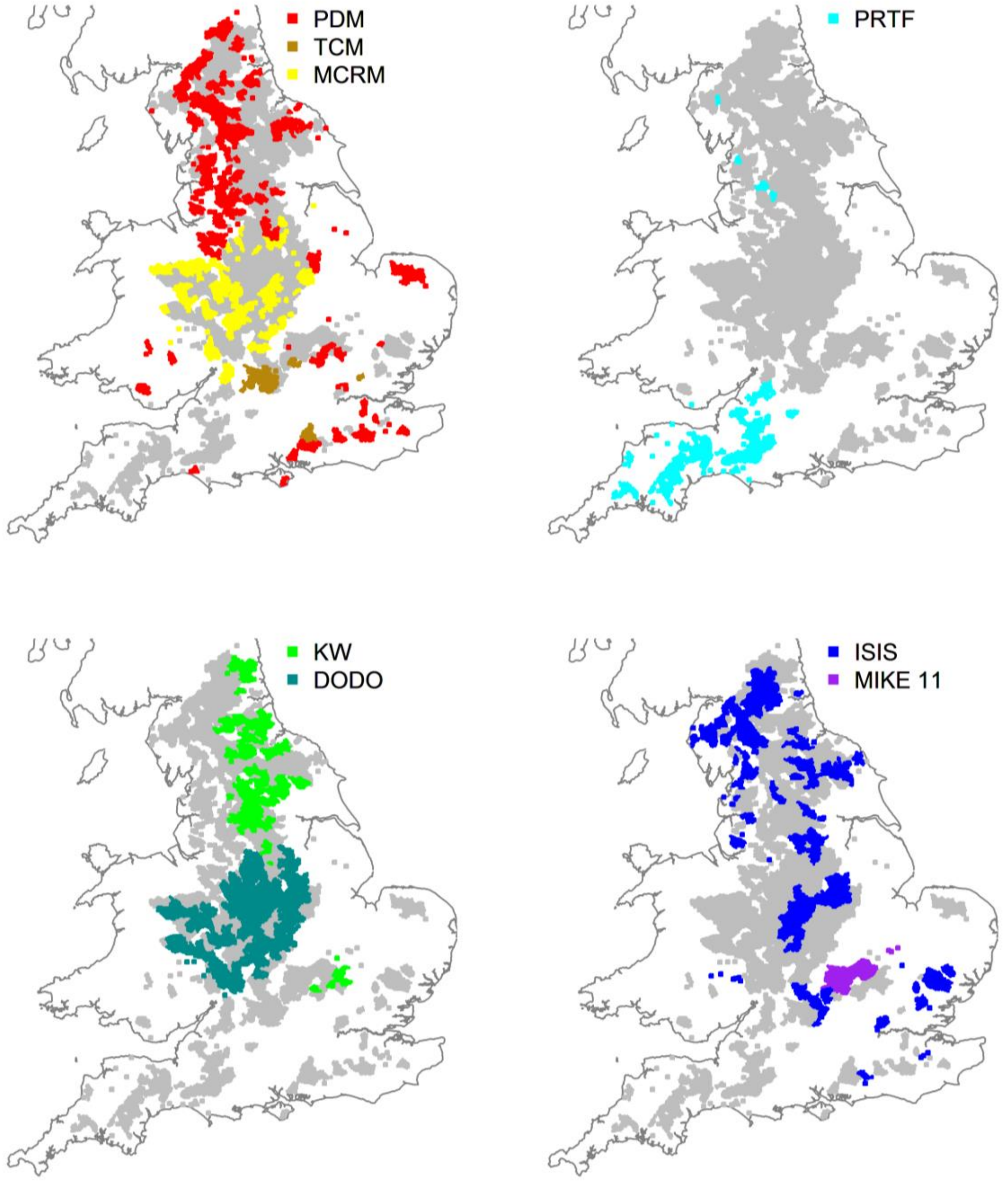


Figure 4.3 Location of local models used in this study grouped as conceptual (PDM, TCM, MCRM), transfer function (PRTF), hydrological routing (KW, DODO) and hydrodynamic routing (ISIS, MIKE 11)

4.2.2 Quality control

A significant quality control task was carried out as part of the study. This involved reviewing, on a site-by-site basis, the data used in producing each of the several hundred Performance Summary pages. A significant number of queries were referred back to the regional experts for comment. Editing of the data was made at some sites, for example, to remove spikes or step changes, while other sites were rejected for use in the study.

Appendix D documents the issues identified from detailed inspection of the Performance Summary pages, what was queried with the regional experts, and what amendments were made.

There were a number of sites for which data were received but for which it was necessary to omit them from the analyses: Figure 4.4, together with Table 4.3**Error! Reference source not found.**, provide a summary and Appendix E gives further details. Reasons for exclusion included:

- sites becoming decommissioned or models no longer in operational use
- models now out-of-date and replaced by new ones
- sites that had strong tidal influences and were thus out of scope for this study
- data too poor to justify analysis
- datasets for which the model used was not recognised, possibly because regional experts were aware of issues such as the above

Table 4.3 Reasons for omission of local model outputs from performance analysis

Region	Tidal/severe abstractions	Poor data	Old model	Other	Total
Anglian	2	2	1	0	**5**
Midlands	1	2	0	0	**3**
North East	2	0	4	2	**8**
North West	3	2	49	20	**74**
Southern	2	3	6	1	**12**
Thames	0	0	8	2	**10**
Wales	0	0	0	0	**0**
Total	**10**	**9**	**68**	**24**	**112**

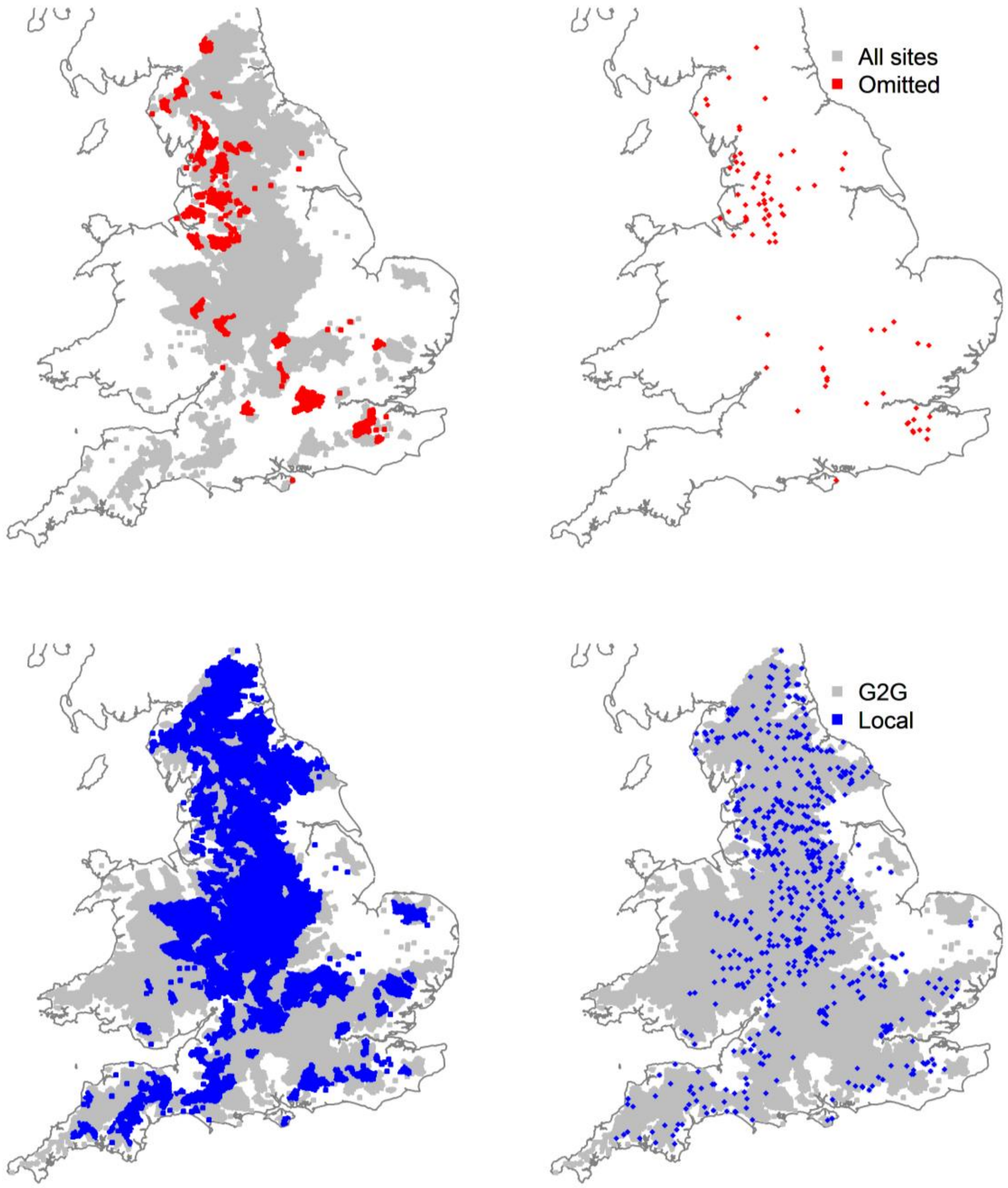


Figure 4.4 Map of local model omitted locations (top) and comparison of coverage of G2G and local models (bottom)

Notes: G2G currently has a wider coverage than the local model sites used in this study.

4.3 Initial summary of the performance datasets

This section presents a summary of some important model-related aspects of the datasets. It reveals strong regional differences which are likely to be a factor in understanding and interpreting the performance analyses.

4.3.1 Rainfall scenario

The following rainfall scenarios are commonly used in FFMP assessments:

- **'Perfect' Rainfall**. This employs observations of rainfall as input to the model, assuming perfect foreknowledge. It is most useful in assessing how good the model is, without being confounded by errors in the rainfall forecast.
- **Forecast Rainfall**. This employs the rainfall forecast available in real-time and thus reflects the operational performance of the model.
- **No Rainfall**. This is what the model would forecast operationally if zero rainfall is assumed in the future, instead of using a rainfall forecast.

An important objective of this report is to assess and allow comparison of model performance. The Perfect Rainfall scenario is thus the most appropriate scenario for this purpose. Although the Forecast Rainfall scenario provides the most realistic picture of operational model performance, it mixes together model error and rainfall error, and can be difficult to interpret. The focus here is on model error which is most easily understood through analyses employing the Perfect Rainfall scenario.

For many areas, Perfect Rainfall scenario model outputs are available for analysis, but this is not true everywhere. Where a location did not have a Perfect Rainfall scenario output and when a Forecast Rainfall scenario output was available, then the latter was used. Figure 4.5 shows that it was necessary to use Forecast Rainfall scenarios for some sites in the Midlands and Thames regions because Perfect Rainfall scenarios were not available.

For G2G, only the 'Perfect Rainfall' scenario is available and all model outputs relate to this scenario.

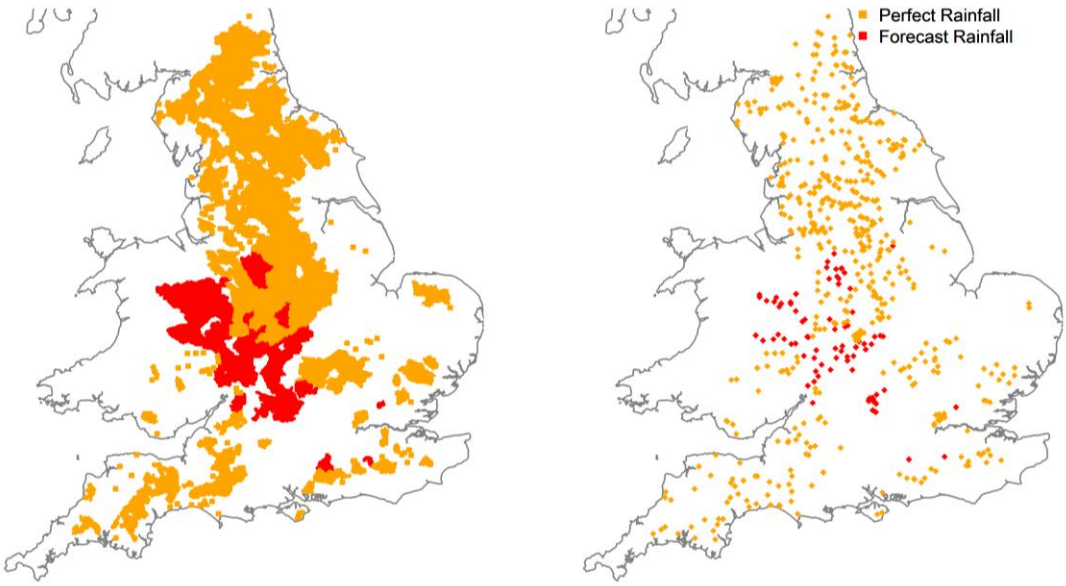


Figure 4.5 Local model locations for which Perfect Rainfall and (second choice) Forecast Rainfall scenarios have been analysed

Notes: Locations are shown as catchment areas on the left hand map and as gauge points on the right hand map.

4.3.2 Model output variable: river flow or level

For a given river gauging station, available data from past performance studies may relate to observed and/or modelled flow and/or level. There are also significant regional differences in this. Most commonly, river levels are measured at a river gauging station and, for a certain number of stations, rating equations are derived for conversion of level to flow. Rating equations only exist at some sites.

Hydrodynamic models (ISIS and MIKE 11) operate in terms of both level and flow whereas hydrological models such as G2G, PDM and KW are based on water mass conservation and are flow-based. Only where a rating exists can the hydrological model flows be converted to river level.

For the local models, the type of model output variable available is very mixed, although river level is most common. Only 17 sites have both types of variable available (9 sites in Anglian region and 8 in Thames region) and in these cases levels have been analysed.

At some locations, forecast and observed data, or forecast and simulated data, have been stored as different data types – one as levels, the other as flows. Sites are only included in the analyses if they have forecast and observed data measured on the same scale. Similarly, simulation data are only used where there is a matching observed series.

For some locations the forecast and simulation data are on differing scales, but each have a matching observed series. For these sites, the forecast and simulation datasets are analysed despite this difference, as is the case for most sites in the North East. These sites are labelled as 'mixed' because part of the data are analysed as levels and part as flows. The distribution of model variables is shown in Figure 4.6. The site breakdown into model output variable is 387 level, 35 flow and 254 mixed (240 as forecast level and simulated flow; 14 as forecast flow and simulated level). The G2G dataset, observed and modelled, is in terms of the flow variable.

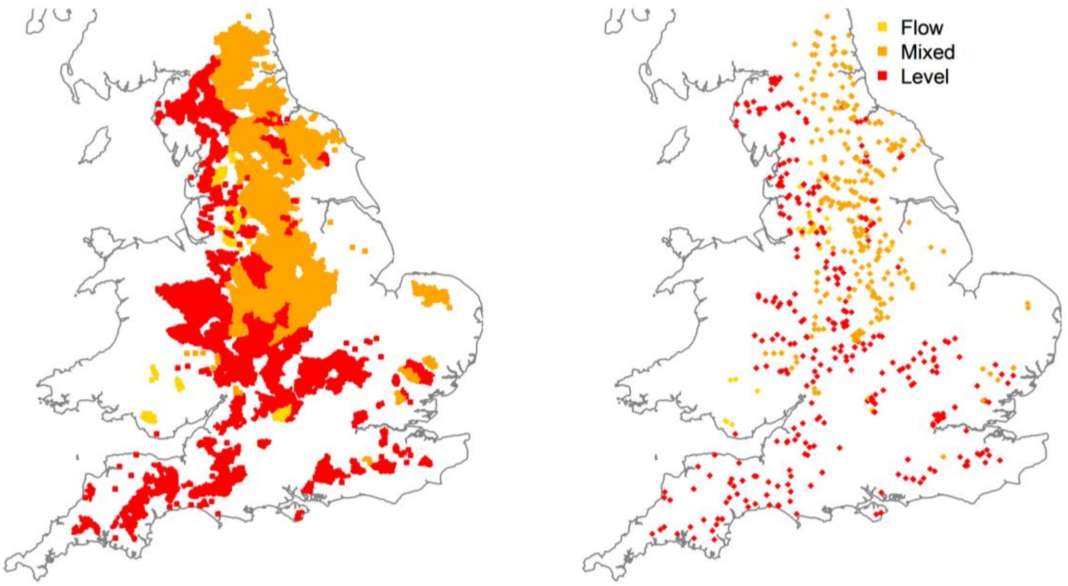


Figure 4.6 Data variable used in local model analyses.

Notes: The left hand map presents the data as catchment areas (based on G2G catchments). The right hand map shows the same data, but with a square symbol at the gauge location.

4.3.3 Availability of historical simulation data

Performance analyses are only undertaken at a site if forecast data are available. Wherever possible, a historical simulation series is also used in the analyses. Lack of such data has not precluded a site from being used but historical simulation data could not be obtained at all sites (Figure 4.7).

A further complication is the selection of the historical simulation series. In many cases there are several historical simulation series available, including a 'With Levels' run (in which upstream observed flows/levels are inserted) and a 'No Levels' run (in which no use of observed level/flow is made). The choice of which series is appropriate depends on the model setup and, in most cases, it was necessary to refer this question back to regional experts to select the most appropriate simulation series. The selections made (where known) are presented in Figure 4.7. This figure suggests that the selections made differ on a regional basis, which may indicate a regional bias.

G2G simulation data are most similar to the 'With Levels' run in that observed flows are mainly inserted. Where flow is inserted at a site, it is the modelled flow prior to insertion that is taken as the historical simulation value. This avoids the common problem of 'With Levels' type runs in which the modelled and observed data become identical after the Levels have been used.

4.3.4 Forecast length and time-step

The length of the forecast series varies from under a day to over 4 days. Some of this variation is due to the way in which model runs have been produced – with longer runs used to capture differences in timings at the top and bottom of a connected group of catchments. The most common forecast length is 36 hours. The forecasts for the Midlands and South West are typically longer (Figure 4.8).

The most common model time-step is 15 minutes. However, for the Midlands and some South West sites, a model time-step of 1 hour is used (Figure 4.8).

The G2G model time-step is 15 minutes. The G2G model has only been run on the hour for this study, but outputs are available for every hour within the period of record. Many of the local models have more frequent runs close to events, for example, every 15 minutes.

4.3.5 Period of record used for performance study

The period of record used in local model analyses varies with gauge location. A summary is presented in map form in Figure 4.9. The majority of analyses employ a 10–15 year record. Many others cover 5–10 years and several less than 5 years, while a small number exceed 15 years.

The G2G performance is analysed over a fixed period of 5 water years: October 2007 to September 2012.

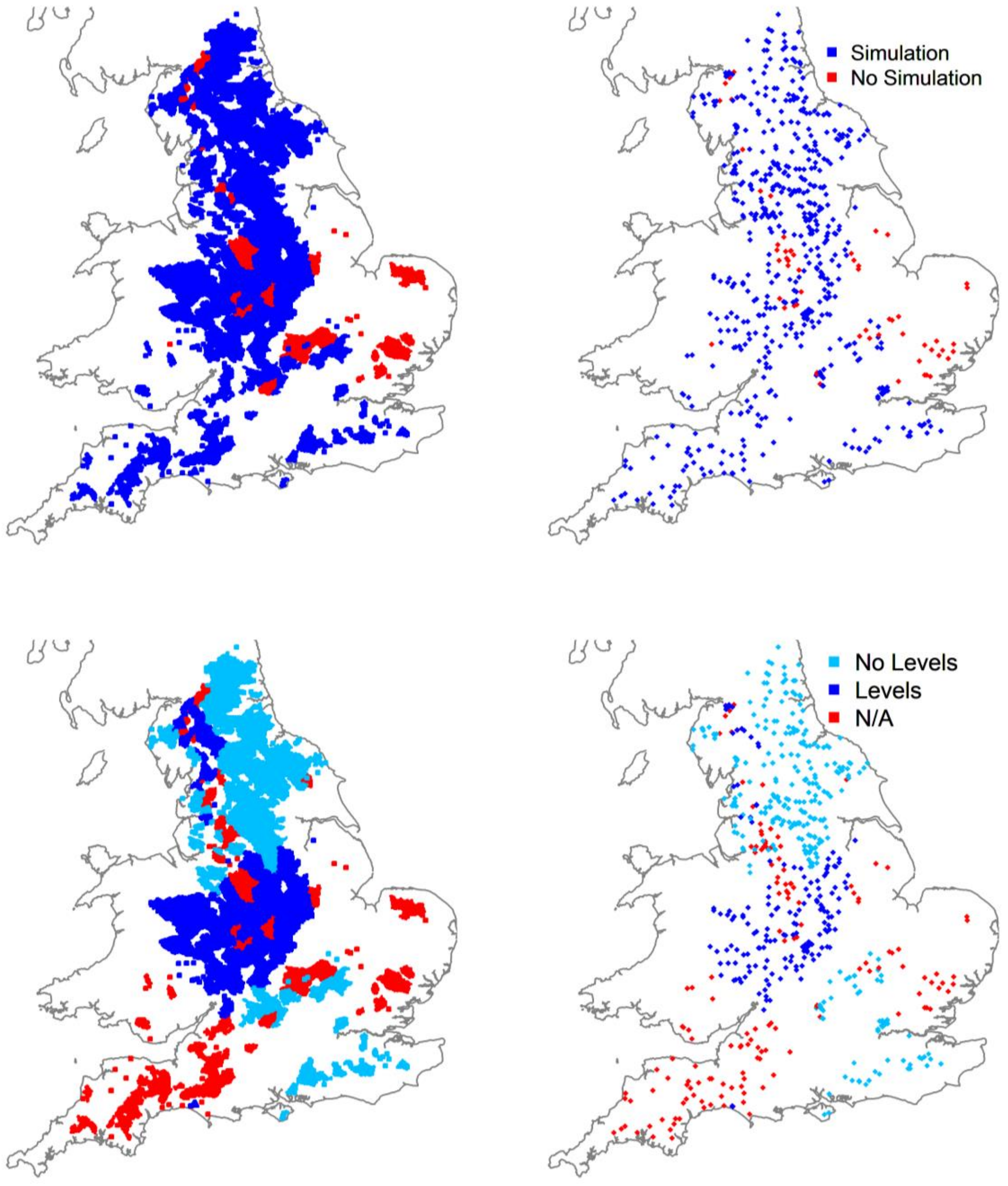


Figure 4.7 Availability of historical simulation data (top) and type of historical simulation data (bottom) for local model analyses

Notes: The left-hand maps present the data as catchment areas (based on G2G catchments). The right-hand maps show the same data but with a square symbol at the gauge location.
N/A = not available

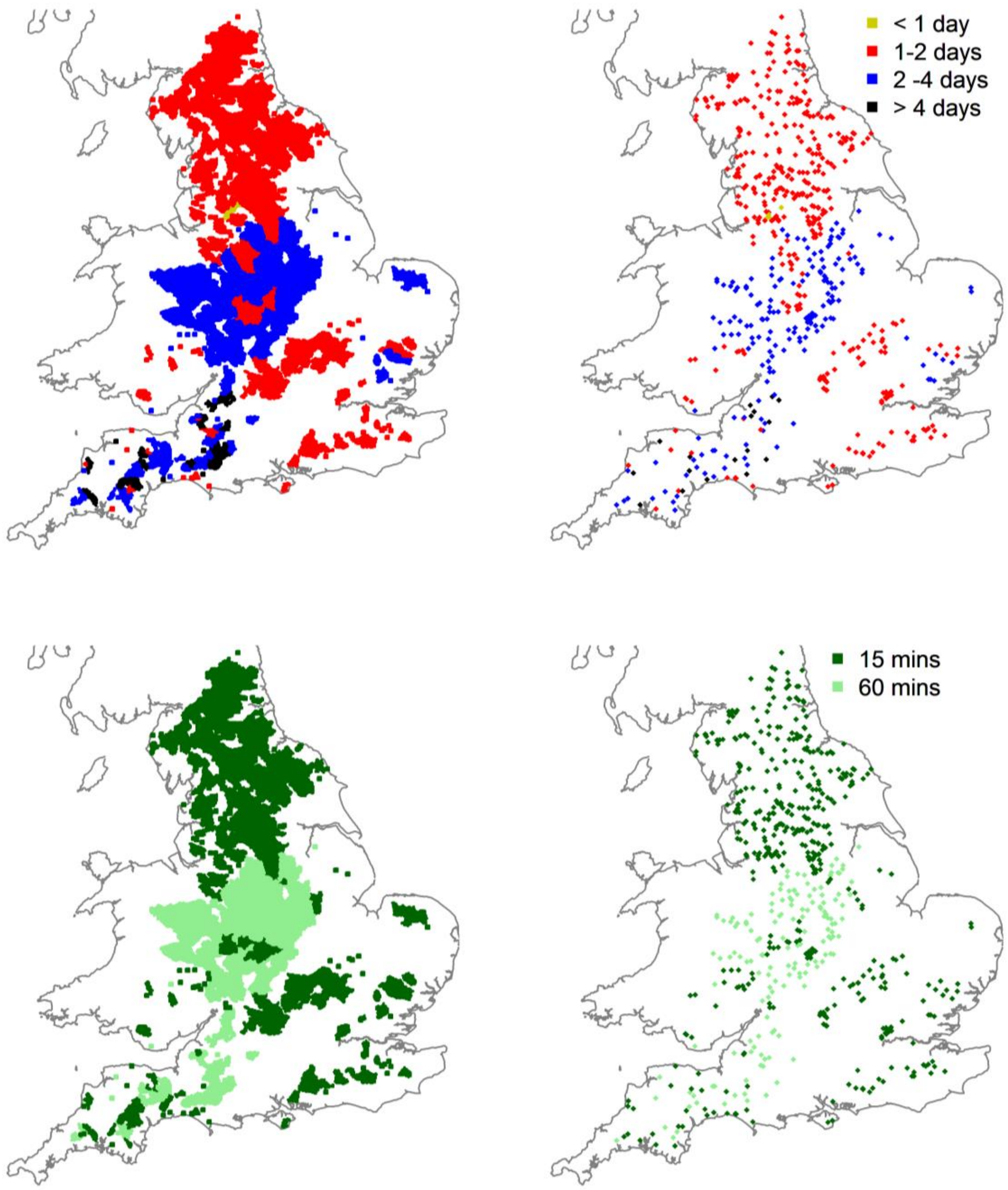


Figure 4.8 Forecast length (top) and model time-step (bottom) used in local model analyses

Notes: The left-hand maps present the data as catchment areas (based on G2G catchments). The right-hand maps show the same data but with a square symbol at the gauge location.

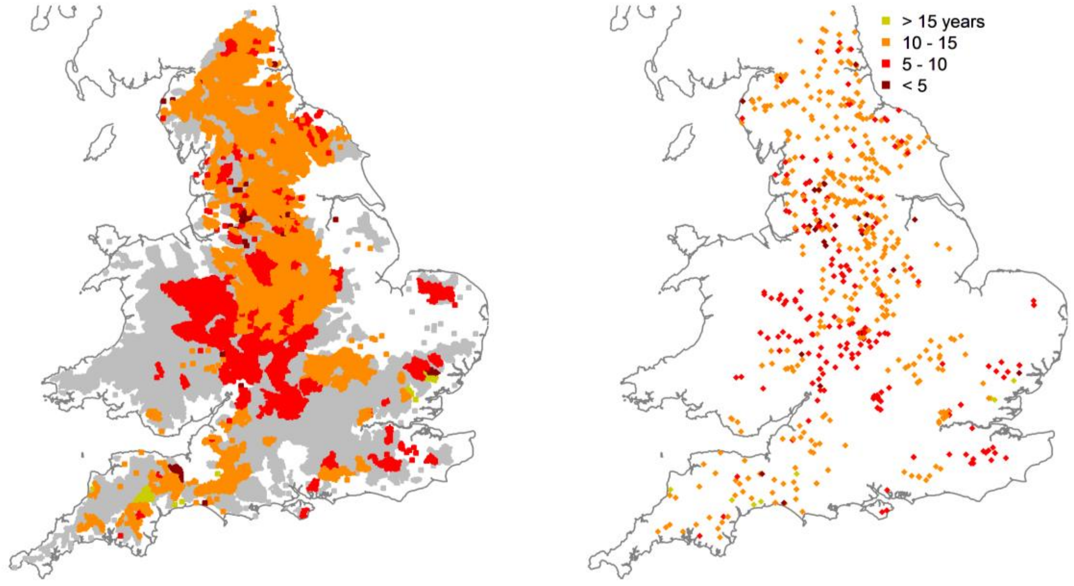


Figure 4.9 Period of record used in local model analyses indicated in the left map for catchment areas (based on G2G catchments) and in the right map by a square symbol at gauge locations

4.4 Sources and formatting of data

For local models, the consultants responsible for past performance studies were JBA, CH2M and Plan B UK. Datasets were provided by each for use in this national project. Data were received as text files and generally included the following:

- observed flows and/or levels
- modelled forecasts as flows or levels
- historical simulation data as flows or levels
- metadata such as thresholds or events used

Although the general format used by each consultant was similar, in practice the differences in data formatting were significant. This caused considerable additional work for the project team.

JBA datasets are extensive and contain many different outputs. This presented an unanticipated challenge because it proved difficult to identify which series were associated with each model, and which series should be included in the analyses reported here.

For G2G, the data are held on CEH databases and consist of forecasts of 15-minute river flow out to 36 hours, with forecast origins updated every hour along with accompanying flow observations.

In some cases, especially where multiple models for the same site were present, or where some sites were using levels or flows, there was no way of ascertaining which datasets to use for each analysis in an automated fashion. A major complication was a lack of consistency in file naming, in part due to changing personnel over time. To remedy this problem, spreadsheets were sent to regional experts to help construct a complete database of what variables should be used for each analysis. This included information such as rainfall scenario, error correction on forecasts, and model types. To mitigate such complications affecting future analyses, recommendations for future formatting and data collation of FFMP datasets are presented in Appendix B with a view to making future dataset take-on as automated as possible.

In addition to these data formatting issues, much of the forecast data received contained forecasts of different length, time-step and time between forecast origins, as illustrated for example in Figure 4.8. Many of the forecasts provided were based upon a one-event-per forecast approach (see Section 5.3.2). In contrast, G2G forecasts were generated following the all-available forecast approach (see Section 5.3.1) in which forecast origins are at regular time intervals, which has benefits for skill score determination. Additional work was involved processing the forecast data correctly according to the approach used, and calculating skill scores and statistics in a consistent manner.

5 Statistics for performance assessment

This section describes the statistical methods used for performance assessment. It presents the concept of an ‘event’ as an upward crossing of a flow/level threshold and how skill scores can be formulated to assess how well these events are forecast by a flood forecasting model. Other performance measures are described that judge model efficiency in relation to the difference between observed and forecast values, and in terms of the magnitude and timing of hydrograph peaks. Statistics targeted at assisting the operational user are highlighted. An Overall Performance Summary statistic is defined that aims to summarise the performance of a given site model to make it easier to compare models for that site and also between sites. Finally the box plot, used extensively to quantify variability in performance statistics in the main analyses of performance (see Section 7), is explained as necessary background to what follows.

5.1 Use of thresholds, tolerances and time windows

5.1.1 Choice of thresholds

In this report, the skill score performance statistics are obtained for events based on exceeding a chosen threshold. The choice of threshold is complicated by several factors. First, the limited available record lengths mean that, so as to have enough events to obtain sensible statistics, it is necessary to use a lower threshold than might be ideal. In addition, the model performance data used here are a mix of river levels and flows; all G2G model data are as flows, but for many of the other models data are as levels.

It is useful to define the following terms.

- QMED denotes the median annual maximum flood. This has a return period of 2 years and is indicative of bankfull conditions for natural rivers.
- Q(T) denotes the flood flow Q of return period T years, so QMED = Q(2).
- G2G Q(T) grids are flood flow grids based on the FEH 1km Q(T) grids but scaled by the ratio of FEH Q(2) to G2G Q(2) to better assess G2G flow rarity/severity for flood guidance. The G2G Q(2) grid is currently estimated from G2G river flows over a 5 water year period.

Where possible, the aim has been to:

- evaluate model performance at 2 nationally consistent thresholds:
    - Threshold 1: G2G QMED/2
    - Threshold 2: G2G QMED
- use the same threshold for the different models at each site, converting it to levels when required.

The G2G QMED thresholds were identified as follows.

1. Find an appropriate G2G location. For every gauged site with a known catchment area and a rating curve, search for a location on the 1km G2G digital terrain maps. Note that in a few cases it was not possible to find a suitable location.

2. Extract the G2G QMED value from the G2G Q(T) grids.
3. If local model analysis is in levels, convert the G2G QMED value (and tolerances – see next section) to levels using local NFFS ratings if available (done by the Environment Agency).

There are sometimes important differences in the rating equations used for G2G (primarily NFFS-FFC) and local NFFS systems. In some cases, this means that a local model assessment had very few or no events. If fewer than 10 events for QMED or fewer than 5 events for QMED/2 were identified for either threshold, both thresholds were rejected for that model.

In cases where the G2G QMED threshold could not be used for the local model assessments because one of the steps above could not be completed, the observed flows provided from the local model datasets were used to derive the thresholds.

The process using the local model datasets is as follows.

1. Identify the maximum and minimum observed flows in the local model dataset which spans *n* years.
2. Repeatedly perform a peak-over-threshold analysis using a threshold that progressively decreases from the maximum to the minimum observed flow. Stop if at least 20 peaks are found. Let *m* denote the number of peaks identified.
3. Order the peaks (P_i, i = 1, … , m) from smallest to largest such that $P_i \leq P_{i+1}$.
4. Calculate Threshold 1.

If $m > 10$ peaks:

Threshold 1: $(P_n + P_{n+1})/2$ if $n > 10$ years

$(P_{10} + P_{11})/2$ if $n \leq 10$ years

If m ≤ 10 peaks:

Threshold 1: no suitable estimate

5. Calculate Threshold 2.

If $m > 5$ peaks:

Threshold 2: $(P_{n/2} + P_{n/2+1})/2$ if $n > 10$ years

$(P_5 + P_6)/2$ if $n \leq 10$ years

If $m \leq 5$ peaks:

Threshold 2: no suitable estimate

5.1.2 Magnitude tolerances on thresholds crossings

In this study, the skill scores are calculated with and without tolerance on the threshold level.

Where possible the tolerances were set to

- G2G derived QMED ± 20%
- G2G derived QMED/2 ± 20%

These tolerances were then converted using rating equations to the equivalent value as a level.

In cases where this approach did not work (for example, G2G QMED not available, or rating curve not available, or too few events for G2G QMED to be used), the tolerances were instead set at:

- ±20% for thresholds expressed as flows
- ±0.2m for thresholds expressed as levels

5.1.3 Lead-times

For each forecast and each threshold level, a **forecast flood event** is defined as occurring if the forecast crosses the specified flow/level threshold in an upwards direction.

The **lead-time of the forecast event** is the time from the forecast origin to when the forecast first crosses the threshold. See Section 5.3 for further discussion and details on how performance skill scores for different forecast lead-times are calculated.

NB This ‘forecast’ definition of lead-time differs from the Environment Agency’s ‘service’ definition, which relates to the elapsed time from a member of the public receiving a warning to the onset of flooding of property or other substantive infrastructure. More specifically it is the time from instruction to issue a warning to when water level exceeds an ‘Impact Threshold’ at the gauge used in flood warning. The threshold is set for each flood warning area/community aligned to when the first property or other valued asset will start to flood.

Lead-times of 1, 2, 4, 8, 12, 24 and 36 hours were examined for this study. For some locations, however, there were not enough data to derive the 36-hour lead-time statistics.

When considering model performance at a specific lead-time, a window is allowed around the target lead-time. This is called the **lead-time window.** It is used to decide which forecasts to include for assessment at a specific lead-time. For example, in the case of performance for an 8-hour lead-time, forecasts with nearby lead-times were also included; that is, forecasts with crossings at lead-times of 8 ± 2 hours (6–10 hour lead-time) were used to evaluate the 8-hour lead-time performance. This is detailed in Table 5.1.

In the regional studies, the forecast lead-time width used was approximately 0–0.5 hours, that is, one event selected within 30 minutes of the specified lead-time.

Table 5.1 Lead-time widths and threshold crossing time windows

Lead-time (hours)	Lead-time window (hours)	Observed to forecast width (W) (hours)
1	0–2	1
2	1–3	1
4	2–6	2
8	6–10	4
12	9–15	6
24	21–27	12
36	32–40	18

5.1.4 Threshold crossing time windows

The skill scores used here allow for some tolerance in timings as explained below and detailed in Table 5.1. For example, when considering an 8-hour lead-time, the maximum time between observed and forecast crossings is 4 hours. The timing tolerance allows for differences in timing of the observed and forecast crossings. Only forecast and observed crossings that are within this timing tolerance are counted as hits – or near misses/ close false alarms (see Section 5.3).

As can be seen in Table 5.1, the observed–forecast tolerance windows increase with lead-time. This is because shorter tolerance windows are more appropriate at short lead-times and longer windows at longer lead-times. The approach also allows for better handling of regional differences in dominant river response times and associated expectations in useful forecast lead-time. Regions where slower river response times dominate and useful longer lead-time forecasts are more achievable tend to use wider tolerance windows. For a threshold crossing to be out by several hours, but for flows to persist above the threshold for days, in a region with slowly responding rivers argues for a wider tolerance, relative to a region where flashier rivers are the norm.

Note that in previous assessment studies, the observed to forecast window was regionally dependent but constant with respect to lead-time. Table 5.2 provides an indication of approaches employed.

Table 5.2 Summary of approaches employed in previous assessment studies

Default	10 hours
North West, South West and Wales	Catchment dependent (1–6 hours), set according to steepness criteria
Anglian	15 hours
Thames, Southern	24 hours

The regionally dependent approach was not judged suitable for this study as national comparison cannot be sensibly made if different settings are used in different parts of the country.

5.2 Skill scores

This section describes the statistical approach used to calculate the following **categorical skill scores** selected to assess the performance of flood forecasting models:

- Probability of Detection
- False Alarm Ratio
- Critical Success Index

The skill scores are calculated based on whether there is an observed threshold crossing, within the specified lead-time period window L ± Δt , for each of the model threshold crossings. The time window will vary with lead-time. The skill scores use the contingency table shown in Table 5.3 as their basis.

Table 5.3 Skill scores contingency table

Event forecast	Event observed		Total
	Yes	**No**	
Yes	*a* hit	*b* false alarm	$a + b$
No	*c* miss	*d* correct rejection	$c + d$
Total	$a + c$	$b + d$	$n = a + b + c + d$

Notes:

a = number of times threshold is crossed in both observed and modelled series within the time L – Δt , L + Δt . **Hit**

b = number of times threshold is crossed in model series, but not in observed series within the time L – Δt , L + Δt . **False alarm**

c = number of times threshold is crossed in observed series, but not in model series within the time L – Δt , L + Δt . **Miss**

d = number of times threshold is not crossed in both observed and modelled hydrographs within the time L – Δt , L + Δt . **Correct rejection**

In the statistics produced here, some tolerance is allowed for near misses in either time and/or magnitude. Table 5.4 shows the skill scores contingency table with tolerance.

Table 5.4 Skill scores contingency table with tolerance

Event forecast	Event observed			Total
	Yes	**Close**	**No**	
Yes	*a* hit	c_{fa} close false alarm	$b - c_{fa}$ false alarm	$a + b$
Close	n_m near misses	*d* correct rejection		$c + d$
No	$c - n_m$ miss			
Total	$a + c$	$b + d$		$n = a + b + c + d$

Notes:

n_m is the number of near misses, that is, the forecast misses but only just.

c_{fa} is the number of close false alarms: an event is forecast but is nevertheless quite close to the observed data.

5.2.1 Probability of Detection skill score

The Probability of Detection (POD) is the proportion of observed events that are successfully forecast by the model. POD can also be referred to as the ‘hit rate’ and emphasises the number of events correctly forecast. It ranges from 0 (poor) to 1 (perfect).

The standard definition of POD is:

$$POD = \frac{a}{a+c}.$$

Allowing for tolerances in time/magnitude it becomes:

$$POD(tol) = \frac{a+n_m}{a+c}.$$

The POD values given here equate to the following specific statistical questions, expressed using an 8-hour lead-time as an example. The equivalent statements can be constructed for the other lead-times

POD (timing tolerance). If an observed event crosses a threshold *T*, what is the probability that forecasts made 6–10 hours before the event will cross the same threshold within 4 hours of the observed crossing?

POD (timing and magnitude tolerance). If an observed event crosses a threshold *T*, what is the probability that forecasts made 6–10 hours before the event will cross a threshold within 20% of flow (or within 0.2m of level) within 4 hours of the observation?

5.2.2 False Alarm Ratio skill score

The False Alarm Ratio (FAR) is defined as the proportion of events that are forecast but for which an observed event did not occur. This emphasises events incorrectly forecast and ranges from 0 (good) to 1 (poor).

$$\text{FAR} = \frac{b}{a+b}.$$

NB The False Alarm Ratio (FAR) is not the False Alarm Rate, *F*, which is reserved for the proportion of non-events that are forecast as false alarms and equal to $b/(b+d)$, also known as the Probability of False Detection.

Allowing for tolerances, FAR becomes:

$$\text{FAR}(\text{tol}) = \frac{b-c_{fa}}{a+b}.$$

The FAR value allowing for tolerance will be lower than without tolerance.

Note that 1-FAR is the probability that an observed event will occur given that an event has just been forecast. The Met Office refers to this quantity as the Confidence, *C*, of a forecast and this terminology is also used here.

The Confidence of a forecast ($C = 1 - \text{FAR}$) is relevant to the operational setting and corresponds to the following statistical questions. Again these are posed for the example of an 8-hour lead-time.

***C* = 1 – FAR (timing tolerance).** If a forecast is made and crosses a threshold *T* in the range 6–10 hours, what is the probability of an event crossing the same threshold within 4 hours of the forecast crossing?

***C* = 1– FAR (timing and magnitude tolerance).** If a forecast is made and crosses a threshold *T* in the range 6–10 hours, what is the probability that an observed event will cross within 20% for flow (or within 0.2m for level) of the same threshold within 4 hours of the forecast crossing?

If *C* is close to a value of 1 it means that, when an event is forecast to occur, it is highly likely that an event will take place.

5.2.3 Critical Success Index

The Critical Success Index (CSI) is a composite performance measure. The CSI combines POD and FAR, and allows for simpler overall comparison of performance.

The CSI will be high (near 1; a good performance) if POD is high and FAR is low.

The CSI will be low (near 0; a poor performance) if POD is low and FAR is high.

The CSI is defined as:

$$\mathrm{CSI} = \frac{a}{a+b+c}.$$

For CSI with tolerance, allowing for near misses and close false alarms, it is defined as:

$$\mathrm{CSI}(\mathrm{tol}) = \frac{a + n_m + c_{fa}}{a+b+c}.$$

The CSI is a useful overall measure of performance because POD and FAR act in opposite directions. For example, a model which has a higher POD may also have a higher FAR, but for a model to be good it needs to have a high POD and a low FAR at the same time. The CSI statistic provides a measure of this property.

CSI values calculated allowing for tolerance will be higher than those without.

5.3 Use of model forecasts for skill scores

This section describes how forecast and observed crossings are calculated and how tolerance criteria have been implemented.

5.3.1 All (available) forecasts approach

To make best use of the available forecasts, this study used an 'all-available forecast' approach. This approach aims to use the information in every available forecast when determining skill scores. For each forecast and each lead-time, questions like the following are asked:

- Did an event occur close to the 24-hour lead-time?
- Was an event forecast close to the 24-hour lead-time?

The statistics obtained for this approach provide the required POD and FAR, and make use of as much forecast data as possible. The approach is aligned to how forecasts are used in practice: operationally, every forecast is examined and not just ones that are exactly 24 hours before an unknown (at the time) event. Looking at the performance of every forecast, and assessing how well the part of the forecast that is close to a lead-time of 24 hours performs, provides a more robust measure of model performance at a specific lead-time. Figure 5.1 illustrates the advantages of the all-available forecast approach.

Ideally for this method, all forecasts at all lead times would be available for analysis – as is the case for the G2G model. For most models other than G2G, forecasts have only been run prior to events, which will mean that the FAR may be underestimated.

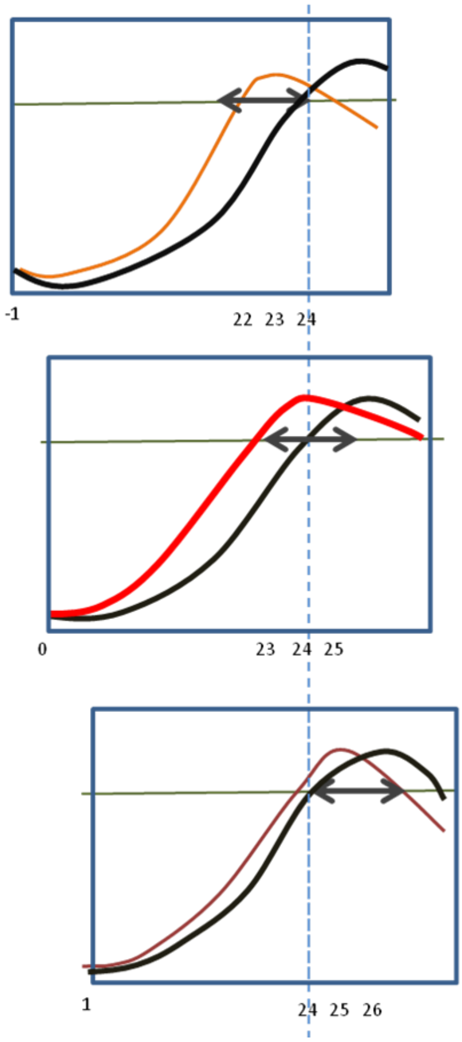


Figure 5.1 Illustration of the all-available forecast approach

Notes: The figure shows how each sequential forecast is examined and compared with the observed flow (black line). Three consecutive forecasts (origins at -1, 0 and 1 hour) are used to examine model performance at a 24-hour lead-time. The black arrow (the 'forecast window') shows the portion of the forecast that is used to assess the 24-hour lead-time performance (the window width is configurable), noting here that it shifts forwards 1 hour with each forecast in the sequence.

Since forecasts 'overlap' with the all (available) forecasts approach, this method has a 'side effect' that an observed event could end up being counted several times for the purposes of skill scores. For example, if there are 12 independent events, the value of '*a*' in the contingency table would be 12 in the event-based approach, but might be 26 in the all-forecasts approach. This impacts the 'counts' of events, but is not an issue for estimation of POD and FAR.

5.3.2 One-event-per-forecast approach

The one-event-per-forecast approach is not used in this study. It is included here for completeness because this method has commonly been used in other model performance studies. It is slightly simpler to implement but makes less use of available forecast data than the all-available forecasts method described above.

For this approach, the first step is to analyse the observed events and then search for matching forecasts. If there are 12 events and the aim is to understand forecast behaviour at a 24-hour lead-time, 12 forecasts are picked out (that is, one forecast per event) and used to calculate the statistics (that is, this is a smaller sample of forecasts than is used in the all-available forecasts method; see Section 5.3.1). The analysis neglects the fact that model performance at lead times of 23 and 25 hours will be rather similar: so if more data are used from nearby forecasts, then some of the small sample 'noise' is likely to be smoothed out.

However, the one-event-per-forecast approach falls down when the FAR is needed. When there is a false alarm, no event occurred so it is not possible to identify a single forecast at the specified lead-time that corresponds to the false alarm (this approach is biased to underestimate FAR). For data that have been limited to forecasts made near events, the one-event-per-forecast approach will give only slightly different values. For models such as G2G with a complete set of forecasts, however, the difference between the two approaches may be significant.

Figure 5.2 illustrates the shortcomings of the one-event-per-forecast approach.

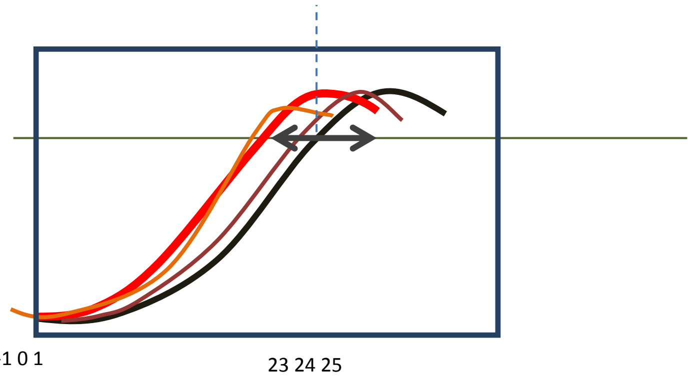


Figure 5.2 Illustration of the one-event-per-forecast approach

Notes: In this approach only the thick red line forecast, which is exactly 24 hours before the observed crossing, is used. Forecasts at 23 and 25 hours, which contain relevant information, are discarded.

5.3.3 Methodology for counting events for POD, FAR and CSI

Some care is needed when counting the number of forecast events and the number of observed events to calculate POD, FAR and CSI.

For every available forecast, an observed series matching the same time-frame as the forecast is evaluated and compared with the forecast. Each observed and forecast series is evaluated to check whether a threshold was crossed and when the crossing occurred. The detail of the method used to count threshold crossing events is as follows.

1. For each available forecast, determine the time (if any) at which a specific threshold is crossed.
2. For each available forecast, find the matching portion of the observed record and determine the time (if any) that the observed data crosses the threshold.

For a selected lead-time:

- **Hits:** number of times the threshold is crossed in both observed and modelled series within the time L – Δt , L + Δt . **Hit**
- **Misses:** number of times the threshold is crossed in model series, but not in observed series within the time L – Δt , L + Δt . **False alarm**

- **False alarms:** number of times the threshold is crossed in observed series, but not in model series within the time L – Δt , L + Δt . **Miss**
- **Correct rejection:** number of times the threshold is not crossed in either observed or modelled hydrographs within the time L – Δt , L + Δt . **Correct rejection**

The case of a forecast HIT is illustrated in Figure 5.3

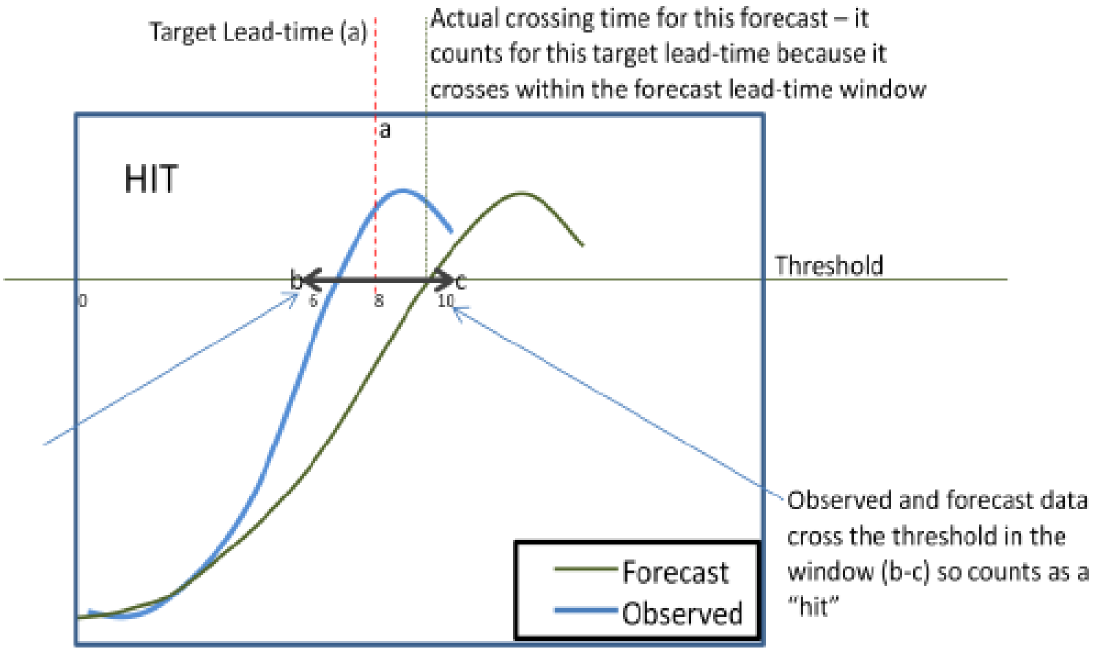


Figure 5.3 Illustration of a forecast HIT

Notes: Here both the forecast and the observed data cross the forecast within the selected forecast lead-time window (b to c) about the target lead-time a.

The next step is to determine the number of close false alarms and near misses. This requires use of the observed forecast windows (W), which is dependent on the lead-time.

For timing tolerances:

- **Close false alarms:** modelled series crosses threshold within the time L – Δt , L + Δt ; observed crosses same threshold outside this lead-time range but within W hours of forecast.
- **Near miss:** observed series within the time L – Δt , L + Δt ; forecast is outside this lead-time range but within W hours of observed.

For timing and magnitude tolerances, the approach is similar but also incorporates a tolerance around the threshold level. For this:

- **Close false alarms:** modelled series crosses threshold within the time L – Δt , L + Δt ; observed does not cross same threshold within this lead-time range but crosses within 20% (0.2m) of the threshold within W hours of the forecast crossing.

- **Near miss:** observed series crosses threshold within the time L – Δt , L + Δt ; forecast does not cross same threshold within this lead-time range but crosses within 20% (0.2m) of the threshold within W hours of the observed crossing.

The 'close false alarm' and 'near miss' are illustrated in Figure 5.4 and Figure 5.5, respectively, and those accounting for magnitude tolerance in Figure 5.6 and Figure 5.7, respectively.

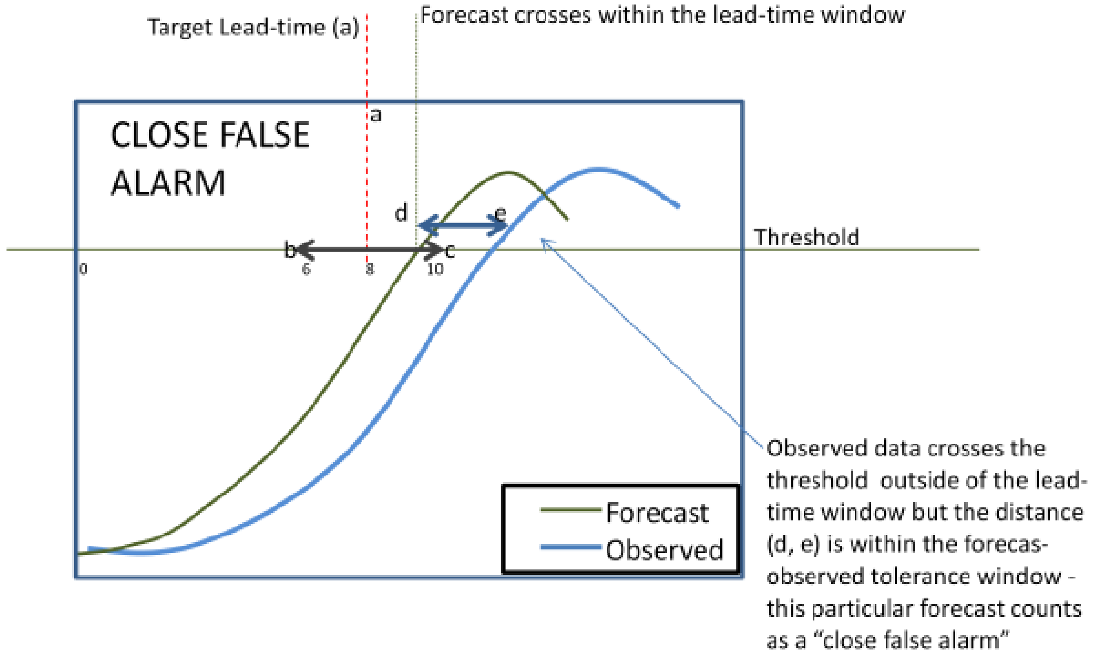


Figure 5.4 Illustration of a close false alarm

Notes: Here the forecast predicts an event within the forecast window (b to c) and counts as a false alarm as the observed crosses outside this window. It is a 'close false alarm' because the time difference between the observed and forecast crossing (d to e) is short (less than the observed to forecast tolerance window b to c).

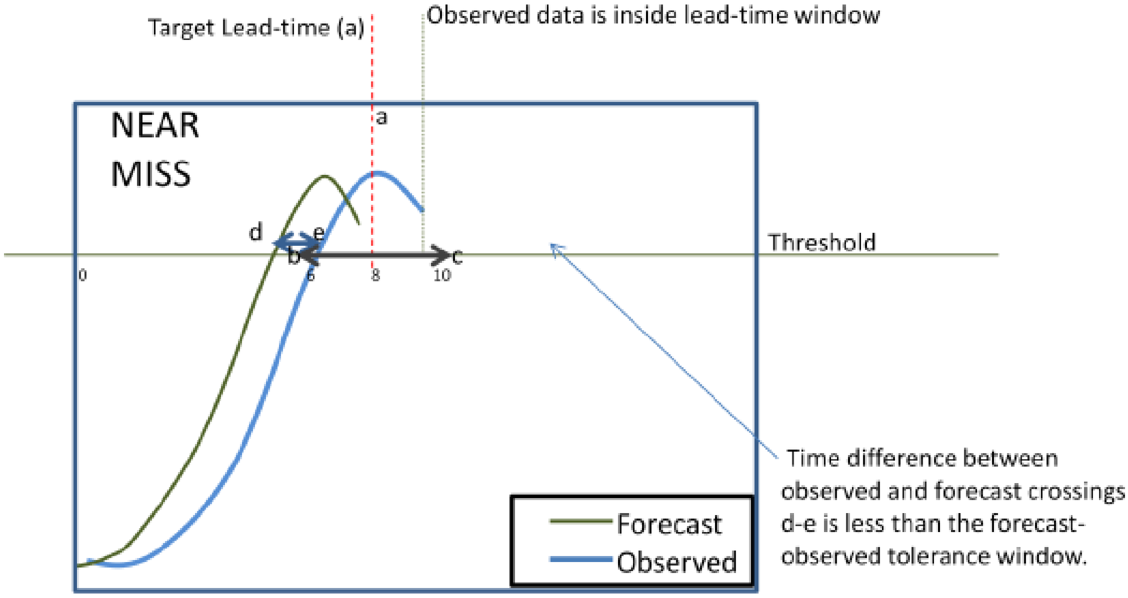


Figure 5.5 Illustration of a near miss

Notes: Here the forecast misses the observed event within the forecast window b to c. It counts as a near miss because the time difference between the forecast and observed crossing (d to e) is short (less than the observed to forecast tolerance window b to c).

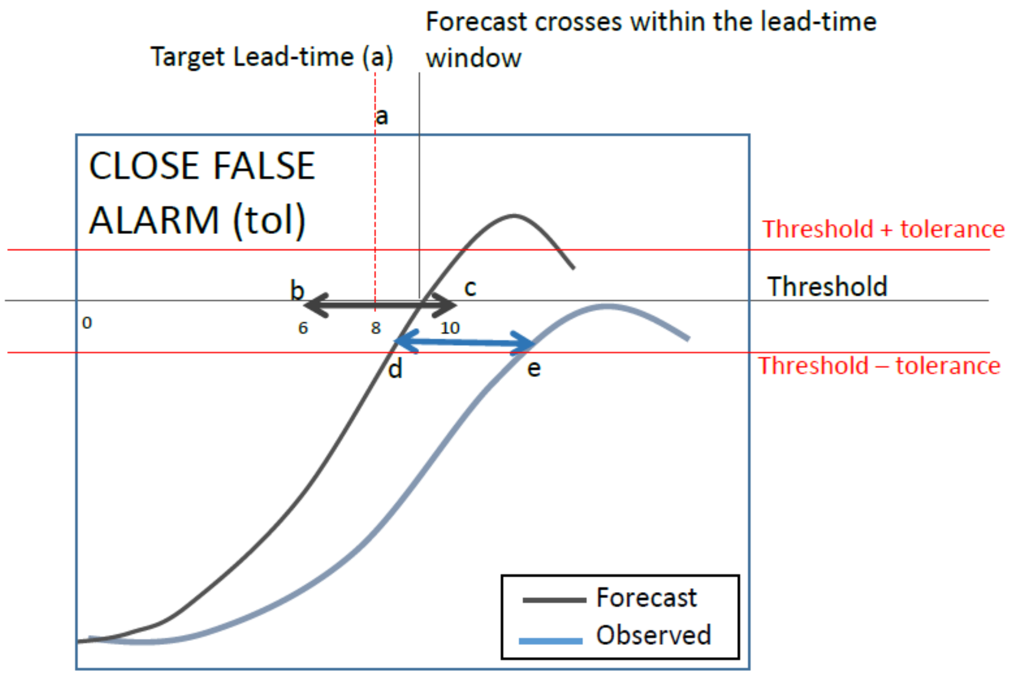


Figure 5.6 Illustration of close false alarm within magnitude tolerance (tol)

Notes: The forecast does not cross the threshold within the lead-time window but crosses within a ±20% (±0.2m) tolerance of the threshold. The observed data cross the threshold outside of the lead-time window, but the distance d to e is within the forecast to observed timing tolerance window b to c.

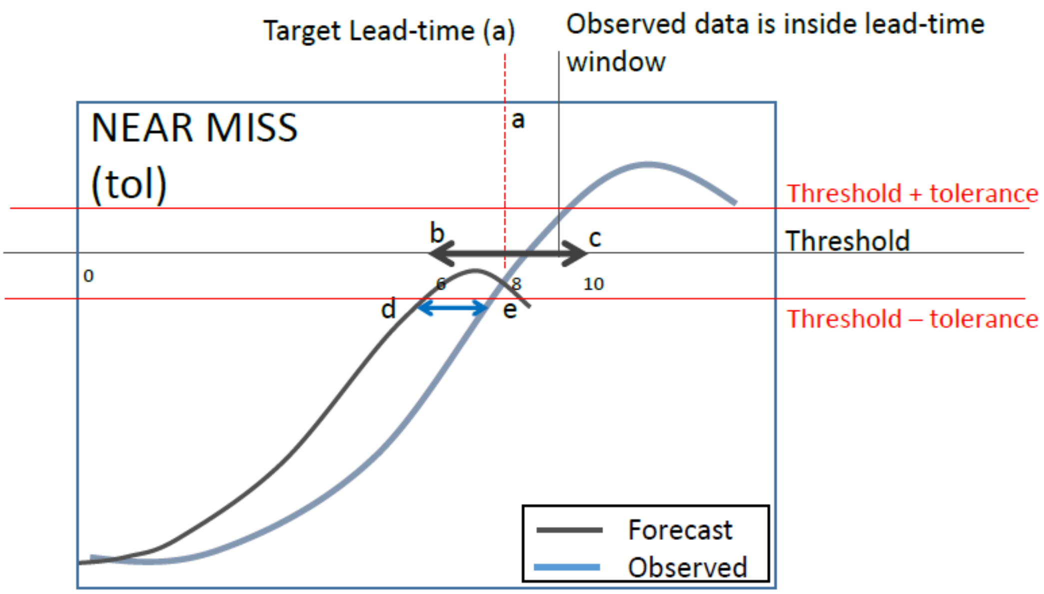


Figure 5.7 Illustration of a near miss within magnitude tolerance (tol)

Notes: The forecast does not cross the threshold within the lead-time window but crosses within a ±20% (±0.2m) tolerance of the threshold. The forecast misses the observed event within the forecast window b to c. A near miss is registered because the time difference between the forecast and observed crossing (d to e) is shorter than the forecast to observed timing tolerance window (b to c).

5.4 Other performance statistics

5.4.1 R^2 Efficiency

The R^2 Efficiency gives the proportion of variance in the observations that is accounted for by the model. It is a dimensionless measure and allows meaningful comparisons across different observation periods, catchments and models.

The following notation is used:

Q_t	Observed flow at time t
q_t	Modelled flow at time t
n	Number of observations
$e_t = Q_t - q_t$	Model error at time t
$\overline{Q} = n^{-1}\sum_{t=1}^{n} Q_t$	Mean of the observed flow over n observations

The R^2 Efficiency performance measure is defined over n observations as:

$$R^2 = 1 - \frac{\sum_{t=1}^{n} {e_t}^2}{\sum_{t=1}^{n} (Q_t - \overline{Q})^2}.$$

This statistic has a value of 1 for a perfect simulation and takes negative values if the simulations are worse than that provided by the mean observed flow $\overline{Q}$. Values below zero are difficult to use and hard to interpret. Negative values are typically set to a value of zero.

5.4.2 Proportion of peaks within magnitude tolerance

For simulation series, the proportion of observed peaks for which there is a simulation peak within a tolerance range is estimated. The tolerance around the observed peak magnitude used is:

- ±20% for thresholds expressed as flows
- ±0.2m for thresholds expressed as levels

5.4.3 Proportion of peaks within timing tolerance

When assessing peaks (forecast and historical), a timing tolerance is required to determine if peaks have been matched with the observed data. In this study, two standard timing tolerances were selected for use with the simulation datasets. These were ±4 hours and ±12 hours.

5.5 Statistics to aid operational use

Some of the statistics described here have been specifically included because they are particularly suited for use in an operational setting.

The statistics targeted at real-time (operational) use address the following questions.

A forecast has just been issued that crosses a threshold level. What is the probability that an event of this magnitude will actually take place?

The probability that an event will take place, given that an event has been forecast, is *C* = 1 – FAR and is referred to as the Confidence in the forecast event. This report has several measures of Confidence and the equivalent 1 – FAR. These are:

- Confidence for specific lead-time with timing tolerance
- Confidence for specific lead-time with timing and magnitude tolerance
- Confidence for full forecast
- Confidence for early, middle and late parts of the forecast.

In addition, the forecast may derive from a model using forecast rainfall as input, and then the Confidence statistic will be directly relevant to operational use. When the Confidence statistic is derived from forecasts with perfect foreknowledge of observed rainfall as model input, it still has operational value because it focuses on confidence in the model forecast aside from the reliability of the rainfall forecast. It answers the question: 'If I had foreknowledge of rainfall observations, how confident would I be in the forecast event occurring?'. Statistics based on foreknowledge of rainfall are the more common case in the datasets analysed and reported in the Performance Summary to be discussed later.

This comment is also relevant to the following question relating to the timing of the forecast.

A forecast has just been issued that crosses a threshold level. When is the most likely time at which an observed event could occur?

For every occasion where a forecast correctly forecasts an event, the time differences between the forecast and observed event are determined.

The **mean time difference** indicates whether, on average, observed events occur before or after the forecast:

- Positive values of this statistic mean that the forecast is generally late compared with that observed.
- Negative values of this statistic mean that the forecast is generally early compared with that observed.

A **histogram of timings** and the **90% spread statistics** of the time difference data give an indication of the uncertainty in the timings. For example:

- The most likely time of event is -4 hours.
- The time range within which 90% of events occur is -7 to +1 hours.

Operational performance statistics do not incorporate a magnitude tolerance.

5.6 Overall Performance Summary Statistic

A general aim of the project was to be able to summarise, in one or two numbers, the overall performance of a model at a site such that model performance could be readily compared at a site or between sites.

Appendix A describes an initial proposal for a measure of model assessment and model performance. However, this measure as stated was not sufficiently automatable and thus not suited for a study of this national breadth.

The Overall Performance Summary Statistic used here is formed of an average of several performance statistics. Each component is chosen or scaled to be in the range 0 to 1, and the resulting average is therefore also in the range 0 to 1. The measure is not set in stone and part of the purpose of this study is to assess whether it is suitable. Indeed, in preparing this report, some minor modifications were made as these were judged beneficial. In particular the scaling of the timing measure was changed to give a better spread.

Measures that contribute to the Overall Performance Summary Statistic are:

Forecasts:

I_1 CSI at a lead-time of 4 hours using the QMED threshold

I_2 CSI at a lead-time of 4 hours using the QMED/2 threshold

I_3 CSI at a lead-time of 24 hours using the QMED threshold

I_4 CSI at a lead-time of 24 hours using the QMED/2 threshold

I_5 Scaled measure of average time difference between observed and forecast crossings

I_6 Scaled measure of average time difference between observed and forecast crossings that fall within the timing tolerance window

Simulation:

I_7 R^2 Efficiency

I_8 Proportion of peaks within magnitude tolerance

I_9 Proportion of peaks within timing tolerance (12 hours)

Here $I_5 = 1/(1 + \text{abs}(I_5))$ and $I_6 = 1/(1 + \text{abs}(I_6))$, such that I_5 and I_6 scale from 0 to 1.

The **Overall Performance Measure** is the average of I_1 to I_9 and ranges from 0 to 1 in value. It is a heuristic statistic and the relative weighting of the components may need future adjustment. When the performance assessment is reported (see Section 7), the Overall Performance Measure is also considered in 2 parts:

- the forecast component – average of the 6 forecast components
- the simulation component – average of the 3 simulation elements

5.7 The box plot

The analyses of performance reported in Section 7 make extensive use of box plots. Box plots are plots which summarise the distribution of the data. Figure 5.8 explains the statistics contained in a box plot.

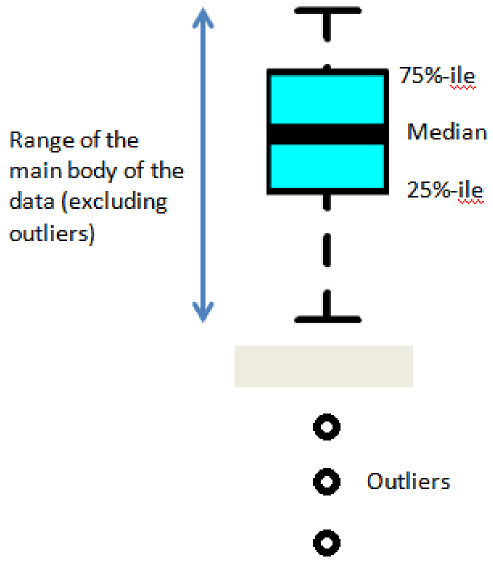


Figure 5.8 Illustration of box plot statistics

Notes: The central horizontal line on the box plot is the median and the coloured box extends from the first quartile (Q1, also called the 25%-ile) to the third quartile (Q3, also called the 75 %-ile).
The inter-quartile range (IQR) is the difference between these quartiles, that is, Q3 – Q1, and is used to help identify possible outliers in a dataset.
The circles are possible outliers and are points that lie more than 1.5 × IQR from the quartiles. That is, if a data point is below Q1 – (1.5 × IQR) or above Q3 + (1.5 × IQR), then it is considered to be an outlier.
The whiskers (dashed black line) show the range of the remainder of the data.

6 Flood Forecasting Model Performance Summary

The Flood Forecasting Model Performance Summary aims to provide, on one page, a concise indication of the performance of a flood forecasting model. It has two purposes. These are to:

- help assess and compare the performance of the various flood forecasting models used by the Environment Agency and Natural Resources Wales for flood guidance and warning across England and Wales
- aid with interpretation of flood forecasting models when used in an operational setting

It is intended that the Performance Summary will evolve over time to include as many useful summary statistics and displays as possible.

6.1 Annotated Performance Summary: a quick guide

An annotated example Flood Forecasting Model Performance Summary is given overleaf and serves as a concise user guide to its contents. This is supplemented by a one page ‘brief’ that outlines the methods and datasets used. Together, they form a two-sided quick guide to be used when interpreting the Performance Summary for a particular flood forecasting model and river gauging station.

Appendix C contains examples of the Performance Summary for individual sites in various regions and using different models. Details on each element of the Performance Summary are given in Section 6.2.

Flood Forecasting Model Performance Summary

1a.Location ID
NFFS ID (WISKI ID, NRFA ID)

1b. Catchment outline and location

- G2G boundary
- G2G outlet
- Catchment
- River gauge
- River
- Raingauge

1c. Site information: (if available)
1 = Artificial influences
2 = Gauge data quality for low, medium and high flows:
Green = good, Yellow = fair, red/amber= poor
3 = Urban factor. Weighted average of urban (0.7) and suburban (0.3) fractional coverages (area of circle also).
4 = Area in km^2. Recorded area (G2G area in brackets), plus area of circle.
5 = Percentage of area that is lakes
6 = Grid reference from the WISKI database
7 = Grid reference from the 1km G2G location

5. Flood hydrographs: 10 biggest events, showing a sequence of forecasts

- Observed
- Simulated (Historical)
- Forecast (hit)
- Forecast (miss)
- Tolerance Box

Details of model

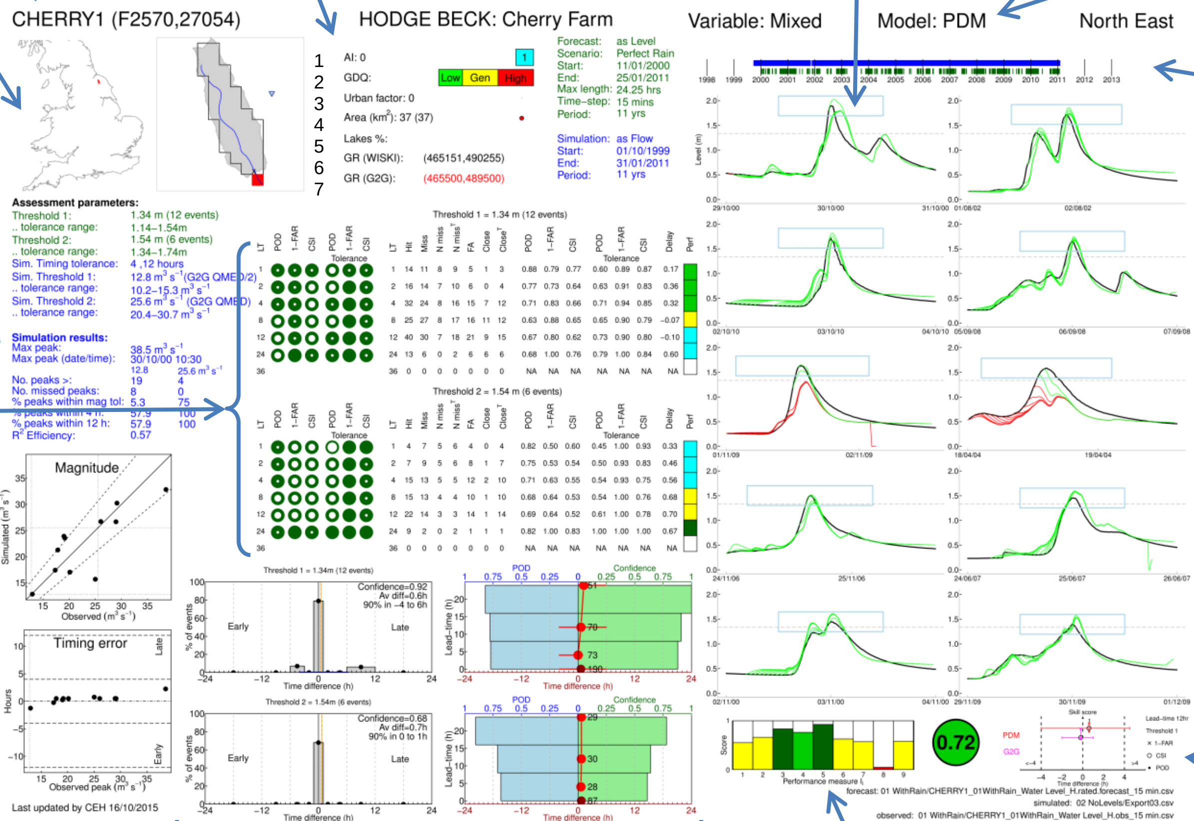
3. Assessment parameters: settings used to assess the forecasts. Standard tolerances on skill scores with tolerance are flows ±20% and levels ±0.2m. Standard thresholds are QMED and QMED/2.

2. Date info/line
Forecast
Simulation

4. Simulation (historical) results (if available)
Peak Magnitude plot: relationship between observed and simulated flow peaks. = tolerance
Peak Timing error plot: Difference in the timing of observed and simulated peaks.
--- at ±4 and ±12 hours.

6. Forecast Performance Measures. Probability of Detection (POD), False Alarm Ratio (FAR) and Critical Success Index (CSI) for lead-times: 1, 2, 4, 6, 12, 24, 36 hours, and 2 thresholds.
"Hit" = Observed event is correctly forecast
"Miss" = Observed event is not forecast
"FA"= Event was forecast and did not occur

- 0.9-1 excellent
- 0.7-0.9
- 0.5-0.7
- 0.2-0.5
- 0.0-0.2 poor
- no result (no crossings)



9. Model comparison
12 hour forecast performance measure and timing error comparing all models at this site for Threshold 1 with tolerance.

7. Acting on a forecast that has just crossed a threshold.
Right display. Information for lead-times: 0-8, 8-16 and 16-32hrs
Confidence scale gives the chance, *once a forecast has crossed the threshold*, that **an event occurs at some point within the forecast period.** Lots of green = very likely.
POD scale gives the chance that an actual event will be forecast at some point in the forecast period. Lots of blue = very likely

Right display (cont'd). Red denotes the mean (circle) and range (line) of time difference between forecast and observed events for 3 lead-time ranges (dark red is 0-36 hrs). +ve=forecast later than observed, -ve=forecast is early.
Left display: Histogram of time differences for 0-36 hrs.
Orange solid (dashed) line = mean (median) time difference.

8. Summary model performance statistics. Individual model performance statistics and Overall Performance Score.

The **Flood Forecasting Model Performance Summary** provides a nationally consistent model assessment of flood forecasting models. The datasets analysed derive from previous performance assessments. Where possible "Observed" rainfall is used as model input; otherwise, "Forecast" rainfall is used.

1. Site information (if available)
The catchment outline and location within the UK, and other known catchment details are shown if available. This information was collated for sites used in G2G studies. The raingauge locations are those used to derive the G2G model rainfall grids.

2. Thresholds and tolerance
Standard thresholds are QMED and QMED/2 based on G2G QMED grids. Standard tolerances are QMED and QMED/2 ±20% (as flow): these and the thresholds are converted back to levels if the rating is known. If ratings/G2G QMED values are not known then thresholds are based on n and n/2 events, where n is the record length; and the tolerances are ±20% for flows or ±0.2m for levels.

3. Summary of available data/ date-line
Start/end dates and line plot of available dates for forecast and simulated data including any breaks or gaps. G2G has forecasts every hour (continuous for 5 years); other models have selected forecasts corresponding to identified events. Model time-step is typically 15 minutes (occasionally 1 hour)

4. Simulation (historical) results (if available)
Peak magnitude and timing error plots show all points above lower threshold. Timing tolerances of 4 and 12 hours are shown.

***R^2* Efficiency** gives the proportion of variance in the observations accounted for by the model.

Q_t, q_t,	observed and modelled flow at time t
e_t	model error at time t
n	number of observations
$\overline{Q}$	mean of the observed flow over n observations.

$$R^2 = 1 - \sum e_t^{\,2} \Big/ \sum (Q_t - \overline{Q})^2$$

1 is perfect simulation; negative means it's worse than using $\overline{Q}$ - these are shown as 0.

5. Flood hydrographs
Forecasts for the 10 largest observed peaks are plotted (48 hours). All available forecasts in this period are shown. The box shows a timing tolerance of 12 hours and a magnitude tolerance of 20% (for flows) or ±0.2m (for levels). Forecasts which peak inside the box are "hits" and shown in green; the others are "misses" and are in red. Simulation data are shown if available and in the same units.

6. Table of categorical skill scores. Flood events are defined as occurring whenever the flow crosses the specified threshold level in an upwards direction.
Skill scores assess the ability of the model to forecast a crossing of a threshold within time Δt of the observed series also crossing the threshold. Performance is assessed at up to 7 lead-times with a lead-time window Δl used to include nearby forecasts. Δt and Δl increase with lead-time:

Lead-time	Δt	Δl
1	1	1
2	1	*1*
4	2	2
8	4	2
12	6	3
24	12	3
36	18	4

The skill scores use the following contingency table as their basis:

Event forecast	Event observed: Yes	Event observed: Close	Event observed: No
Yes	a (hit)	c_{fa} (close false alarm)	b-c_{fa} (false alarm)
Close	n_m (near miss)	d (correct rejection)	
No	c-n_m (miss)		

Timing tolerances are included in all results. An additional tolerance of magnitude is included in the tolerance results. Based on the above tables the skills scores shown here are:

Probability of Detection (POD). When an observed event does occur, POD is the proportion of events that were forecast to occur. Emphasises the number of events correctly forecast and ranges from 0 (poor) to 1 (perfect).

$$POD(tol) = \frac{a + n_m}{a + c}$$

False Alarm Ratio (FAR). When an event is forecast to occur, FAR is the proportion of occasions when an observed event did not occur. This emphasises events incorrectly forecast and ranges from 0 (good) to 1 (poor).

$$FAR(tol) = \frac{b - c_{fa}}{a + b}$$

Critical Success Index (CSI). A composite performance measure combining POD and FAR and allows for simpler comparison of performance.
The CSI will be high (near 1; a good performance) if POD is high and FAR is low; the CSI will be low (near 0; a poor performance) if POD is low and FAR is high.

$$CSI(tol) = \frac{a + n_m + c_{fa}}{a + b + c}$$

The coloured boxes at the extreme right are defined by a combined POD/FAR score, stratified by the colour-coding:

Dark green:	POD ≥ 0.8,	FAR ≤ 0.2
Light green:	0.8 > POD ≥ 0.7,	0.2 < FAR ≤ 0.3
Blue:	POD(tol) ≥ 0.7,	FAR(tol) < 0.3
Yellow:	0.7 > POD ≥ 0.5,	0.3 < FAR ≤ 0.5
Orange:	0.5 > POD ≥ 0.3,	0.5 < FAR ≤ 0.7
Red:	POD < 0.3,	FAR > 0.7

7. Acting on a forecast that has just crossed a threshold:
Forecast Confidence:
Similar to statistics in main table but uses forecast period for the comparison.

$$Confidence = \frac{a}{a + b} = 1 - FAR$$

POD shown here is a forecast period POD (if a forecast crosses anywhere in a forecast period it counts as a hit) – it is more generous than in the main table.
The circles and ranges (red lines) illustrate the expected time difference and range of times in which 90 % of the forecasts will occur (relative to the actual event). The values accompanying the circles indicate the number of events where the forecast occurs within each of the timing windows.

8. Summary model performance statistics
A set of 6 forecast and 3 simulation performance statistics with the first 6 averaged into an overall score of forecast performance, displayed in a colour-coded circle. All scores are scaled to be between 0 and 1.

1 and 2: CSI at 4 hour lead-time (upper and lower threshold)
3 and 4: CSI at 24 hour lead-time (upper and lower threshold)
5: Scaled average observed–forecast crossing time difference
6: Scaled average observed–forecast crossing time difference falling in timing tolerance window
7: R^2 Efficiency for simulation
8: Proportion of simulation peaks within magnitude tolerance
9. Proportion of simulation peaks within timing tolerance (12 hours)

9. Model comparison
If multiple models exist at a site, the 12 hour CSI and average timing error are plotted for each model, with vertical bars giving POD and Confidence, and horizontal bars 5% and 95% timing range. A 'good' point is at centre of x-axis (0 hour time error) and CSI = 1 with tight timing and POD/Confidence bars.

Further information
More details are given in 'Flood Forecasting Model Performance Summary: a User Guide' and 'Understanding the performance of flood forecasting models'.

Abbreviations

G2G	Grid-to-Grid
NFFS	National Flood Forecasting System
NRFA	National River Flow Archive

…

6.2 Details of performance summary

Provided they are available, the site/model summary part contains:

- a catchment map showing raingauge and river gauging station locations
- a summary of data availability
- other catchment information
- a dateline for the dataset
- the parameters used in model assessment

These are outlined in turn below.

6.2.1 Part 1: Map and outline of site

The catchment outline and location within the UK is shown (if available): Figure 6.1 gives an example whilst Figure 6.2 displays the accompanying legend.

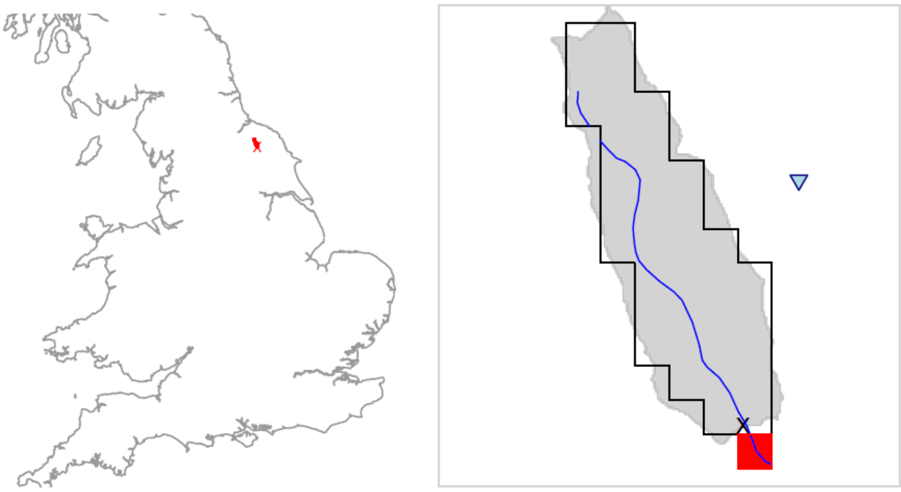


Figure 6.1 Example catchment outline and location maps

Notes: The catchment location within the UK is shown.
A map of the catchment is provided with Figure 6.2 giving legend details.

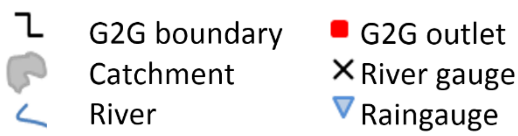


Figure 6.2 Catchment map legend details

The raingauge locations in the catchment map are those used to derive the Perfect Rainfall grids (HyradK raingauge-only 1km 15-minute rainfall totals) for input to G2G.

Other catchment information

Other catchment information presented on the Summary page (if available) is:

- artificial influences (AI) – an Environment Agency grading of catchments ranging from 1 (no artificial influences) to 9 (very heavily influenced)
- gauged data quality (GDQ) – an Environment Agency measure of how well a site is considered to be gauged at low, medium and high flows; colour-coded as green = good, yellow = fair, red/amber = poor
- urban factor – weighted average of urban (0.7) and suburban (0.3) fractional coverages (area of circle also)
- area in km^2 – recorded area (G2G area in brackets), plus area of circle
- percentage of area that is lakes
- location of outlet expressed in WISKI and G2G 1km co-ordinates

6.2.2 Part 2: Date information and dateline

This part provides details of the data used to assess the model. It includes:

- start and end date
- length of record
- forecast time-step
- forecast length

If a historical simulation series is available, this is also shown.

Dateline

The dateline is used to show the extent of the observed/modelled data including any breaks or gaps. The profile is shown for forecast series (dark green) and historical simulation series (dark blue). For some models, the runs are continuous (full line) while for others they are sporadic or event-based (broken line).

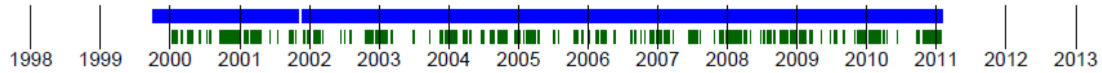


Figure 6.3 Example dateline

Notes: The dateline shows the availability of data for the forecast (dark green) and, if available, the historical simulation data (dark blue).

6.2.3 Part 3: Thresholds

The model assessment parameters include:

- the peak and timing tolerances used
- the selected thresholds
- the timing windows used with the forecasts

Standard tolerances are ±20% for flows and ±0.2m for levels. These values are cross-converted to help understand whether they are similar or different at specific sites.

Model performance measures as skill scores are presented for the 2 nationally consistent thresholds, G2G QMED (Threshold 1) and G2G QMED/2 (Threshold 2), or their river level equivalents when required. In circumstances where these thresholds could not be used for the local model assessment, the observed flows within the local model datasets were used to derive the thresholds following the procedure set out in Section 5.1.1.

For models run on an event-only basis, there is no guarantee that the 'lower' Threshold 2 and the 'peaks' Threshold 1 (used to try and capture false alarms) will be sufficiently low.

6.2.4 Part 4: Simulation (historical) performance

These outputs summarise the performance of the model when operated in simulation mode (no use of observed flows/levels). Sometimes this is referred to as 'historical' performance.

For G2G, this will be a model simulation using slow-state updating but with no flow-insertion and no ARMA error prediction. This makes a slow adjustment to deeper water stores to align the baseflow to observations for groundwater-dominated flow regimes, compensating for the model's shortcomings in such areas. For other models, it is considered to be the best match to simulation-mode operation.

The outputs detailed below include summary statistics and graphs of observed versus simulated flood peaks and their associated timing errors.

Summary statistics

The performance of the model is summarised using the following metrics:

- % of simulated peaks that fall within the tolerance level of the observed peaks
- % of simulated peaks that fall within the timing tolerance level of the time of the observed peaks
- R^2 Efficiency (Nash–Sutcliffe efficiency) for the simulated data

Observed versus simulated peaks

The graph in Figure 6.4 shows the relationship between observed and modelled flow peaks. The horizontal and vertical dotted lines show the thresholds used, and the diagonal dotted lines show a tolerance of ±0.2m (levels) or ±20% (flows).

When flows are being used, the diagonal lines diverge since the tolerances are multiplicative, whereas for levels the tolerances are additive and hence run parallel. Only observed flows larger than the lowest threshold used are show in the graph.

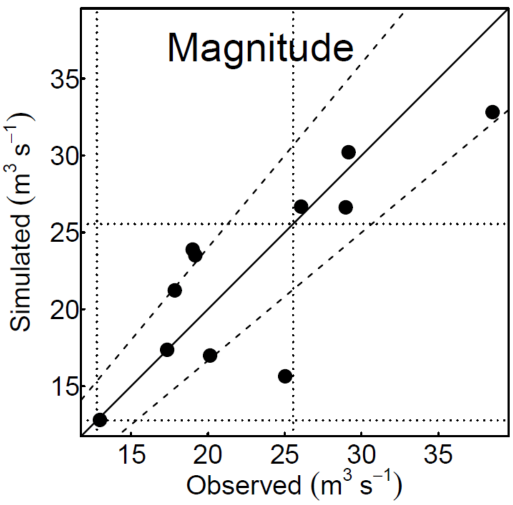


Figure 6.4 Example plot of observed versus simulated peaks for the historical simulation data

Notes: The diagonal line is the 1:1 line with tolerance marked as the dashed line.
Dotted vertical and horizontal lines are the two thresholds used (if available).

Timing errors

The graph of timing errors shows the difference in the timing of peaks between observed and simulated series. The horizontal dashed lines show timing thresholds of 4 and 12 hours. Only observed peaks larger than the lower threshold (indicated by the vertical dotted line) are shown.

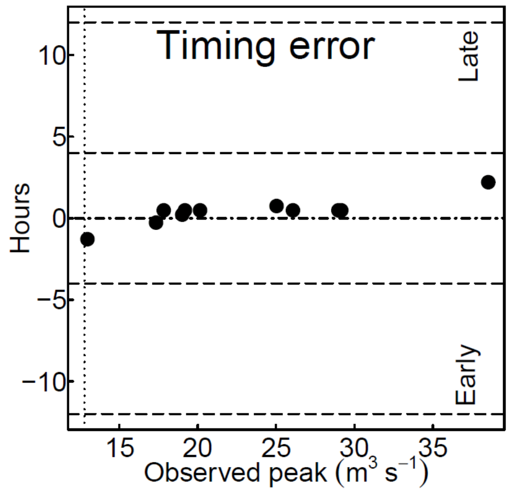


Figure 6.5 Example plot showing timing error in the historical simulation data as a function of observed peak magnitude

Notes: Horizontal dashed lines show 4 hour and 12 hour time differences.
Forecasts which predict events later than the observations are shown with positive time differences.

6.2.5 Part 5: Event hydrographs for the largest events

Flood forecasting model performance for the 10 largest observed peaks is illustrated using event hydrographs. The displays include the following information:

- observed data (black)
- model simulation (**blue**)
- model forecasts (only forecasts prior to the observed peak are shown)
  - where the forecast peak is within a magnitude and timing threshold of the observed, as shown in green – these forecasts are 'hits'
  - where the forecast peak is outside these thresholds, as shown in red – these forecasts are 'misses'
- threshold window around the peak – this is the time and magnitude 'box' that forecasts must pass through in order to be a hit / green; this box is marked in light blue
- threshold lines – grey horizontal dotted

6.2.6 Part 6: Performance tables of POD, FAR and CSI

The performance tables presented here use a combination of text and graphical output. A separate table can be provided for each required rainfall scenario and threshold.

The text output includes the POD, FAR and CSI skill scores – with and without tolerance. The counts on which these scores are based are also detailed. This includes the number of:

- hits (Hits)
- misses and false alarms (FA)
- near misses (N miss)
- close false alarms (Close)

The POD, FAR and CSI values are graphed using circles that are graded into 5 categories (Figure 6.6). The circles with more shading indicate 'good' model performance and the empty circles indicate poor performance.

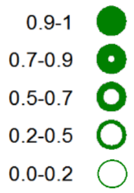


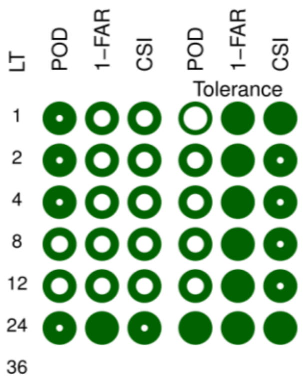
Figure 6.6 Circular scale for skill plot tables for values ranging from 0 to 1

Notes: Best performance is for the filled in circles.
Poor performance is marked by the emptier circles.

In the circle graphs, FAR values are shown as Confidence, *C* = 1 – FAR. This allows for a convention of shaded circles meaning 'good' performance.

Lead-times are presented for 1, 2, 4, 6, 12, 24 and 36 hours (if available).

Figure 6.7 shows the skill score display and table for Threshold 2 from the example in the quick guide (Section 6.1).



LT	Hit	Miss	N miss	N miss^T	FA	Close	Close^T	POD	1–FAR	CSI	POD (Tolerance)	1–FAR (Tolerance)	CSI (Tolerance)	Delay	Perf
1	4	7	5	6	4	0	4	0.82	0.50	0.60	0.45	1.00	0.93	0.33	
2	7	9	5	6	8	1	7	0.75	0.53	0.54	0.50	0.93	0.83	0.46	
4	15	13	5	5	12	2	10	0.71	0.63	0.55	0.54	0.93	0.75	0.56	
8	15	13	4	4	10	1	10	0.68	0.64	0.53	0.54	1.00	0.76	0.68	
12	22	14	3	3	14	1	14	0.69	0.64	0.52	0.61	1.00	0.78	0.70	
24	9	2	0	2	1	1	1	0.82	1.00	0.83	1.00	1.00	1.00	0.67	
36	0	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	

Figure 6.7 Example skill score display and table

Notes: The skill score display is presented with and without magnitude tolerance (all results include a timing tolerance).
The legend for the circles (heavily filled circles mean a good performance, empty circles poor performance) is shown in Figure 6.6.
The skill score table shows the counts of the contingency table along with near misses (N miss) and close false alarm (FA) scores for both timing tolerance and magnitude tolerance.
Columns headed ‘T’ indicate an additional timing tolerance.
The results are for lead-times (LT) from 1 to 36 hours.
The counts may include multiple forecasts for an event and thus there may be more ‘hits’ than events.

The final column of numbers in Figure 6.7 (headed ‘Delay‘) indicates the average time delay in hours between the observed and forecast event. This average is taken over all observed hits and near misses. It does not include events where the observed data signify an event and the forecast does not, or vice versa. The sign of the value indicates whether the average is early or late: a positive value indicates that the forecast is on average registering an event late, and a negative value that an event is forecast earlier than observed.

The skill score display and table for some site/model combinations can show model performance improving with increasing lead-time, while normally it is expected to be better at shorter lead-times. Such behaviour can be explained when the timing tolerance windows are being applied. At higher lead-times, it is expected that uncertainty in the timing of forecasted events will increase, and as such, the lead-time window (in which forecasts must fall to be analysed) increases. The actual lead-time windows used are given in Table 5.1 and are chosen to increase with lead-time. An apparent improved performance with increasing lead-time could be interpreted as an indication that the lead-time windows are too large at higher lead-times. However, since greater uncertainty in forecast timing is expected, and therefore there is a lower expectation of timing accuracy, such behaviour can be seen to be appropriate *given the understanding that there is a lack of timing accuracy at higher lead-times* which is reflected in use of a wider lead-time window.

In addition to the skill scores, a colour-coded chart is included as an indication of the combined quality of the POD and FAR scores, incorporating those allowing for tolerance. The chart provides an immediate idea of the reliability of the event detection success of the forecast at each lead-time.

The colour scores are derived using the procedure summarised in Table 6.1. The procedure uses a grading system similar to that employed by JBA (see, for example, JBA Consulting 2015).

Table 6.1 Skills performance grading for POD and FAR scores

Grade	Description	POD	FAR
1	Exceeds target	POD ≥ 0.8	FAR ≤ 0.2
2	Meets target	0.8 > POD ≥ 0.7	0.2 < FAR ≤ 0.3
3	Meets target with tolerance	POD (with tolerance) ≥ 0.7	FAR (with tolerance) < 0.3
4	Does not meet target	0.7 > POD ≥ 0.5	0.3 < FAR ≤ 0.5
5	Significantly below target	0.5 > POD ≥ 0.3	0.5 < FAR ≤ 0.7
6	Poor	POD < 0.3	FAR > 0.7

Notes: The final grade is defined as the best that can be achieved by both the POD and FAR scores; that is, the lowest of the 2 individual grades.

The final grade combining both the POD and FAR scores is defined as the best grade at which both the POD and FAR can achieve, that is the lowest of the 2 individual grades. For example, a score of POD = 0.6 (0.65 with tolerance) and FAR = 0.25 (0.21 with tolerance) gets a Grade 4 (yellow) because, although the FAR score gets a Grade 2 (light green), the POD only achieves Grade 4.

This scoring system is used in Appendix F to summarise model performance for all sites and in Appendix G to compare performance across models for sites with multiple models.

6.2.7 Part 7: Additional statistics for operational use

The graphs of additional statistics in the Flood Forecasting Model Performance Summary provide information that seeks to address the question of what action should be taken at a site if a forecast has just been issued that crosses a threshold. The information is provided for both the QMED and QMED/2 thresholds. Four graphs are provided:

- time difference display for Threshold 1 (QMED/2)
- time difference display for Threshold 2 (QMED)
- forecast performance display for Threshold 1 (QMED/2)
- forecast performance display for Threshold 2 (QMED)

For operational use, the distinction between forecast assessments using perfect foreknowledge of rainfall (the majority) and those using forecast rainfall needs to be borne in mind when using the additional statistics described here (see Section 5.5). The former has value in removing the confounding influence of errors in the rainfall forecast and giving focus to the quality of local model performance.

Time difference display

The time difference histogram shows the distribution of the time differences between forecast and actual events and can be used to assess whether forecasts are typically early and late and whether the timing is consistent or quite variable.

In the example display shown in Figure 6.8, most of the forecasts relative to the observed data have little timing error, which on average is only 0.6 hours. There is variation in timing error seen for some events, and these are quite balanced between early and late. The 90% statistic provides a time-range within which 90% of the events occurred. Here this is 10 hours, ranging from 4 hours in advance to 6 hours too late. The forecast Confidence, *C*, is the probability that an observed event will occur within the range of the forecast for a forecast that has crossed a threshold.

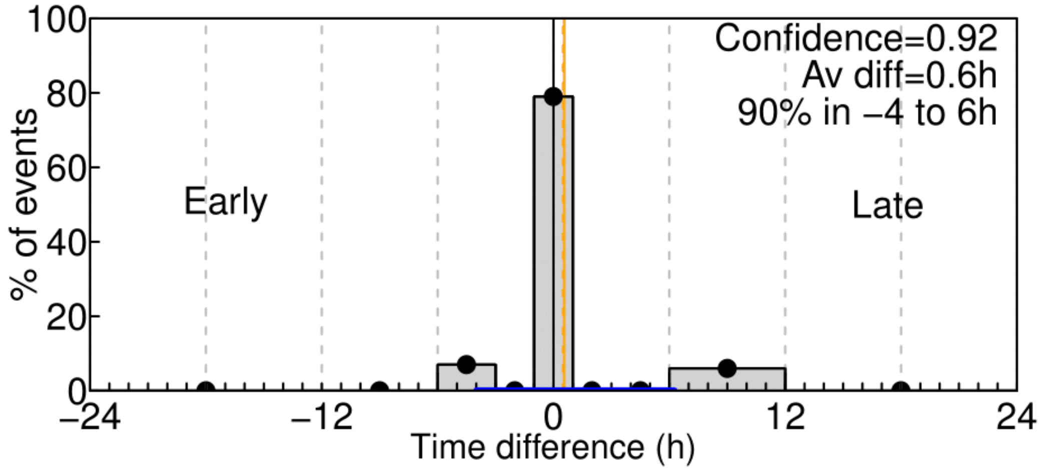


Figure 6.8 Timing difference display showing distribution of timing differences between forecast and observed data

Notes: In this example, most of the forecasts occur later than the observed events. The top right hand details give the average and range of the time differences. Forecast Confidence is also included (0.87 is the probability that an event occurs if it is forecast).

Forecast performance display

A second display, shown in Figure 6.9, is used to present additional information on forecast skill, again aimed at deciding what to do in an operational setting. This can be used alongside the table of skills scores (Section 6.2.6).

In this display, the information is grouped by lead-times of: 0–8, 8–16 and 16–32 hours. For these lead-time ranges, the POD is shown on the left of the display and the Confidence of the forecast (that is, the probability that an observed event occurs at some point within the forecast period) is shown on the right.

In the example shown in Figure 6.9, for forecasts with lead times of over 16 to 32 hours, there is a ~77% chance that an event is forecast (POD), and a ~100% chance that an event occurs if the forecast crosses the threshold in this range (Confidence). The red dots and ranges illustrate the expected time difference and range of times in which 90% of the forecasts will occur (relative to the actual event). The values accompanying the red dots indicate the number of events where the forecast occurs within each of the timing windows. The dark red dot relates to information for the entire 36 hour lead-time.

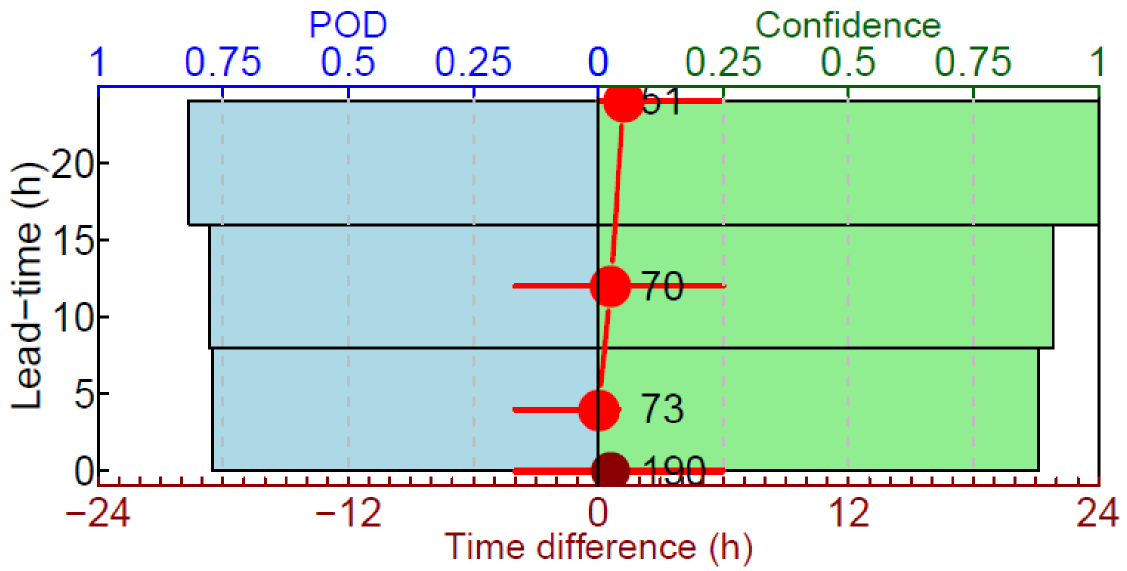


Figure 6.9 Forecast performance display showing POD (blue) and confidence (green) for early, mid and late part of the forecast

Notes: The red dots and line show the timing differences (dots) and the time range within which 90% of forecasts fall (line). The values accompanying the red dots indicate the number of events where the forecast occurs within each of the timing windows. The dark red dot relates to information for the entire 36 hour lead-time.

6.2.8 Part 8: Overall Performance Summary Statistic

The overall performance of the model is summarised by the component statistics described in Section 5.6. These are displayed as a set of vertical bars, as shown in the examples in Figure 6.10.

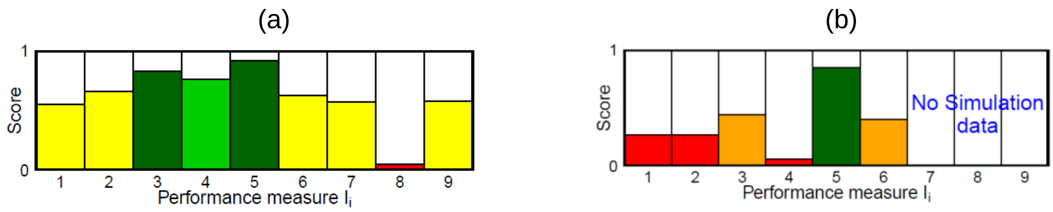


Figure 6.10 Overall Performance Summary display for two examples where simulation data are available (a) and unavailable (b)

Reading from left to right, the bars correspond to the values of I_1 to I_9. For the statistics I_i, $i \in \{7 \ldots 9\}$, simulation data are required to construct the statistic. In cases where no simulation data are available, these three columns furthest to the right are left blank, as in Figure 6.10b. The colouring is defined in a similar way to the combined POD/FAR scores described in Table 6.1. Given a score of **S**, the intervals are as shown in Figure 6.11.

S < 0.3: ; 0.3 ≤ **S** < 0.5: ; 0.5 ≤ **S** < 0.7: ; 0.7 ≤ **S** < 0.8: ; **S** ≥ 0.8:

Figure 6.11 Colour coding used for the Overall Performance Summary display

In addition to the individual summary statistics, an overall score is provided based on the mean of the statistics that employ forecast data (I_1 to I_6) that are independent of the quality of the simulation data. Note that since simulation data are not available for all sites, scores based on them would introduce a bias if included in an overall score measure. The score is out of one and is colour-coded as for the Overall Performance Summary information (Figure 6.11). An example is shown in Figure 6.12.

Figure 6.12 Example of an overall score display

Notes: The maximum score is 1.
The colour-coded grading is as for the Overall Performance Summary information.

6.2.9 Part 9: Comparison with other models

Many of the sites analysed have forecast data produced by more than one model, whether that be a local one and the associated national G2G model, or multiple local models used at the same site.

To provide a concise comparison of model performance for a particular site, a display in the form shown in Figure 6.13 is included on each Performance Summary page.

The CSI value, indicated by an open black circle, for a lead-time of 12 hours at the lower threshold (with tolerance) is shown for each model on the vertical axis (scale 0 to 1). The average timing difference between observed and forecast events at the same lead-time (early forecasts are negative) for each model is shown on the horizontal axis.

The horizontal bars illustrate the 90% range of timing differences at this lead-time for each model. The values of POD and Confidence (1-FAR) are also included in relation to the vertical axis scale, designated by the smaller filled circle and cross respectively affixed to the vertical coloured line. In cases where the timing difference is greater than 4 hours (early or late), values are plotted at a fixed distance to the outside of the vertical dashed lines, such as to maintain equal plot axes for ease of comparison.

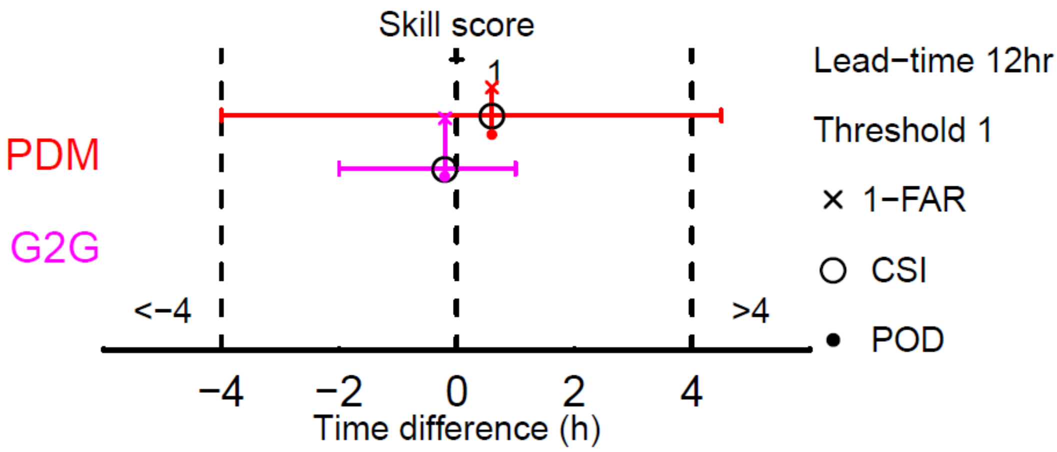


Figure 6.13 Example of a model performance comparison display for all models with forecasts at a given site

Notes: The horizontal bars illustrate the 90% range of timing differences at the 12 hour lead-time for the particular model.
The values of POD and Confidence are included for each model. They are designated by the smaller filled circle and cross respectively and joined by a vertical line coloured by model name.

7 Analysis of Performance Summary Statistics

This section examines FFMP statistics from a national and regional perspective. It examines how well different model simulations perform and how well flood forecasts perform in different parts of England and Wales. It also compares results from NFFS local models and the G2G countrywide national model.

In considering the results, it is important to remember that differences between different parts of England and Wales may arise for a complexity of reasons, including:

- different regional conditions, for example, different mixes of land use and terrain, drainage systems, influences of urbanisation and industry
- different choices of model type at a regional level – models were typically selected or developed that were believed at the time to be appropriate to local circumstances
- different consultants with differing levels of expertise will have calibrated the models used
- differences in quality of flow rating, selection of gauging site, technology used for gauging and other considerations will all affect the flood forecasting model performance achieved
- differences in the quality, including any bias, of rainfall inputs
- differences in rainfall scenarios used, with some local assessments only having flood forecasts available that use rainfall forecasts as input and not raingauge rainfall (see Section 4.3.1).
- differences in the model time-step, with hourly used instead of 15 minutes depending on region and/or model context (see Section 4.3.4).
- differences in the number and timing of forecast runs – for assessment purposes, G2G forecasts are run every hour while other model forecasts are run in relation to event threshold crossings
- differences in the source of the magnitude tolerances used – these will affect model comparison of the 'with magnitude' tolerance skill scores

Other factors that are important when evaluating differences between models include the use of different models within a river basin for different purposes, for example, ISIS for downstream river reaches and PDM for upstream catchment areas. In addition, some of the models have only been applied within one region, for example, MIKE 11 in Anglian, TCM in Thames and MCRM along with DODO in Midlands.

When making comparisons between national G2G and local models, the following two differences should be borne in mind. First, all forecasts (produced every hour) are used for forming performance statistics for G2G, whereas forecasts for the local models are generally limited to those made prior to event threshold crossings. This would be expected to result in a lower estimate of False Alarm Ratio (a higher estimate of Confidence) for the local models. That is, it should slightly favour the assessment of the local models relative to G2G. Second, G2G uses a different rainfall input to the local models, employing gridded rainfalls obtained from spatial (multiquadric) interpolation of raingauge network data using HyradK.

Because of these various factors, it cannot simply be concluded when comparing model or regional performance that a model can be successfully transferred for application to another region to improve flood forecasting performance there. For example, good performance of PDM in the North West does not mean it would be suitable or outperform the use of MIKE 11 in Anglian region; in this case the two models are used for very different purposes.

As discussed in Section 3, the models can be grouped by type as shown in Table 7.1. Previous studies for the Environment Agency have considered the issue of which models perform best in which circumstances and have applied multiple models at selected sites to provide guidance on model choice. See, for example, Moore et al. (2000) and Environment Agency (2001b) in relation to an extensive comparison of local rainfall-runoff models and Environment Agency (2010) for a limited comparison of national G2G and local rainfall-runoff models.

Table 7.1 Flood forecasting model grouping by type

Type	Models
Rainfall-runoff: conceptual	PDM, MCRM, TCM
Rainfall-runoff: transfer function	PRTF
Flow routing: hydrological	KW, DODO
Flow routing: hydrodynamic	ISIS, MIKE 11
Distributed	G2G

Notes: There may be some overlaps between the groupings: for example, ISIS and Mike 11 include hydrological flow routing as an option.
Some form of updating, such as ARMA error-prediction or state-updating, can be invoked for each model type. This is not explicitly considered in the groupings shown.

The figures presented throughout Section 7 make extensive use of box plots to provide a simplified illustration of the distribution of data points analysed. See Section 5.7 for an explanation of these box plot diagrams as background to the analyses that follow.

7.1 Analysis of skill scores

The skill scores analysed here are the POD, Confidence (1 - FAR) and CSI scores for the forecast sites assessed for performance. The results are grouped by:

- lead-time and threshold level
- level of tolerance used – with and without magnitude tolerance

All the results include timing tolerances.

7.1.1 Comparison of model performance by model type

A variety of displays are used to present the model performance as measured by POD, Confidence and CSI as a function of lead-time and model type. For example, in Figure 7.1 (QMED/2 threshold) and Figure 7.2 (QMED threshold), box plots are used to show the distribution of values of these statistics for each model and for lead-times from 1 to 36 hours. The results shown in Figure 7.1 and Figure 7.2 are summarised in Figure 7.3, which shows the mean performance measure for each model at each lead-time for

QMED/2 and QMED. The following observations on Figure 7.1, Figure 7.2 and Figure 7.3 can be made.

- The performance at a lead-time of 1 hour is the highest of all the lead-times for all models.
- Several models show a marked decline in performance with lead-time. This is greatest for PRTF, MCRM, TCM and DODO which do not perform well at longer lead-times. Since a forecast rainfall scenario has been used for TCM, it is not clear whether this effect is due only to the rainfall or also has a model component. For MCRM and DODO, use of a mix of 'perfect' and 'forecast' rainfall, depending on site, again makes interpretation difficult and probably accounts for the greater spread of statistics, especially at longer lead-times.
- G2G, PDM and MIKE 11 show a more even performance over lead-time and may even show some increased measure of performance for longer lead-times, especially when magnitude tolerance is used. This is likely in part to be an artefact of the increasing time tolerances used at longer lead-times. It does not mean that the model predicts better at long lead-times, but reflects a combination of how well the model forecasts at longer lead-time and expectations for what a good forecast at longer lead-times might look like.
- PDM, ISIS, MIKE 11 and KW provide better forecasts at longer lead-times than the other models.
- For all the models, the evolution of POD, confidence (1 - FAR) and CSI with lead-time is broadly similar at the two threshold levels (QMED, QMED/2) and with and without tolerance on magnitude.
- Typically, the magnitude tolerance statistics show similar (but higher) values compared with those for without magnitude tolerance. MIKE 11 shows a particularly dramatic improvement in CSI when there is magnitude tolerance. ISIS, PDM, TCM and G2G also show striking improvements, with slightly more modest shifts for the other models. For MIKE 11, the shift is sufficient to move it from being generally worse than G2G (without magnitude tolerance) to generally better than G2G (with magnitude tolerance). See also Section 7.1.5.
- The results for QMED and QMED/2 thresholds are typically broadly comparable.
- G2G has a different balance between POD and Confidence to the other models (POD is proportionally lower and Confidence higher).
- MIKE 11 and TCM have a much smaller sample size than the other models.

These results are also mapped in Figure 7.4, Figure 7.5 and Figure 7.6 to examine spatial variations.

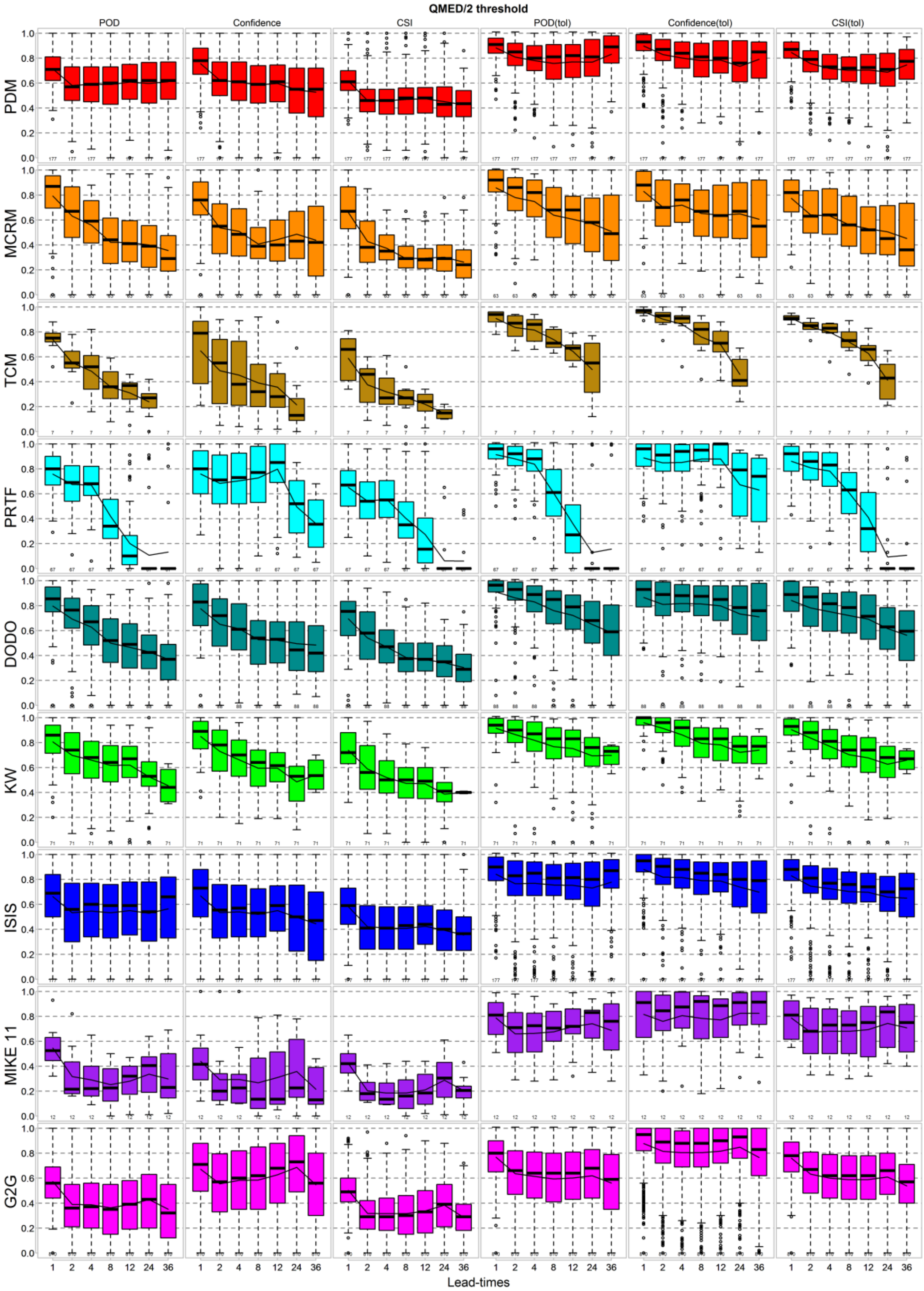


Figure 7.1 Multi box plots of skill scores stratified by model type and by lead-time for QMED/2 threshold

Notes: Results are shown for POD, Confidence and CSI with and without magnitude tolerances.
Each subplot shows a set of box plots (see Section 5.7) with a superimposed black line which indicates the average value at each lead-time.
The number at the bottom of each box plot is the sample size.

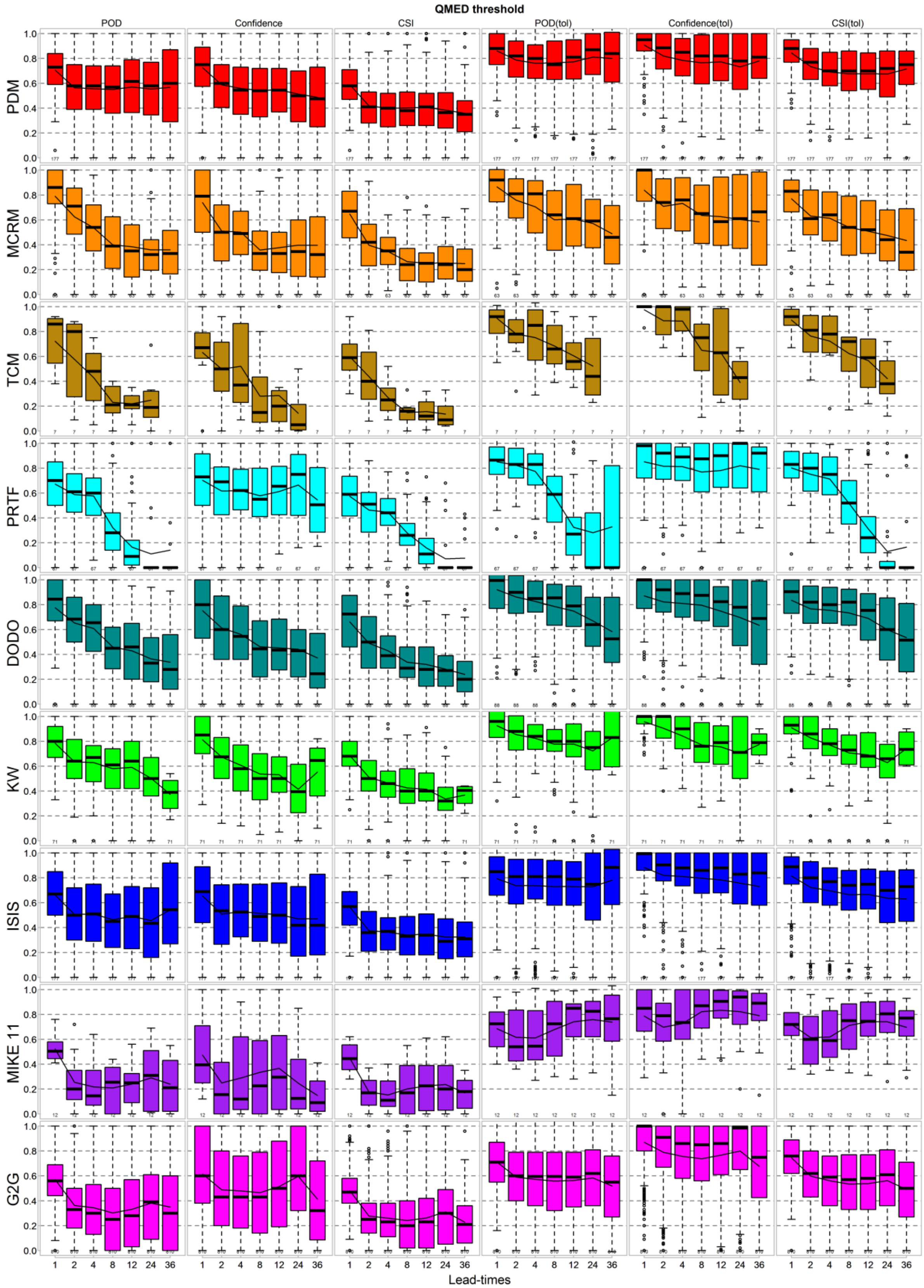


Figure 7.2 Multi box plots of skill scores stratified by model type and by lead-time for QMED threshold

Notes: Results are shown for POD, Confidence and CSI with and without magnitude tolerances. See Figure 7.1 for more details.

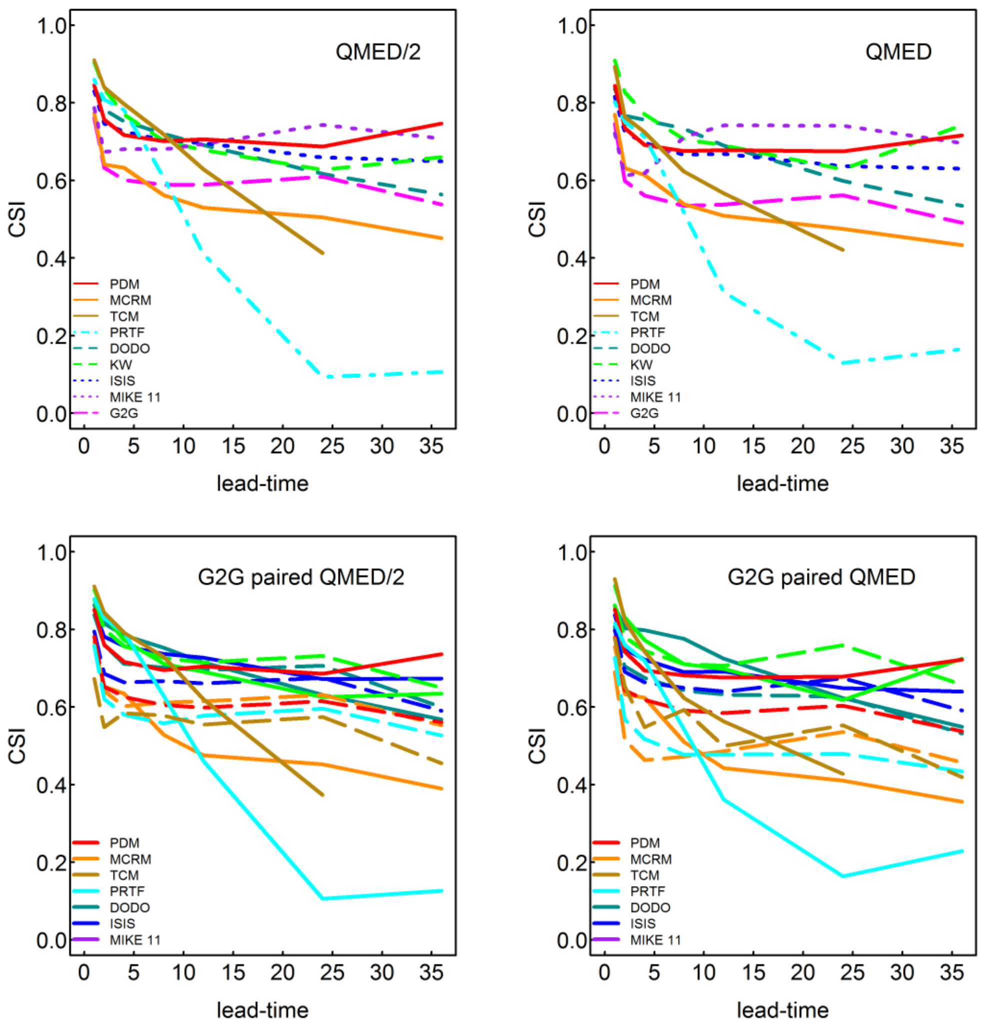


Figure 7.3 Average model CSI performance for QMED/2 and QMED with magnitude tolerance

Notes: In the top pair of graphs, data from all available sites for each model are used. The line colour indicates the model type and the line type indicates the model grouping. For example, ISIS and MIKE 11 both have a dotted line.
In the lower pair of graphs the catchments are paired between each model and G2G. For example, the PDM (red) solid line shows all PDM models for which there is also a G2G model; the PDM (red) dashed line shows the G2G results for the same set of sites.

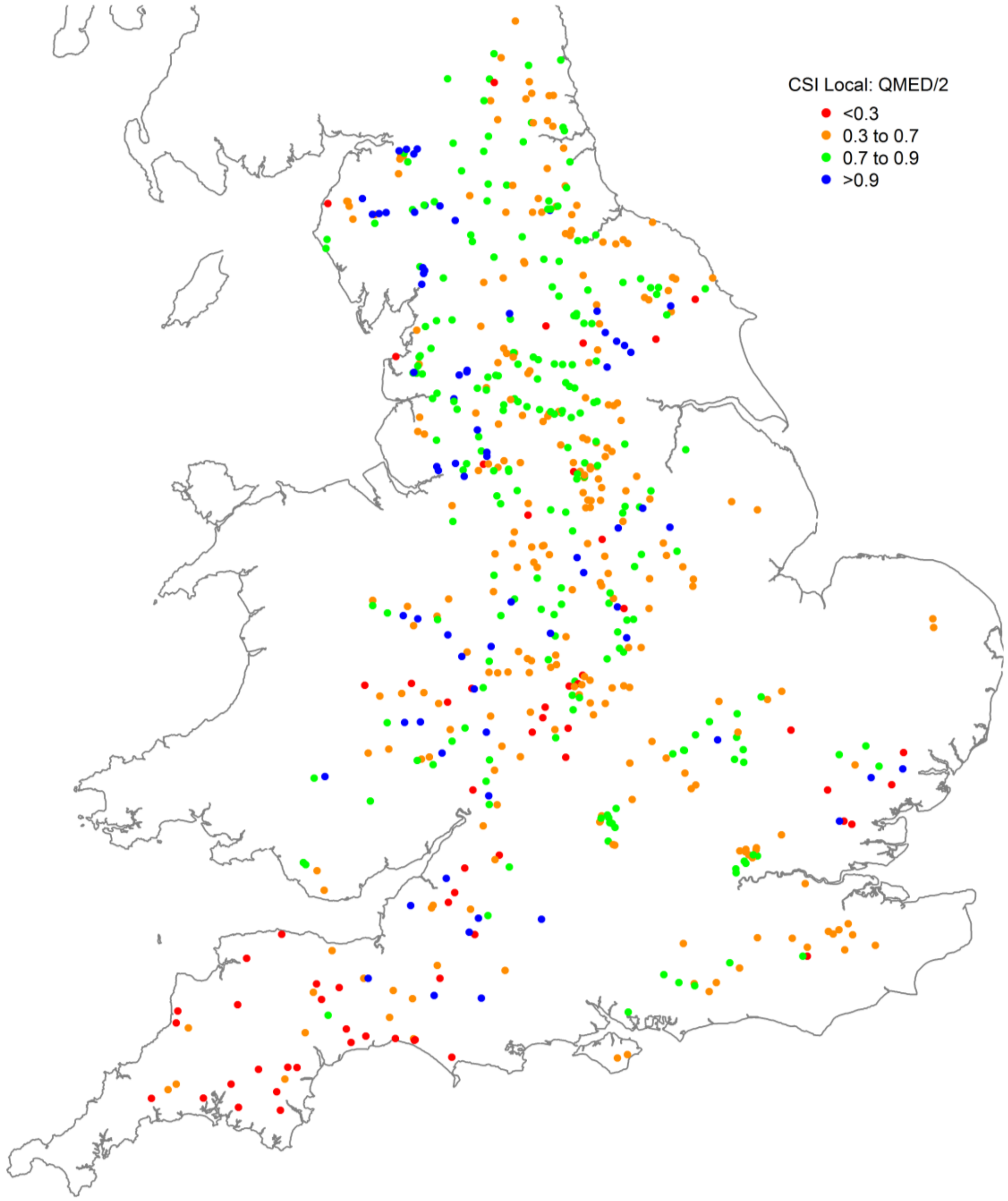


Figure 7.4 Performance map showing CSI with magnitude tolerance for local models at 12 hour lead-time

Notes: Where multiple models exist at a site, results from only one of these models is visible on the map.

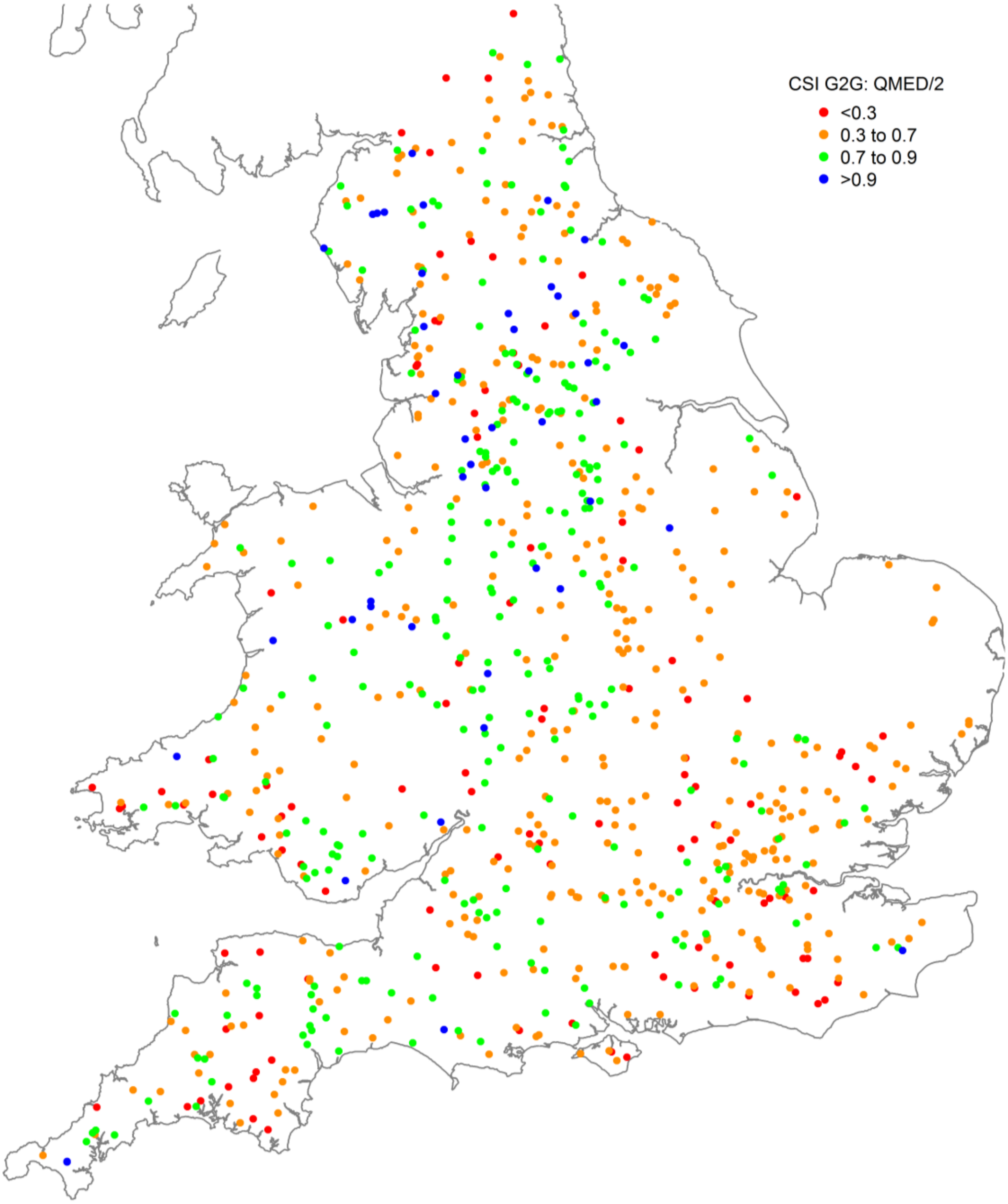


Figure 7.5 Performance map showing CSI with magnitude tolerance for G2G models at 12 hour lead-time for QMED/2 threshold

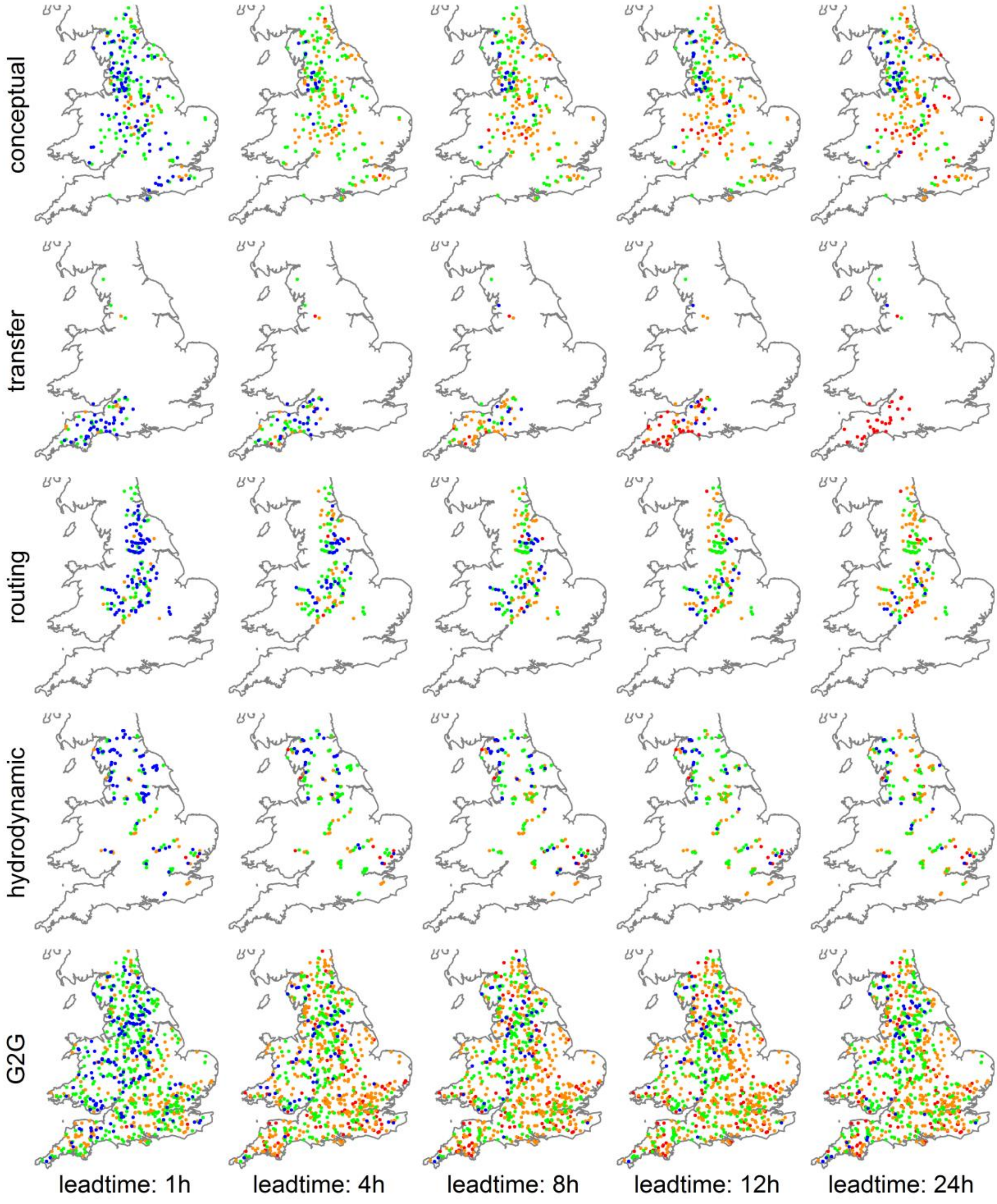


Figure 7.6 Performance maps showing CSI with magnitude tolerance stratified by model group and by lead-time for the QMED/2 threshold

Notes: The colour coding is the same as for Figure 7.5.

The maps of CSI values for the different models indicate that:

- in the north, local models are, on the whole, performing better than G2G
- in the south, G2G has more sites with reasonable performance relative to local models
- the same lead-time characteristics apply as above, with local models tending to outperform G2G at shorter lead-times, but at longer lead-times, G2G performs comparatively well

Among the conceptual rainfall-runoff models, for lead-times of 8 hours and beyond, the PDM typically outperforms the other models. However, the two other conceptual models used (MCRM and TCM) are applied in areas that can be tricky to model and with a different, less accurate, rainfall scenario. It is not necessarily the case that the PDM would perform any better on these catchments.

It appears that the PRTF model performs more poorly than PDM models and that it is really only useful for the first 8–12 hours. PRTF models are mainly used in the South West. However, this is not an area anticipated to be as challenging to model as Thames and Anglian.

Among the flow routing models, KW produces better results than DODO. This may be because it has been applied to more northern and less flat river reaches and because it uses the perfect rainfall scenario (DODO uses the forecast rainfall scenario).

For the hydrodynamic models used here, the performance of ISIS is better than MIKE 11. However, MIKE 11 is applied in Anglian at only a limited number of sites, while ISIS is used in several northern areas that are generally less flat (and less artificially influenced). Hence this may simply be an artefact of where the models have been applied.

G2G shows a bigger spread of performance than other models. This is because it is applied to a much larger number of sites and a wider variety of catchment types.

7.1.2 Pairwise comparison of G2G and local model performance

This section assesses forecasts for sites which have both a G2G model and a local model. This provides a more direct comparison between forecasts from local models and G2G. The aim is to compare G2G model performance with each of the local models.

Figures 7.7 to 7.9 present a comparison of G2G with the various local models shown for:

- CSI with tolerance at a QMED threshold
- POD for QMED/2 without magnitude tolerance
- Confidence (that is, 1 - FAR) at QMED thresholds

The CSI information is also summarised in Figure 7.4 and in

Table 7.2. Compared with the other local models, G2G tends to have a lower POD but higher Confidence. Thus, on average, G2G is less likely to detect events, but when G2G does detect an event it is more likely that it will actually occur than for the other models. It is not clear why this is the case.

Table 7.2 Comparative performance of G2G and local models for POD, Confidence and CSI for sites with matched models.

Model	POD		Confidence		CSI	
	Short	**Long**	**Short**	**Long**	**Short**	**Long**
PDM	PDM	PDM	G2G	G2G	PDM	PDM
TCM	TCM	?	=	=	TCM	G2G
MCRM	MCRM	G2G	=	G2G	=	G2G
PRTF	PRTF	G2G	=	=	PRTF	G2G
DODO	DODO	=	=	G2G	=	G2G
KW	KW	KW	=	G2G	KW	G2G
ISIS	ISIS	ISIS	=	G2G	ISIS	Similar

Notes: The table indicates (approximately) which model, if any, generally performs better for short and long lead-times.
MIKE 11 is not shown as there are too few forecasts for assessment.

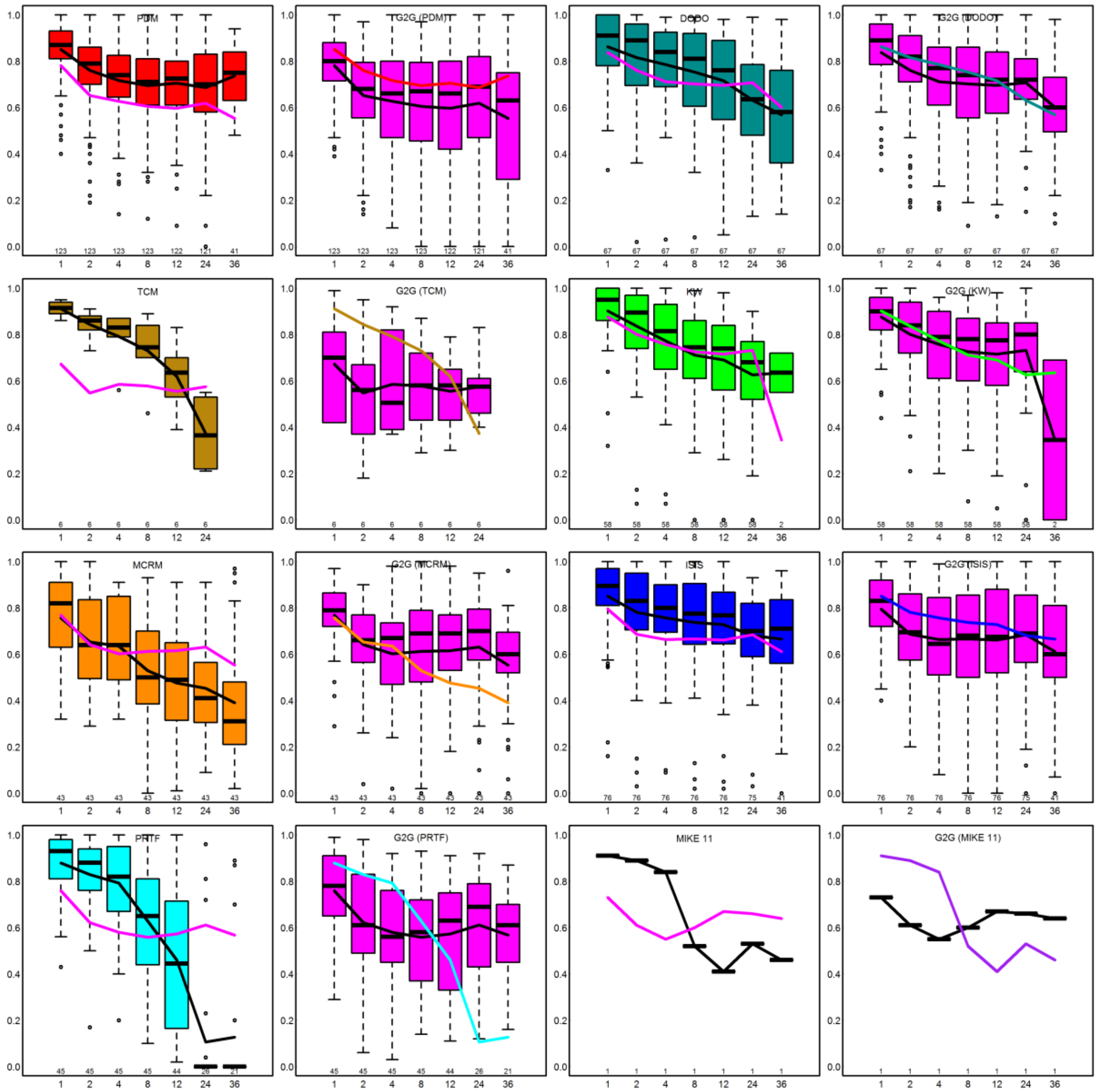


Figure 7.7 Multi box plot showing CSI with tolerance at QMED/2 threshold for matched G2G and local model sites

Notes: Only sites that have both a local model and a G2G model are shown.
Results are presented for each local model type.
The plot on the left shows the distribution of CSI values at each lead-time for the selected local model. The black line on this plot shows the average CSI value for the local model. The pink line shows the comparable G2G average CSI value.
The right hand plots (in pink) show the equivalent for G2G sites that match the selected local model. The black line is the G2G average and the coloured line the corresponding local model average.
MIKE 11 only has one site in common with G2G.

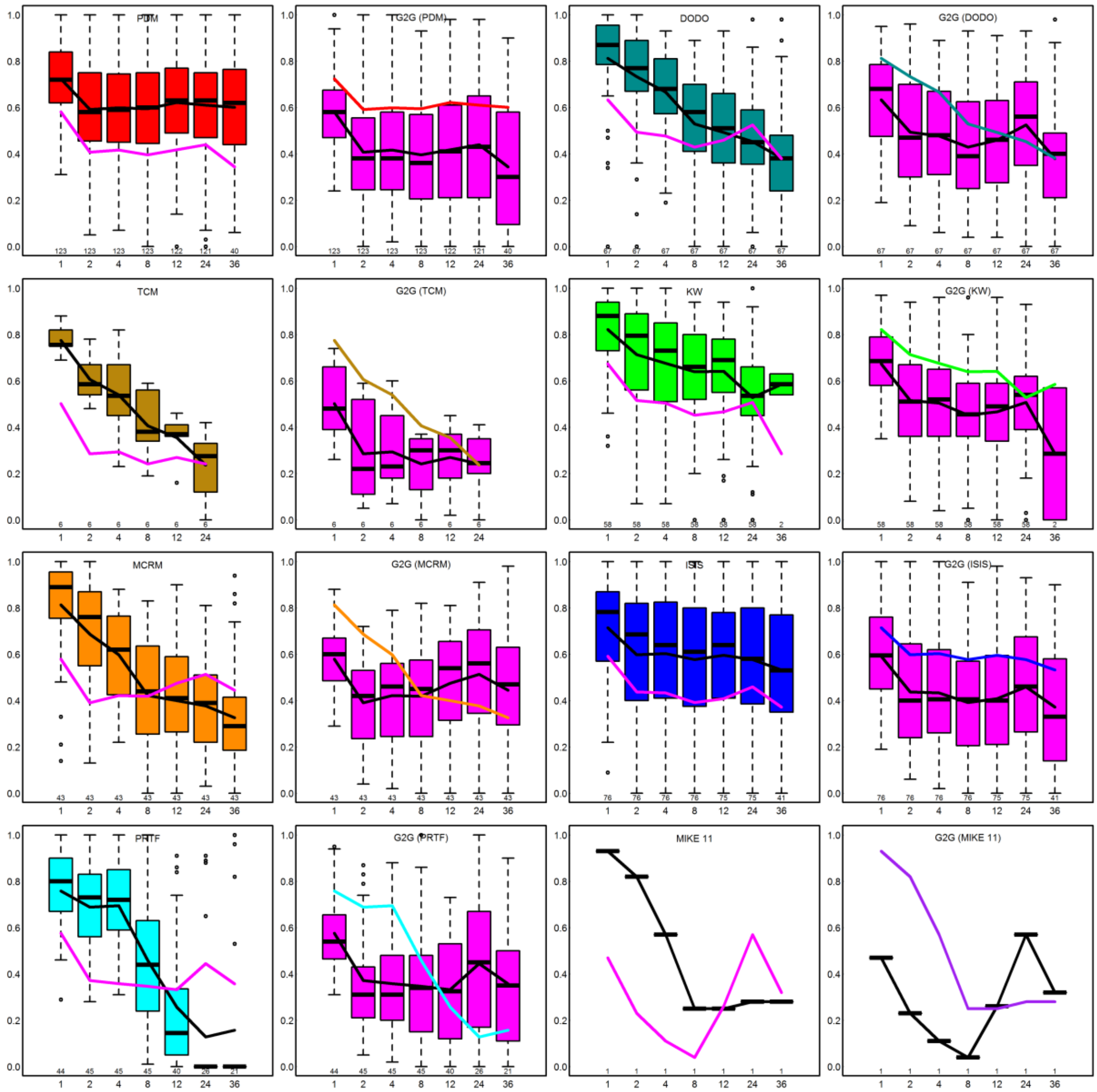


Figure 7.8 Multi box plot showing POD with no magnitude tolerance at QMED threshold for matched G2G and local models

Notes: Details as for Figure 7.7.

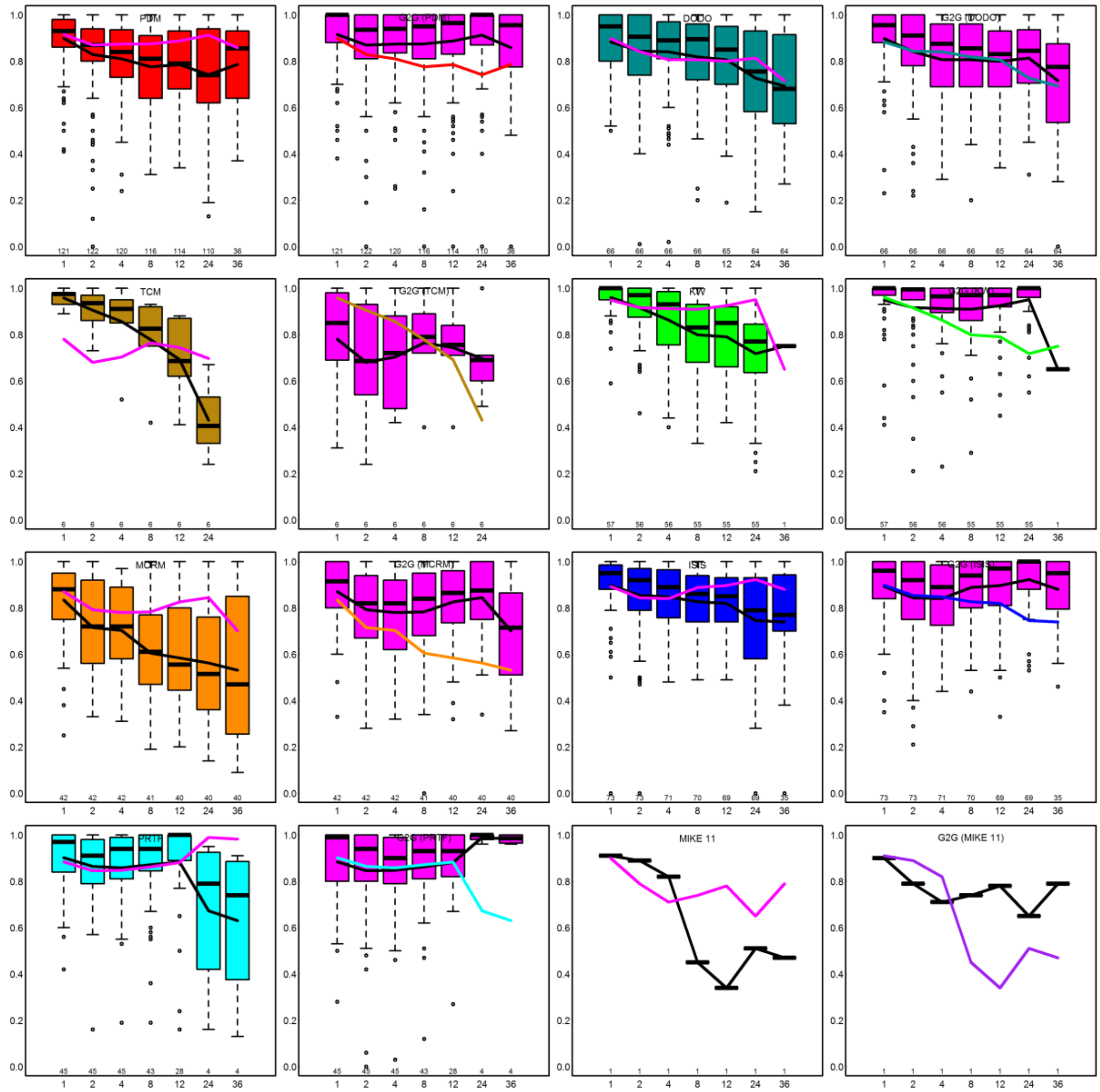


Figure 7.9 Multi box plot showing Confidence (1 - FAR) with tolerance at QMED threshold for matched G2G and local models

Notes: Details as for Figure 7.7.

The comparison of G2G and local models for CSI is shown as a set of scatter plots in Figure 7.10. As before, local models largely outperform G2G at short lead-times, but G2G performs as well or better after 24 hours. The plot also indicates the extent of the variability between sites. Within most model types and lead-times, there is a big variety of behaviours: some sites benefit more using local models while others benefit more with G2G.

A spatial comparison of CSI at three lead times (4, 12 and 24 hours) is presented in Figure 7.11, Figure 7.12 and Figure 7.13. The pattern is complex, although it can be seen that behaviour often tends to be clustered according to river basins.

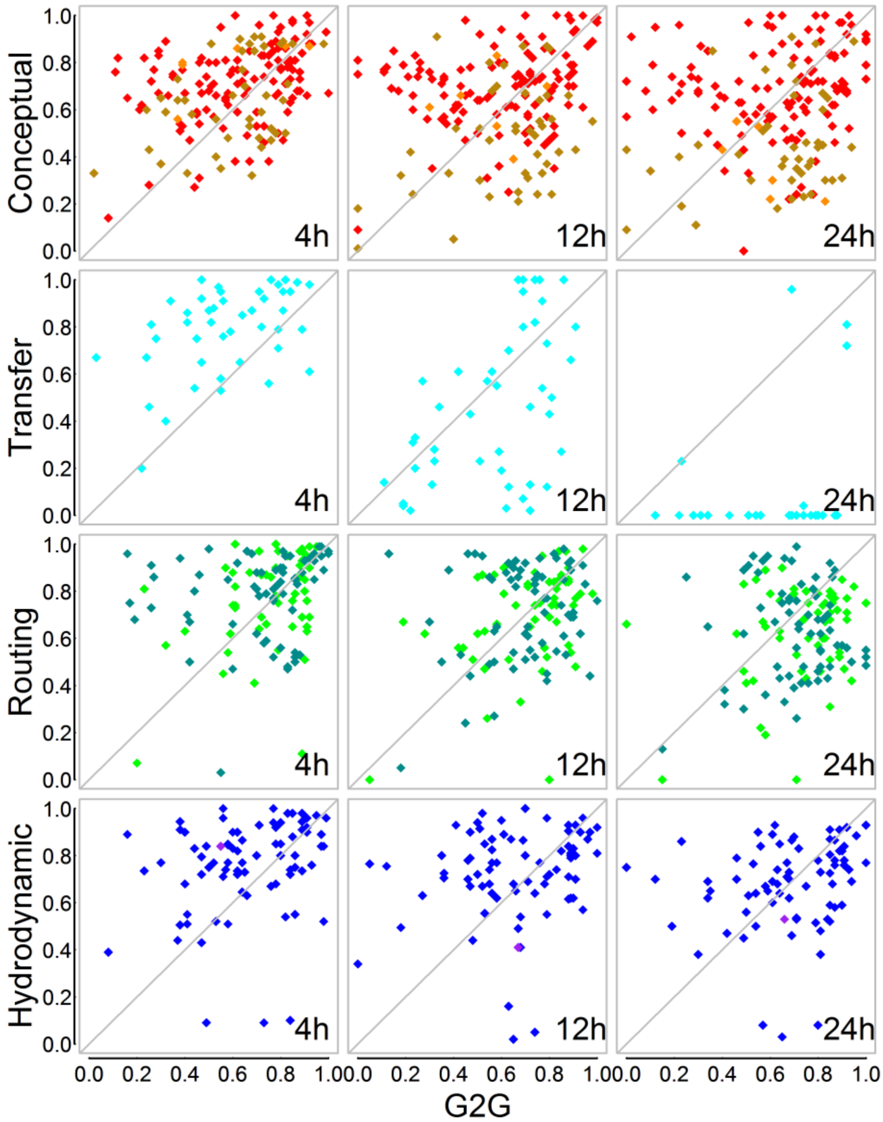


Figure 7.10 Scatter plots showing comparison of CSI (with magnitude tolerance) for the QMED/2 threshold for 4, 12 and 24 hour forecast lead-times

Notes: Points in the top left corner of each plot indicate that the local model outperforms G2G at this site.
Points in the lower right corner have a better performance using G2G.
Sites are colour-coded using the same colour schemes as in Figure 7.7.

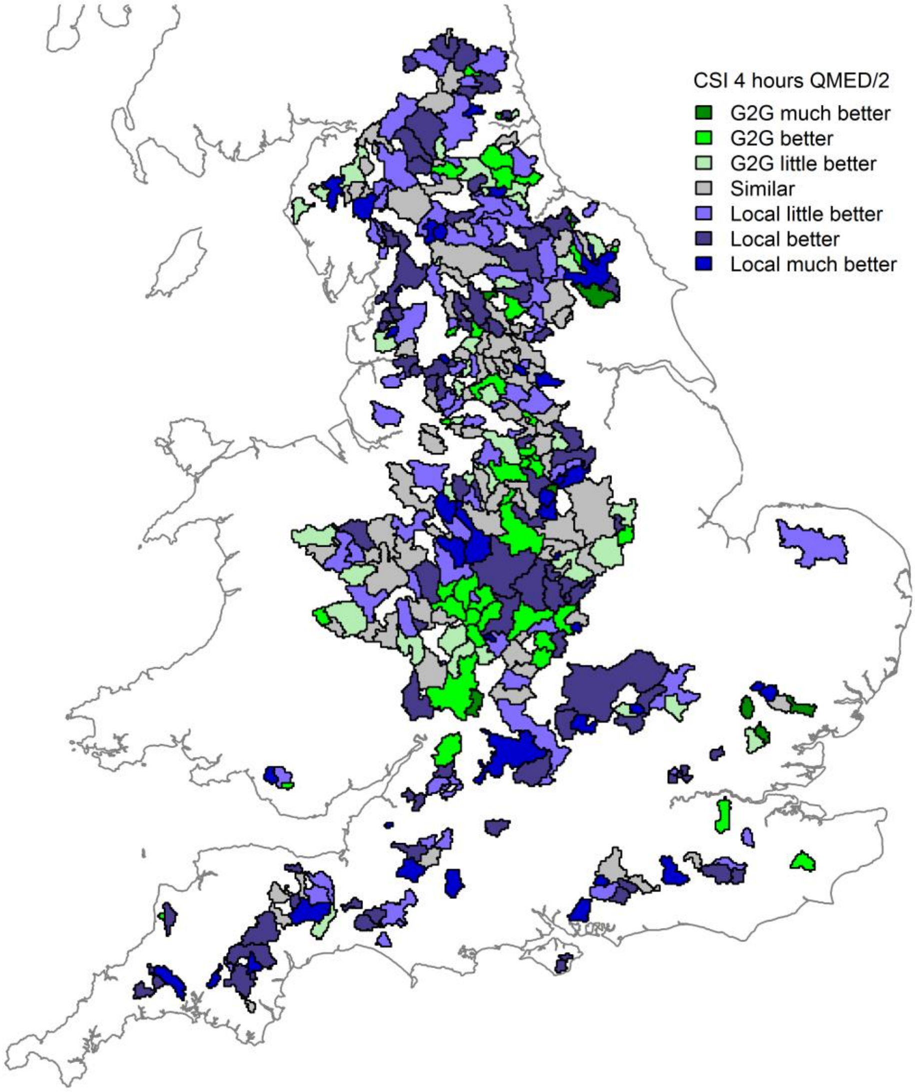


Figure 7.11 Performance map of CSI for QMED/2 at 4 hour lead-time

Notes: The map shows comparative behaviour of G2G and local models. It does not differentiate between situations where one or both models perform well, or both perform poorly. It only examines the relative performance (as a ratio) between G2G and a local model.
The shaded areas are subcatchment areas based on the NFFS G2G configuration.

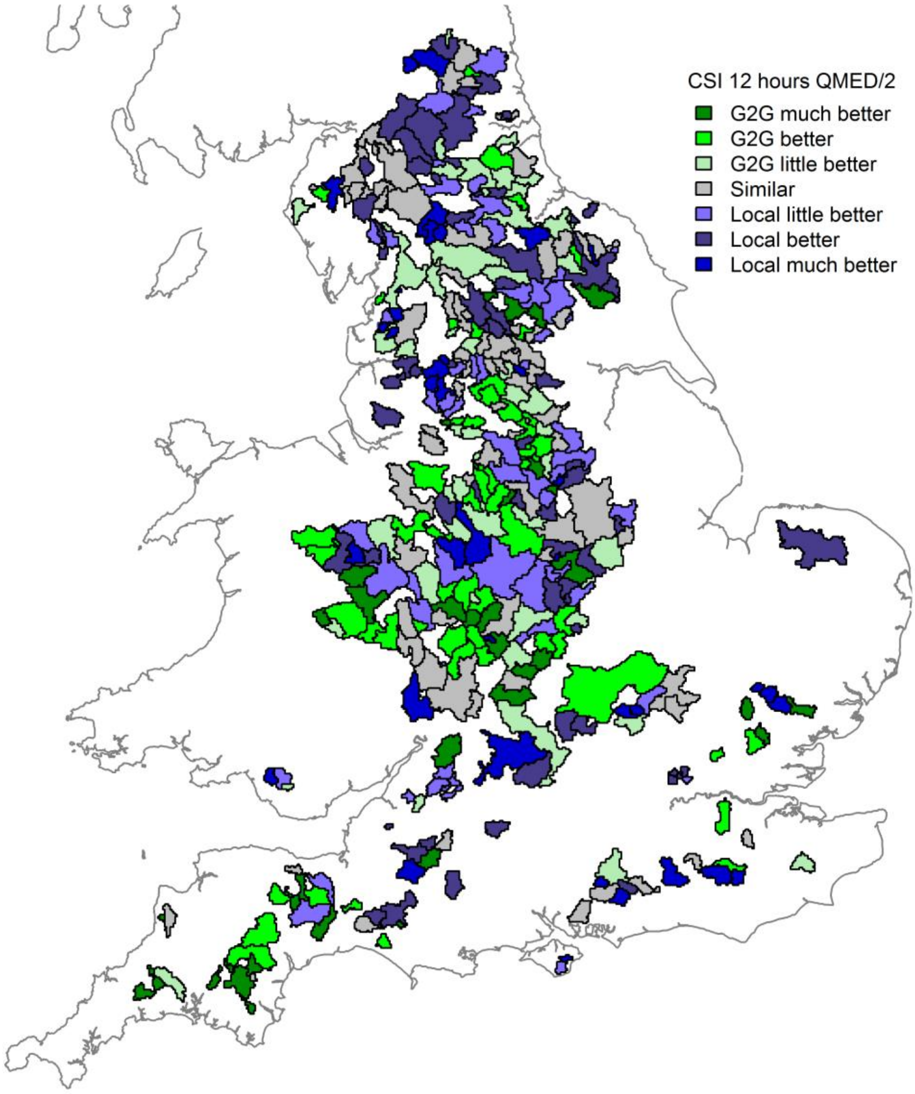


Figure 7.12 Performance map of CSI for QMED/2 at 12 hour lead-time

Notes: See Figure 7.11 for details.

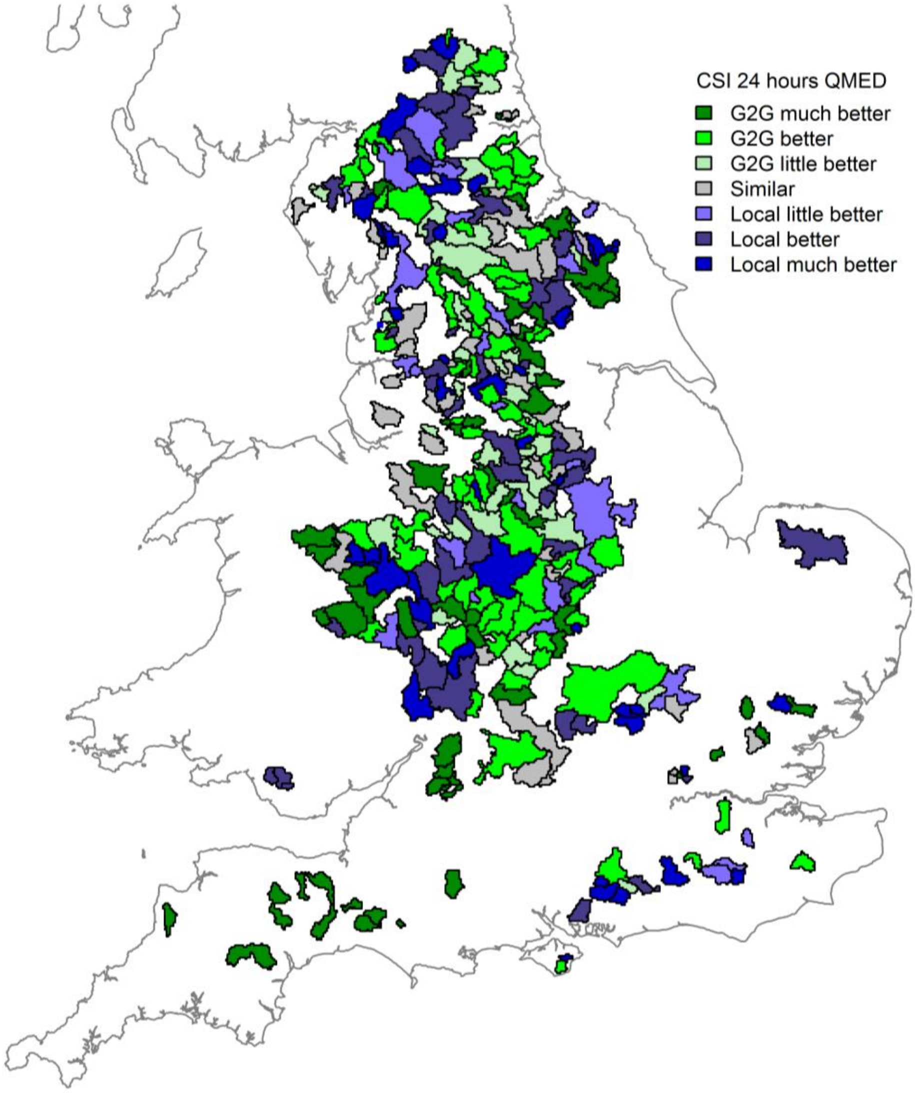


Figure 7.13 Performance map of CSI for QMED/2 at 24 hour lead-time

Notes: See Figure 7.11 for details.

7.1.3 Other pairwise model performance comparisons

In most instances, only one local model is available at each site. The exception to this is in the North West where for some sites both ISIS and PDM models exist. Figure 7.14 compares the results for PDM and ISIS models for these sites. Overall the models produce a comparable performance as judged by CSI at QMED/2.

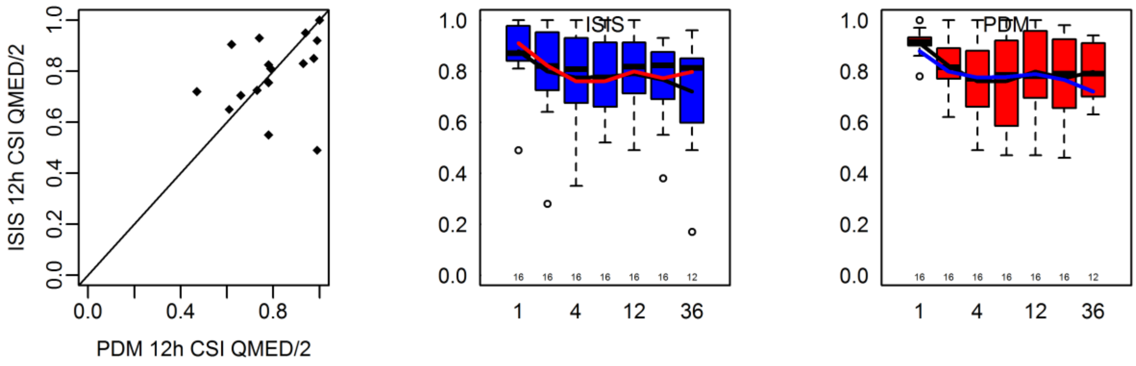


Figure 7.14 Performance comparison of PDM and ISIS models in the North West

7.1.4 Comparison of model performance by region

This section presents a regional summary of model performance. The model performance skill scores are stratified by region and by lead-time for the G2G sites and for local model sites (Figure 7.15 to Figure 7.18). For the local model plots, each region may include a mixture of model types. Figure 7.19 provides a summary comparison.

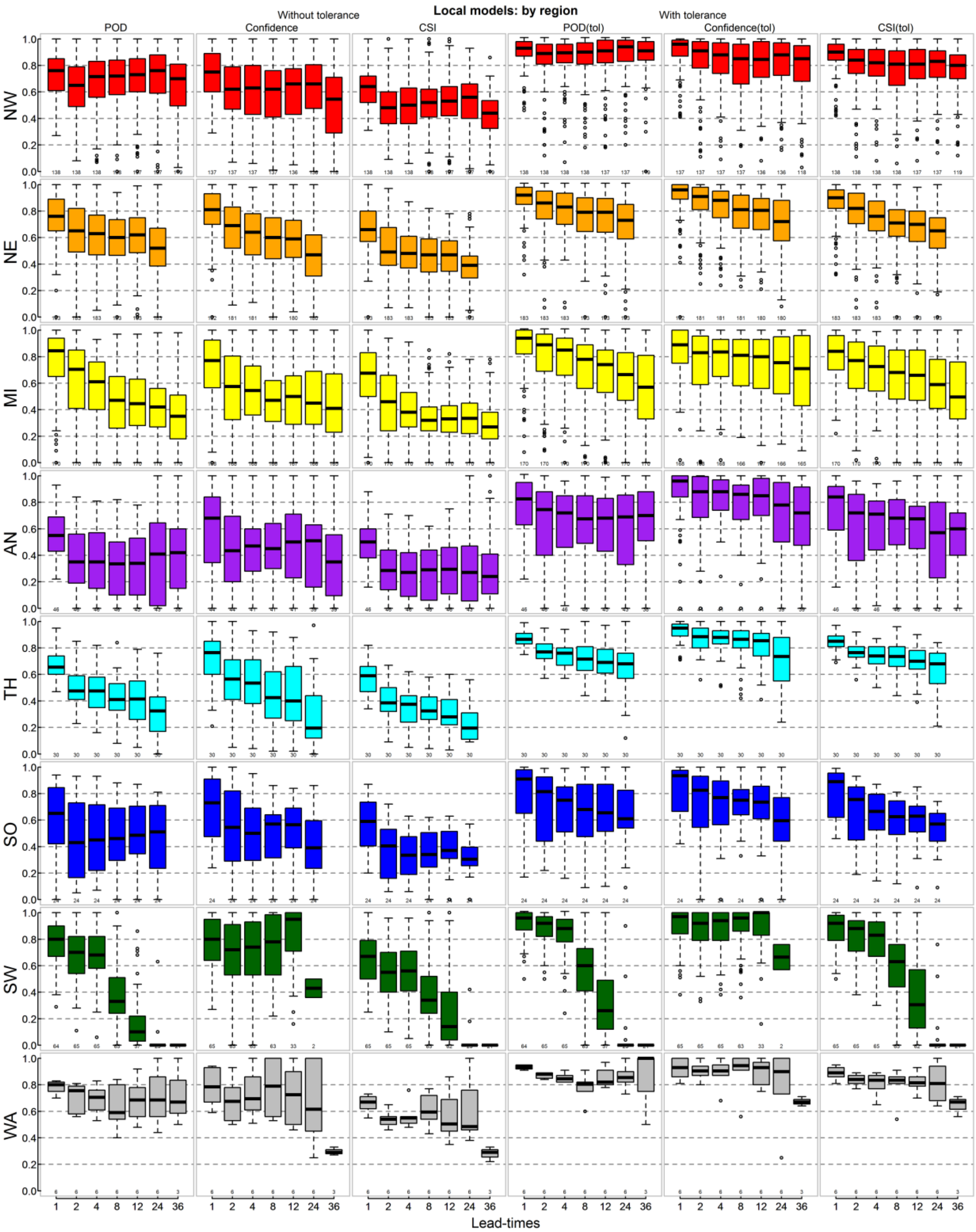


Figure 7.15 Multi box plot of local model skill scores stratified by region and lead-time for QMED/2 threshold with and without magnitude tolerance

Notes: Results are shown for POD, Confidence and CSI.
NW = North West; NE = North East; MI = Midlands; AN = Anglian; TH = Thames; SO = Southern; SW = South West; WA = Wales.

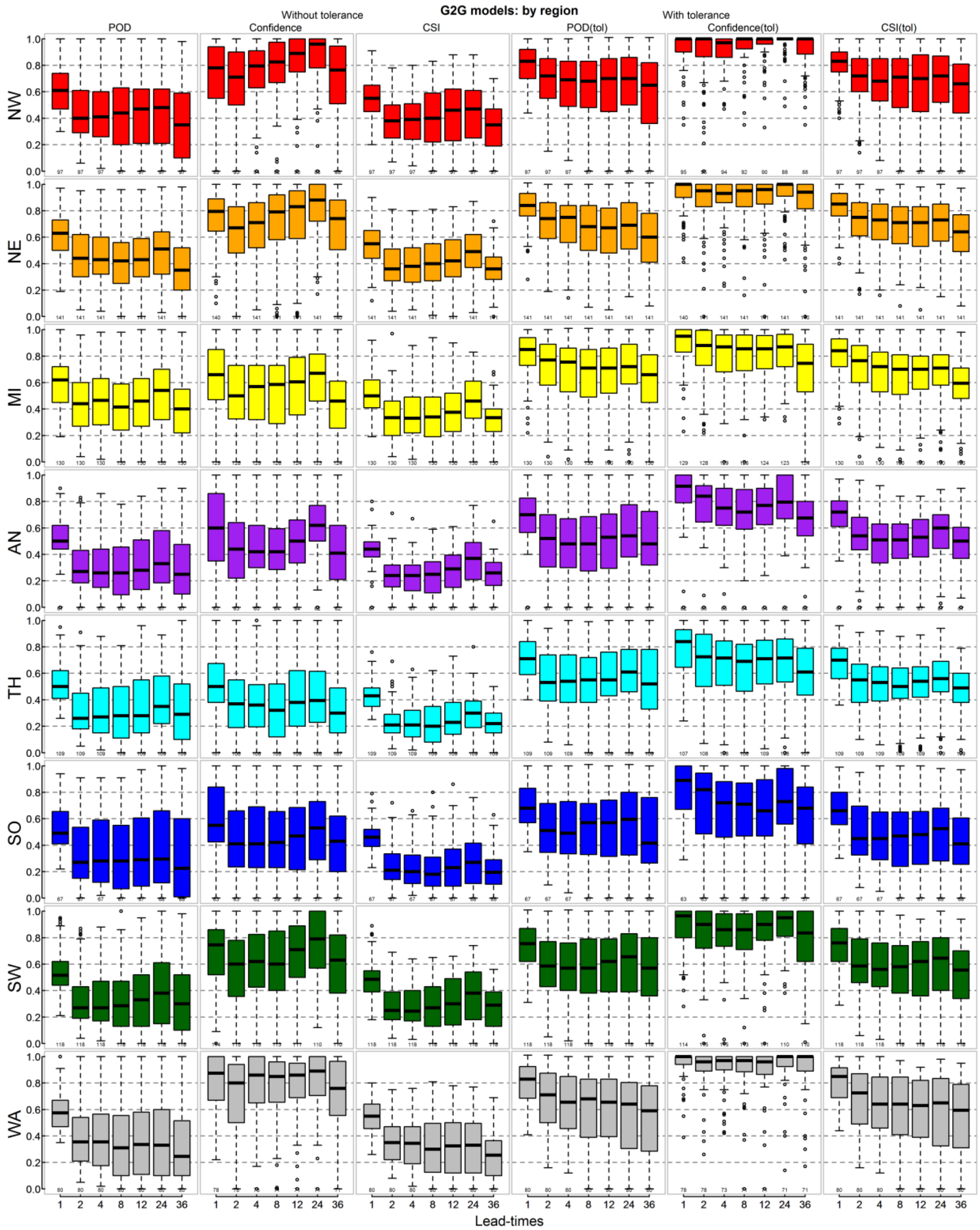


Figure 7.16 Multi box plot of G2G skill scores stratified by region and lead-time for QMED/2 threshold with and without magnitude tolerance

Notes: Results are shown for POD, Confidence and CSI.
NW = North West; NE = North East; MI = Midlands; AN = Anglian; TH = Thames; SO = Southern; SW = South West; WA = Wales.

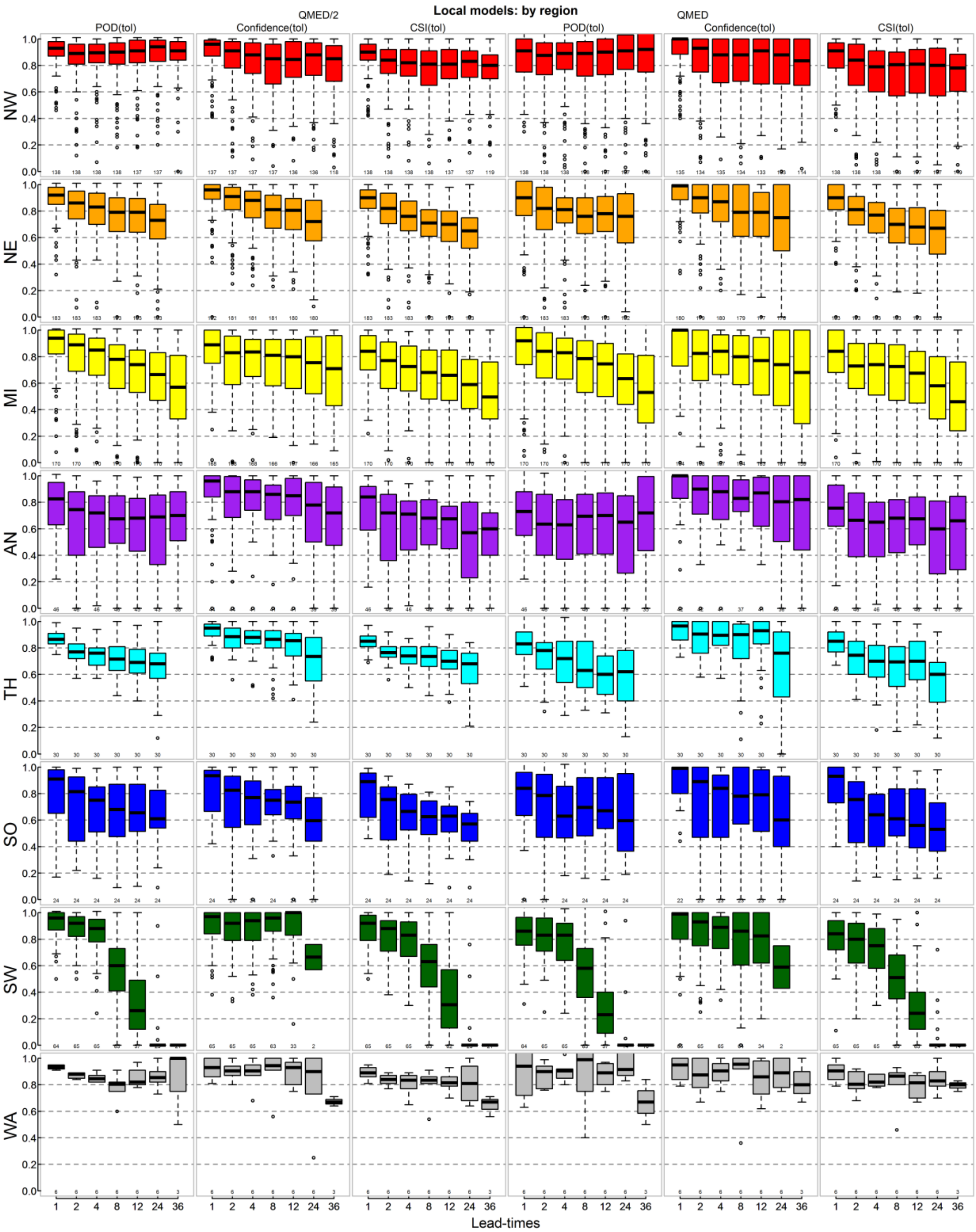


Figure 7.17 Multi box plot of local model skill scores broken down by region and lead-time for thresholds (QMED and QMED/2)

Notes: Results are shown for POD, Confidence and CSI with magnitude tolerance. NW = North West; NE = North East; MI = Midlands; AN = Anglian; TH = Thames; SO = Southern; SW = South West; WA = Wales.

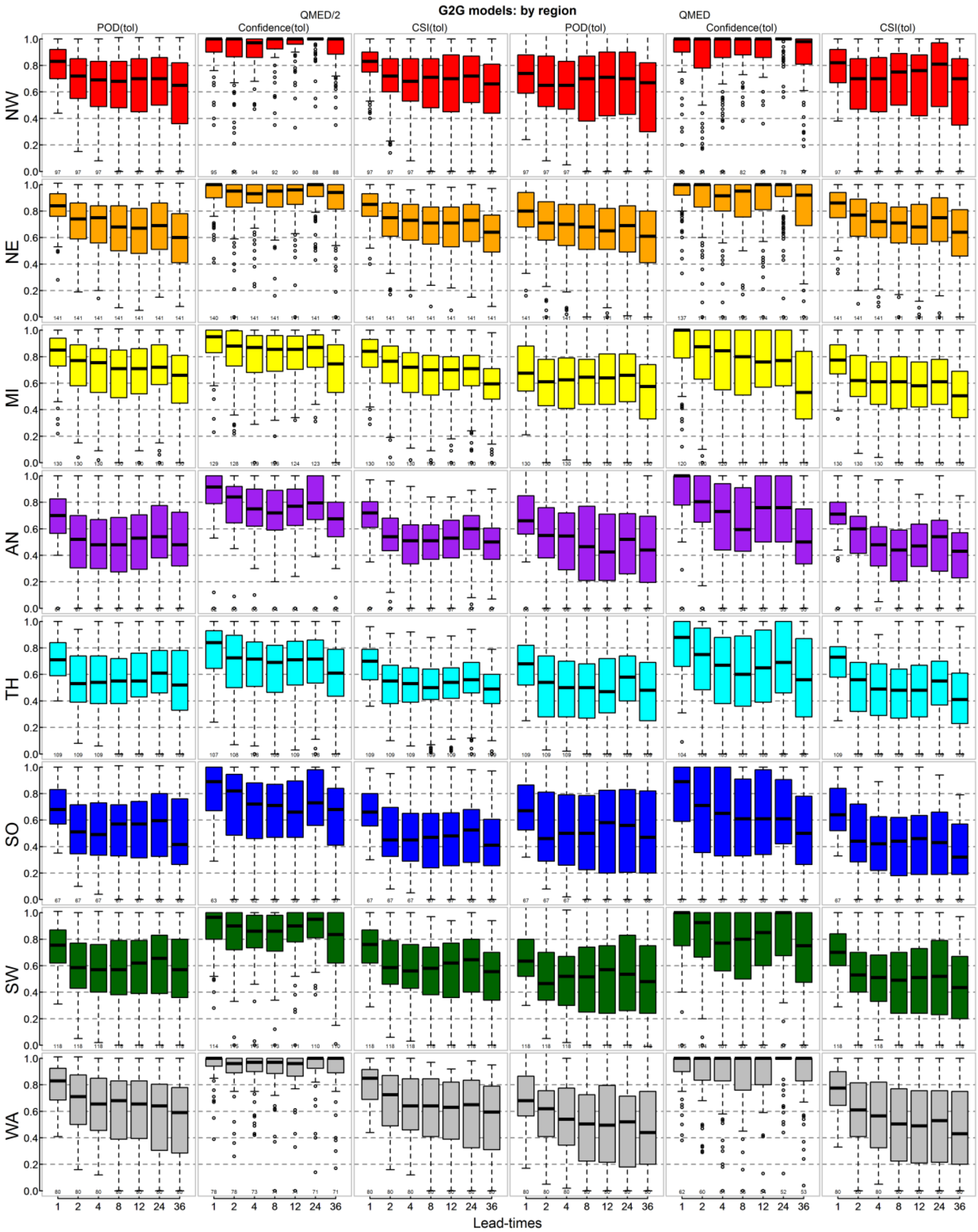


Figure 7.18 Multi box plot of G2G skill scores stratified by region and lead-time for thresholds (QMED and QMED/2)

Notes: Results are shown for POD, Confidence and CSI with magnitude tolerance.
NW = North West; NE = North East; MI = Midlands; AN = Anglian; TH = Thames;
SO = Southern; SW = South West; WA = Wales.

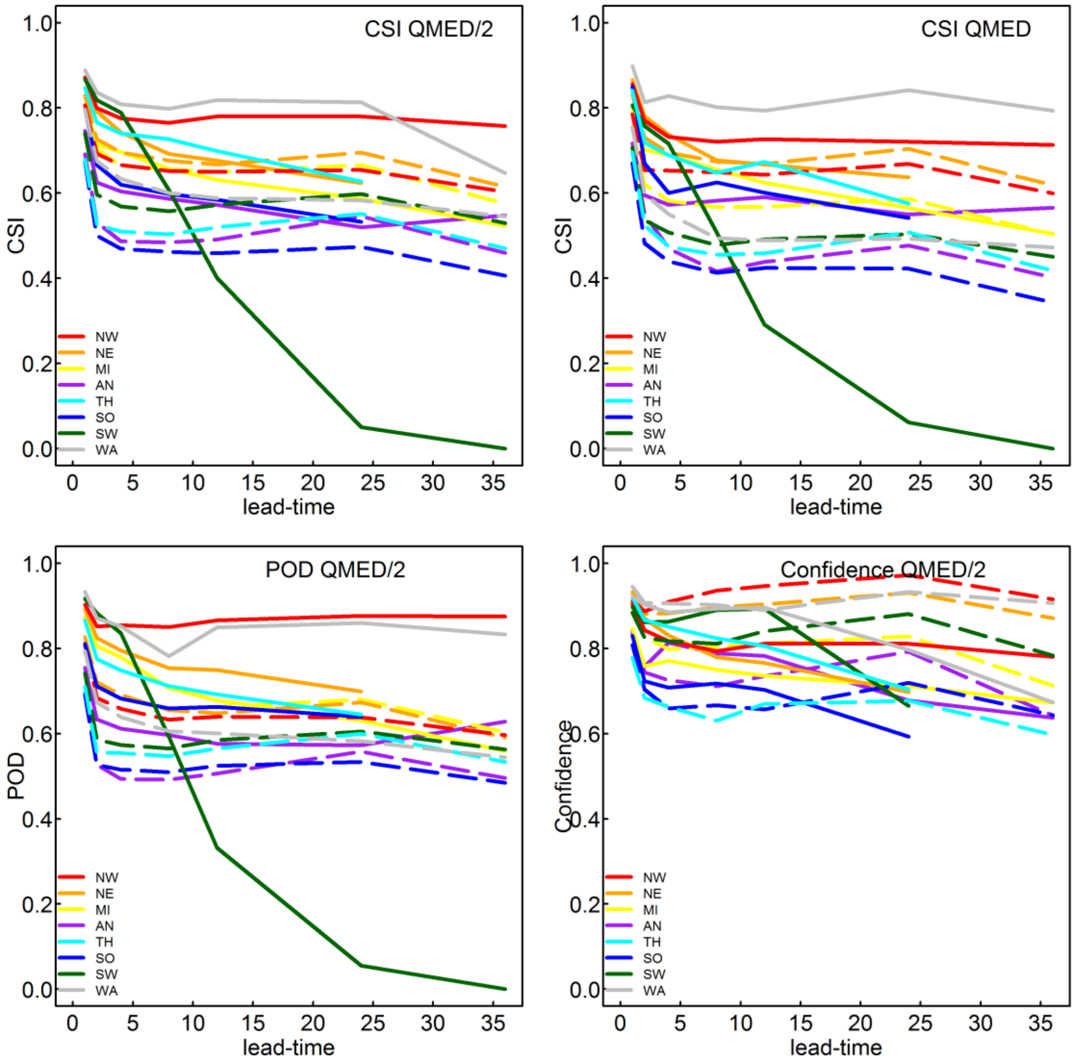


Figure 7.19 Line plot showing average CSI values as a function of lead-time for each region at QMED/2 and QMED thresholds and for POD and confidence at the QMED/2 threshold

Notes: Solid lines show local model averages.
Dashed lines show G2G model averages for each region.
NW = North West; NE = North East; MI = Midlands; AN = Anglian; TH = Thames; SO = Southern; SW = South West; WA = Wales.

The following observations can be made regarding Figure 7.15 to Figure 7.19.

- North West local models perform particularly well. This is maintained to longer lead-times than for other regions.
- Anglian has a particularly wide spread of results.
- Wales has very few sites with local models.
- South West local model performance drops off steeply for longer lead-times – due to use of PRTF.
- G2G maintains performance well over time and has particularly high Confidence in Wales, the North West and the North East.

- G2G POD is generally lower than with local models.
- On average, G2G does better in Midlands and South West. Local models do better in the North West, Anglian, Southern and Thames. While Confidence is better for G2G in the North East and Wales, CSI and POD are worse.

7.1.5 Skill scores with magnitude tolerances

The approach employed to determine the magnitude tolerances used for levels data is described in Section 5.1.2. Its application proved more complex than anticipated because:

- not all sites had rating curves – needed to convert tolerances in flows to tolerances in levels
- changes in rating equations meant that there were several sites for which the thresholds and tolerances were not useable (too few events)

The map shown in Figure 7.20 compares a 20% tolerance on flow threshold when converted into a level value. This is the value ideally used in the analyses, thus providing the equivalent magnitude tolerance for comparisons between G2G models (with flows) and local models (when as levels). However, for sites where this tolerance was not available or suitable, the level tolerance will default to a standard 0.2m.

From Figure 7.20, it can be seen that the flow-derived level tolerances can differ quite significantly from 0.2m. This may result in important biases which will affect model comparisons – especially those with G2G. Sites that are coloured blue in Figure 7.20 and which revert to 0.2m will end up with the tolerance used for the local model being much more favourable towards it than the G2G model. This probably explains why the MIKE 11 model (see also Figure 4.2) results are worse than G2G without magnitude tolerance, and better than G2G with magnitude tolerance. Conversely sites in areas that are coloured green in Figure 7.20 and which revert to 0.2m will tend to favour the G2G with-tolerance results.

In an ideal world, with-tolerance skill scores would seem the most applicable and relevant to flood forecasting. However, the downside of this is that these types of biases make it even more difficult to make regional and model based comparisons. A clearer model comparison may be obtained without use of magnitude tolerance.

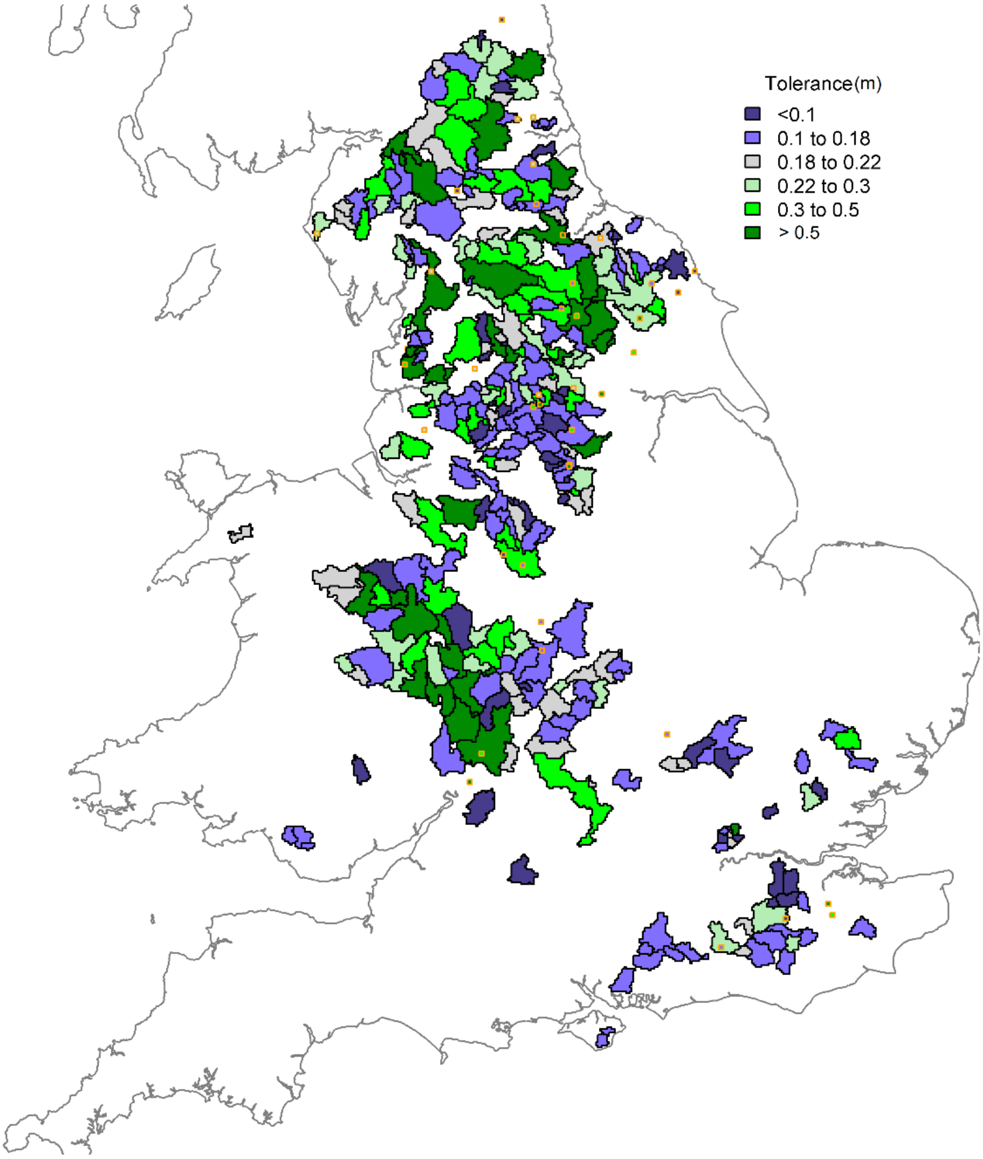


Figure 7.20 Map showing tolerance levels converted from 20% of a flow tolerance (QMED) to a level tolerance using rating curves

Notes: Values are compared with the default value of 0.2m (grey).

7.2 Examining the Overall Performance Measure

The Overall Performance Measure is the average of the 9 underlying performance components described in Section 5.6 and listed below:

Forecasts:

- CSI for QMED and QMED/2, and at 4 hour and 24 hour lead-times
- Two measures based on average time difference in hours between peak and observed, one applying a timing tolerance window

Simulation:

- R^2 Efficiency as a proportion

- Proportion of events within magnitude tolerance
- Proportion of events within timing tolerance

The CSI values presented here do not include magnitude tolerance.

The inter-relationships of the various components of the Overall Performance Measure are presented in Figure 7.21 to Figure 7.23.

As expected there is some interdependence between the CSI measures (Figure 7.21 and Figure 7.22). Some issues with the simulation series are also seen, indicated by R^2 Efficiency values of zero.

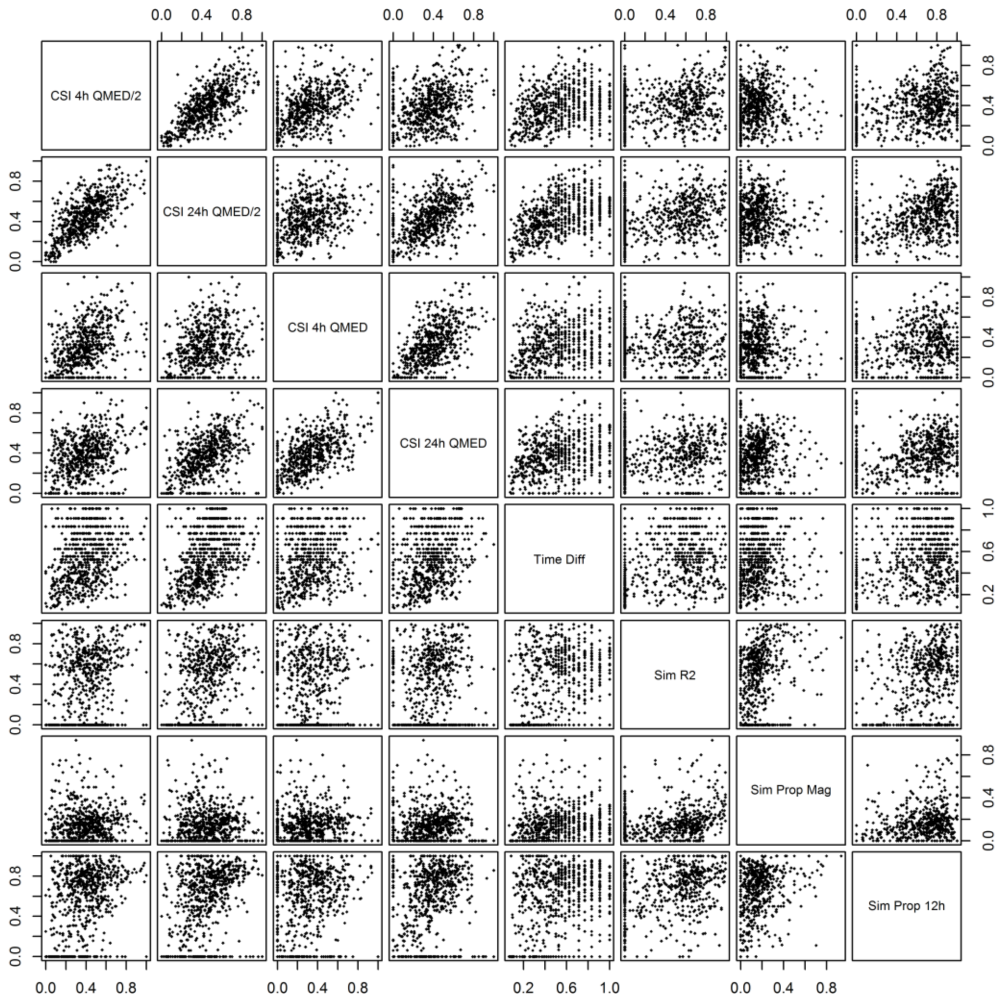


Figure 7.21 Matrix scatter plot of each of the components of the Overall Performance Measure for the local models

Notes: Each scatter plot featured in the top right corner is repeated, and reflected, in the bottom left corner.

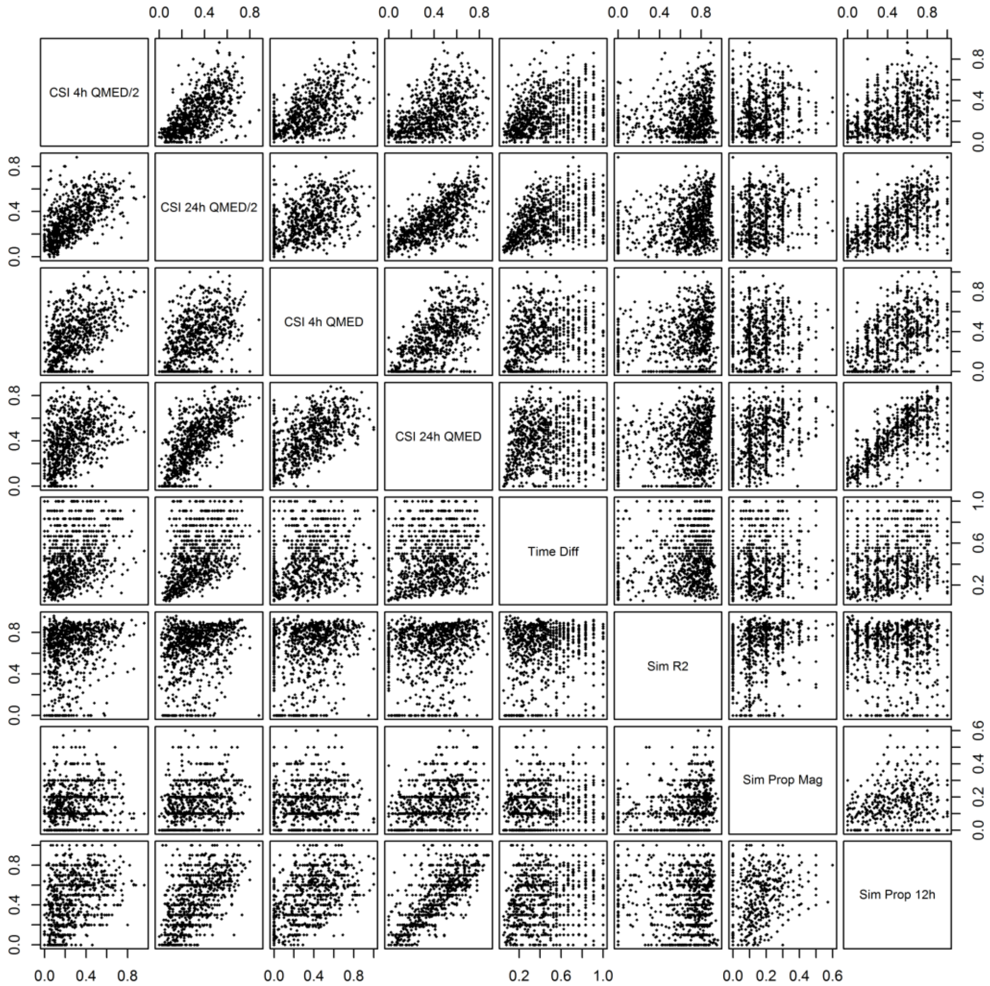


Figure 7.22 Matrix scatter plot of each of the components of the Overall Performance Measure for G2G models

As can be seen from Figure 7.23, the issue of missing simulation data series (the case for quite a number of sites) creates a problem for obtaining an Overall Performance Measure. In Figure 7.23, missing values are treated in two ways: ignored and not used in the average; or set to zero – see the overallperf versus overallperf0 subplot. The two diverging straight lines on this subplot indicate that the treatment of these missing values makes a large difference to the results. In the light of this problem, it seems wiser to look separately at the two subsets of components for the forecast and simulation elements. Of these, the forecast component is probably the most important and relevant to the flood forecasting operational context. Note that the simulation and forecast components show less interdependence than might be anticipated.

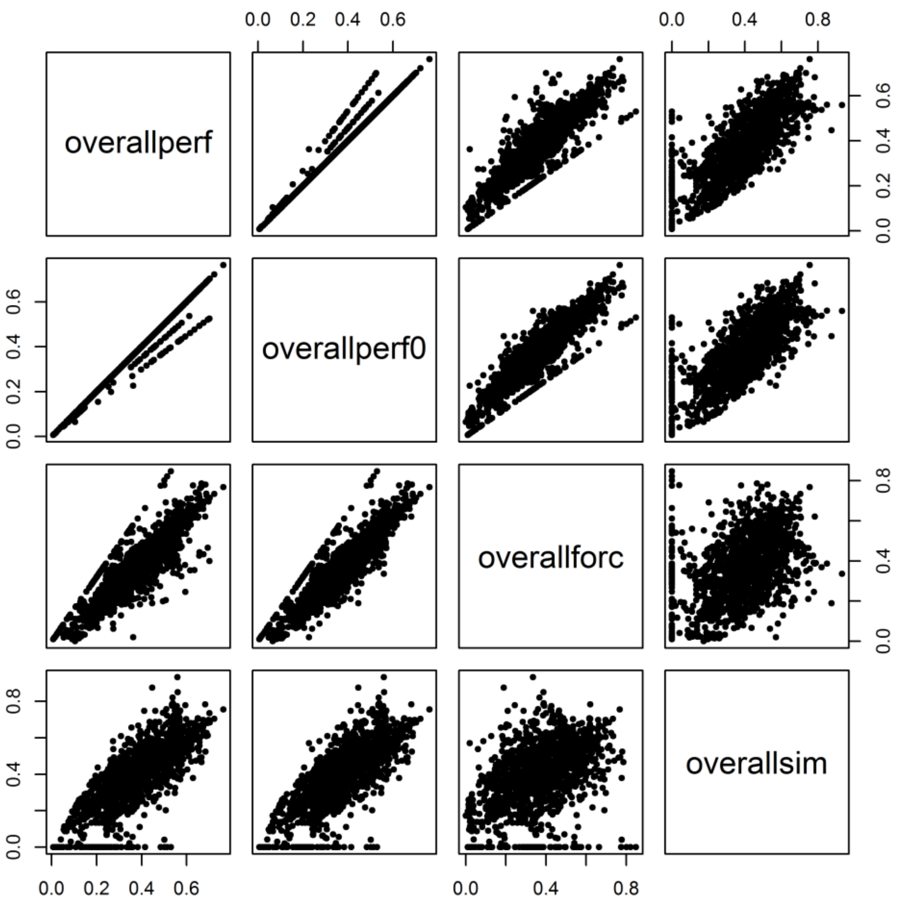


Figure 7.23 Scatter plot of some Overall Performance Measures allowing for different ways of treating missing values

Notes: overallperf = average of all non-missing performance components
overallperf0 = average of all performance components setting missing ones to have a value of zero
overallforc = average of all non-missing forecast components
overallsim = average of all non-missing simulation components

A box plot comparison of the Overall Performance Measure forecast component is shown in Figure 7.24 and is stratified by region and model type. The high performance in Wales for the local models is likely due to the small sample size. For most models, the forecast components for the four CSI-based measures are broadly similar. The exception, as previously, is for the PRTF models in the South West which have very low performance at the 24-hour lead-time. Nevertheless, the PRTF models appear to do particularly well with event timing. The North West and North East typically have the best model performance, with PDM, KW and ISIS models coming out particularly well while G2G lies somewhere in the middle. Figure 7.25 shows a performance map giving a spatial comparison of G2G and local model performance for catchments with both types of model. Sites show some clustering, with it not being uncommon for a whole group of catchments to do best with either entirely local models or entirely G2G. As previously, there are a higher proportion of sites in the north for which local models do best.

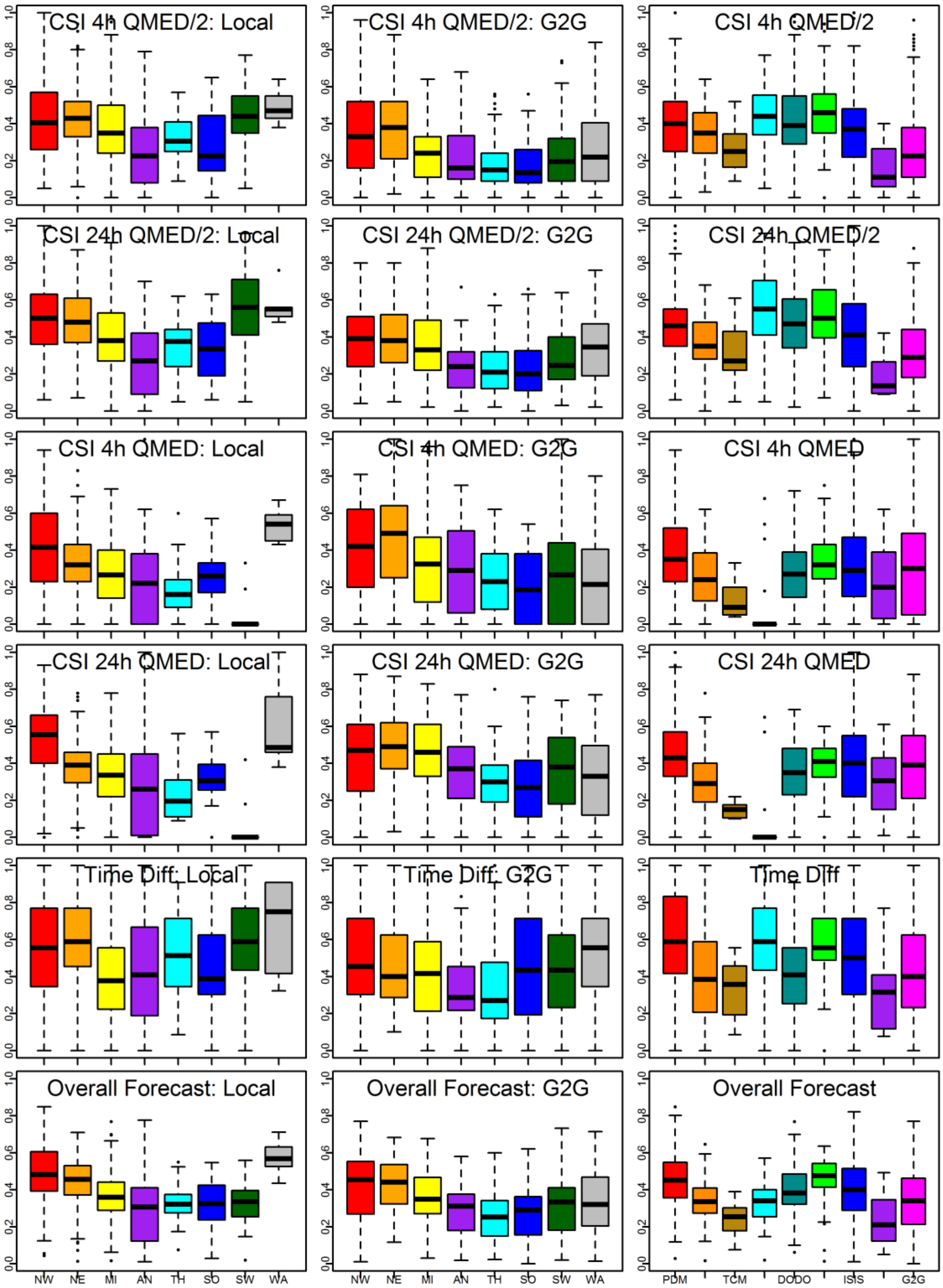


Figure 7.24 Box plot of subcomponents of the Overall Performance Measure forecast component

Notes: Column 1 shows local models by region, column 2 G2G models by region, and column 3 shows results grouped by model.

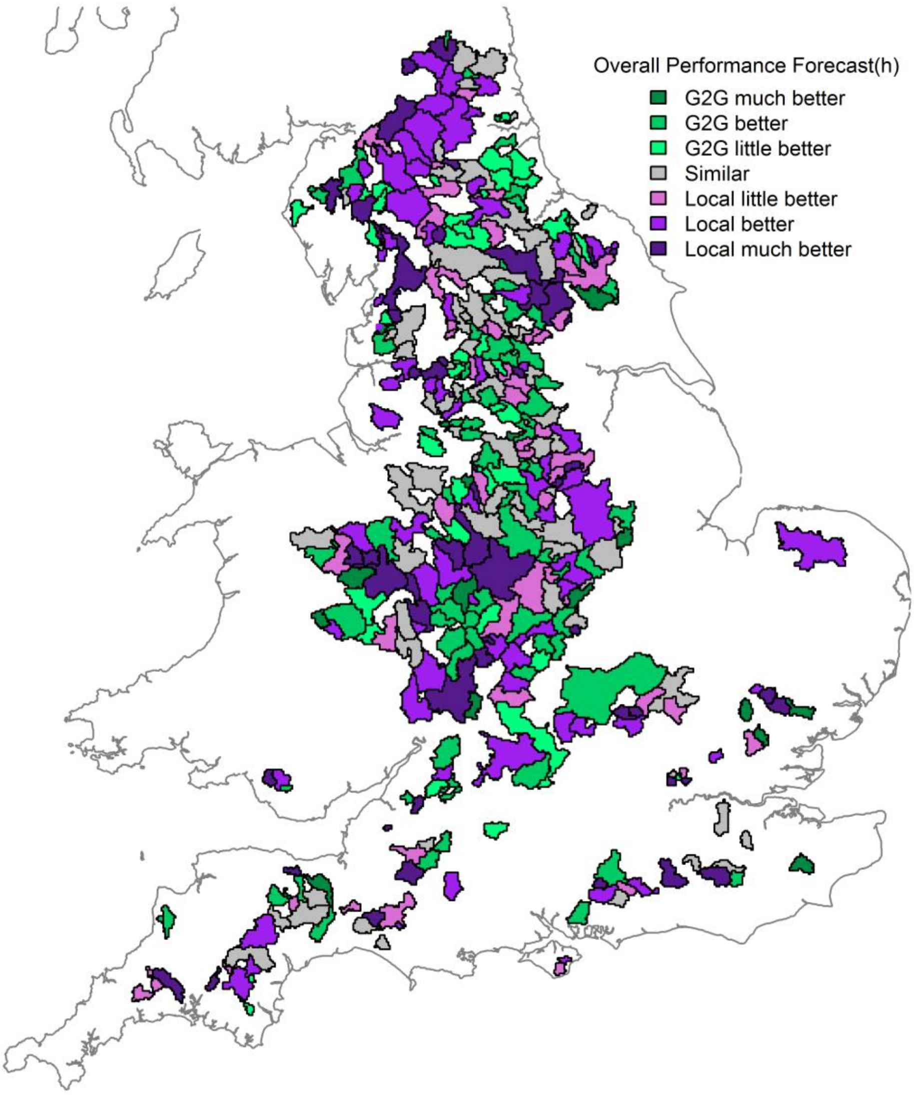


Figure 7.25 Map of Overall Performance Measure forecast component for matched G2G and local model sites

The simulation components are summarised in Figure 7.26. G2G simulation R^2 Efficiency values are higher than for the local models; this is likely linked to how the historical simulation data are produced by the different models. The G2G R^2 value includes the full period (that is, low flow periods as well as event periods) and this has improved the R^2 values. G2G is unlikely to be consistently better in simulation mode. It is quite likely that the R^2 values for other models may depend on which periods are modelled and thus depend on the particular study. G2G does less well than several of the local models in terms of the timing of flood peaks.

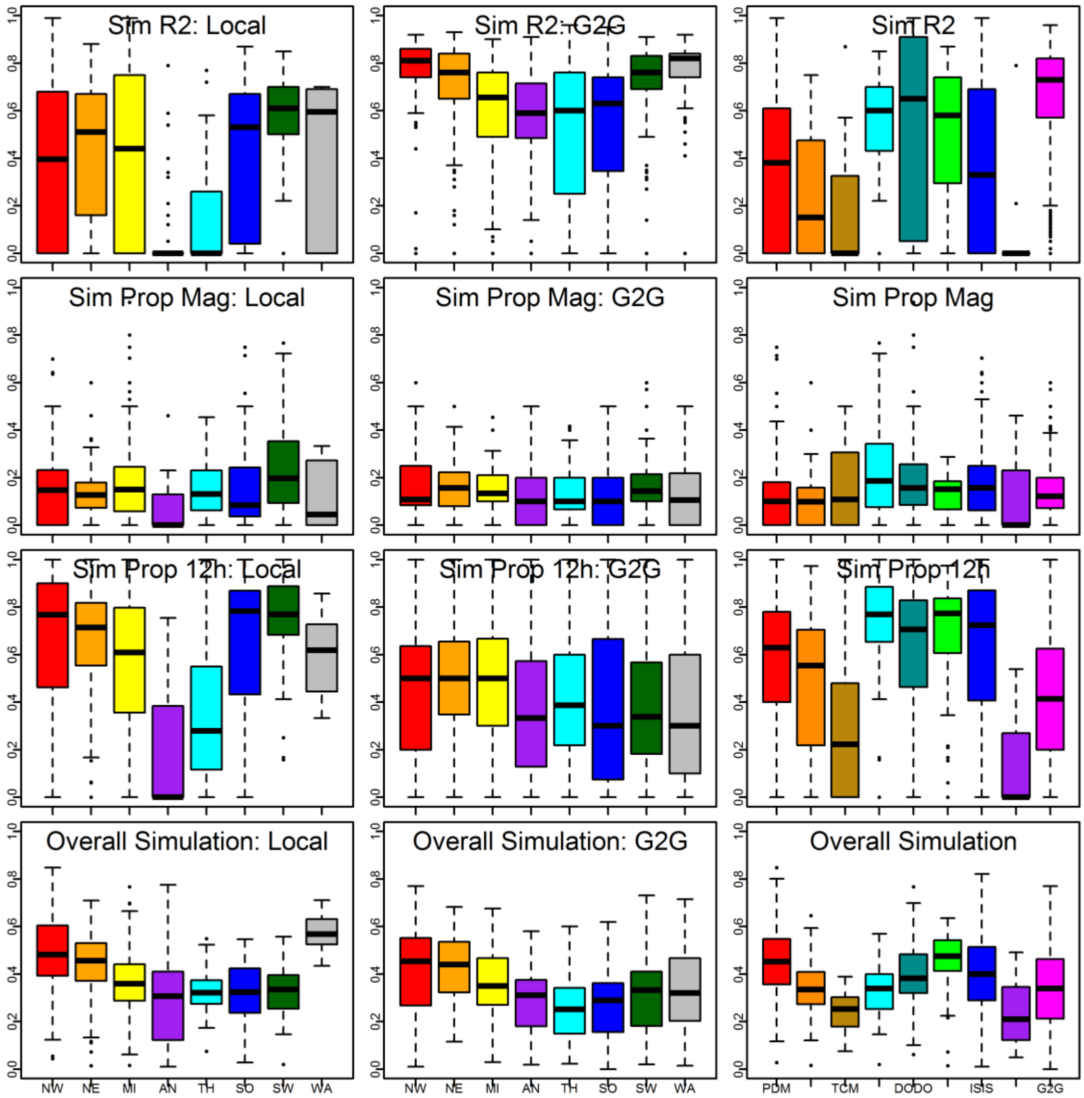


Figure 7.26 Box plot of subcomponents of Overall Performance Measure simulation component

Notes: Column 1 shows local models by region, column 2 G2G models by region, and column 3 shows results grouped by model type.

7.2.1 Linking model performance to Overall Performance Measure forecast component

A disadvantage of using a composite measure such as the Overall Performance Measure forecast component, and indeed measures such as the CSI, is that heuristic interpretation of these measures and what they mean for flood forecasting becomes somewhat unclear.

A selection of site Flood Forecasting Model Performance Summary pages are presented in Appendix C. These examples aim to show how the performance measure links to the outputs summarising forecast performance. Six examples are included:

- two sites with values close to 0.7 (which is high performing)
- two sites with values close to 0.5
- two sites with values close to 0.3

It can be seen that performance is less good for the lower values but that, as is inevitable with composite measures, there are quite different possible combinations of behaviour within a value range.

It would be difficult to choose what value of this measure might distinguish between good, acceptable and poor forecasting. Appendix C also tabulates for each region the 10% lowest performing site models in terms of Overall Performance Score, serving to highlight those that may deserve closer inspection.

7.3 Statistics for operational use

This section examines the statistics included in the 'Statistics for Operational Use' portion of the Performance Summary. These statistics are intended to provide useful information in the case where an event has just been forecast by a model. Note that these results are without magnitude tolerance.

The main statistics are summarised by model type in Figure 7.27 and by region in Figure 7.28. The POD and Confidence measures presented in these figures are less time-specific than some of the related measures presented in Section 7.1. Many of the conclusions that are apparent from these figures have already been made. However, the following can be clearly seen.

- Several of the local models have a tendency to forecast events early (the forecast is earlier than the actual event), with MCRM, TCM, MIKE 11 and DODO being the worst in this regard. It is possible that use of an hourly time-step influences MCRM and DODO.
- PDM, KW, ISIS and PRTF have good and relatively unbiased timing of events.
- G2G timing is also unbiased but is more variable than the above models.
- PDM, KW and ISIS have a notably smaller 90% range in the relative timing of events.
- PRTF behaves differently to the other local models but does have high Confidence and good timing.
- G2G all-forecast POD is not as good as most of the local models but the Confidence is quite high.

The following are apparent when examining the outputs on a regional basis.

- G2G does better in the Midlands and Anglian for model timing.
- G2G generally does better in areas where the local models also do better.
- G2G has slightly more spread in model timing than local models.
- Average G2G POD is around 0.5, whereas for the North West and Midlands it can be as high as 0.8.
- For the North West, North East, South West and Wales, the G2G model averages a Confidence of 0.8 or higher. The lowest G2G confidence is in Thames and Southern.
- Local models are weakest in Anglian, Southern and Thames.

- Although PRTF comes out well in these statistics, the fact that its performance falls off very fast with lead-time means that it is not recommended for use for longer lead-times.

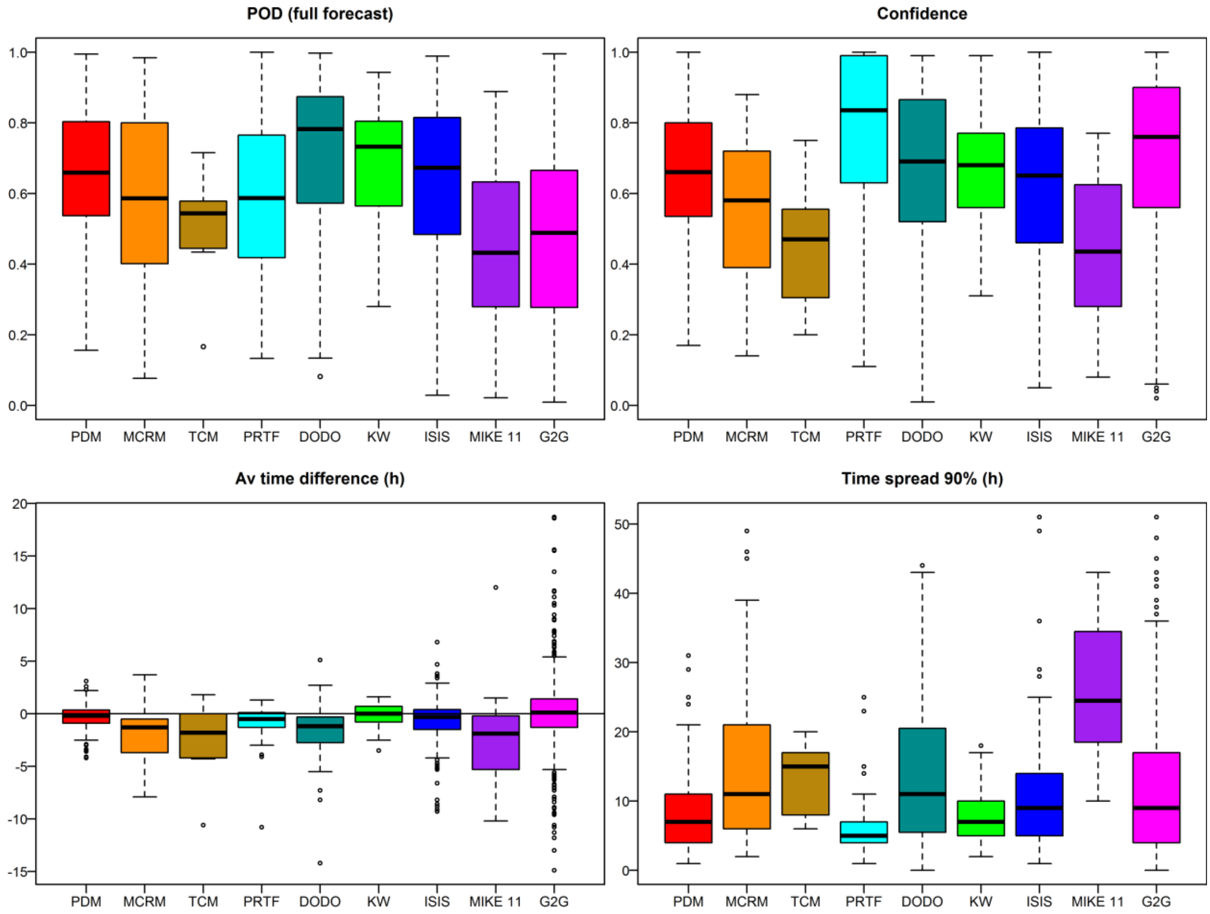


Figure 7.27 Summary box plots of important operational statistics by model type

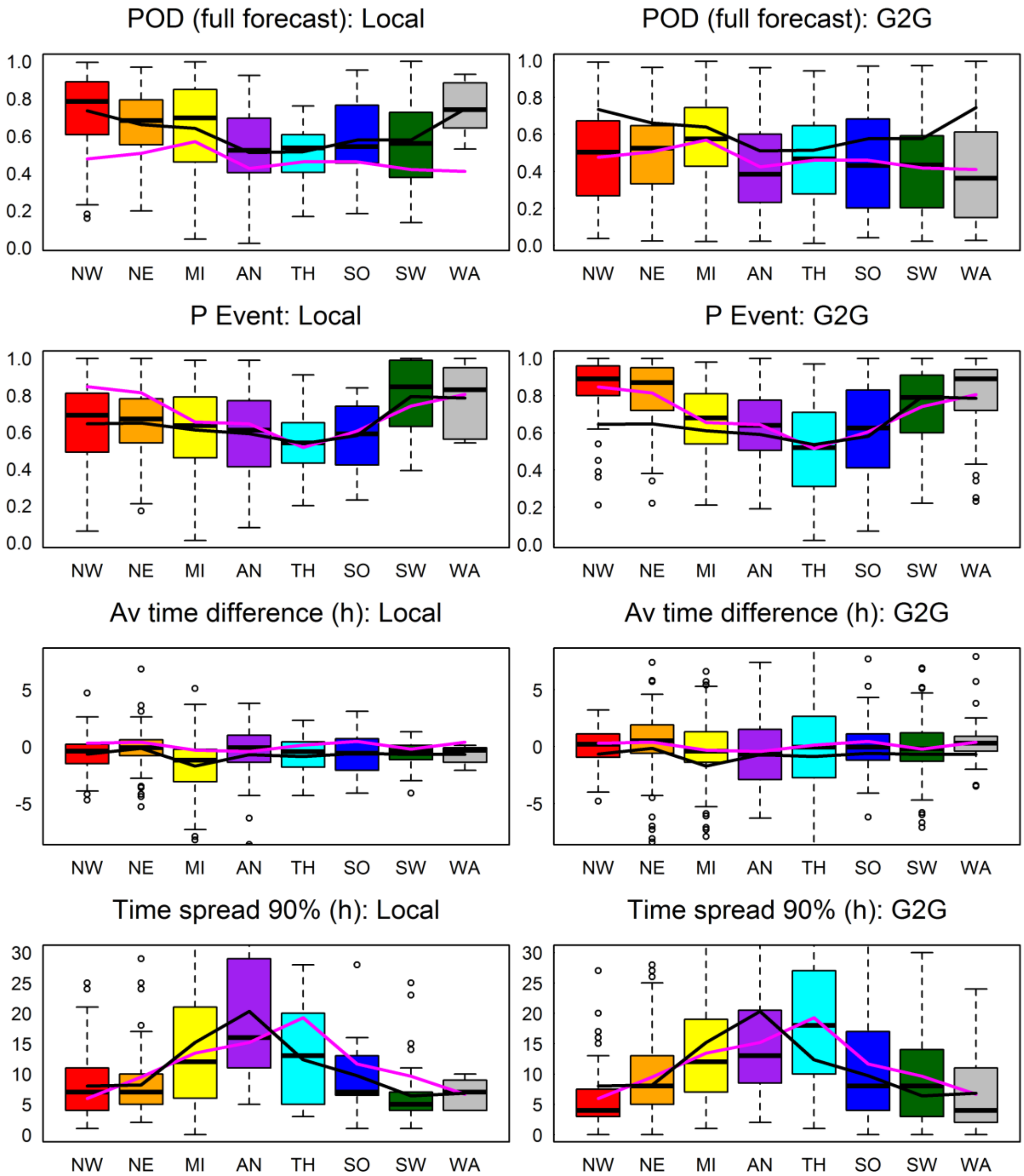


Figure 7.28 Summary box plots of important operational statistics for G2G models and for local models by region

Notes: The black lines show the average values for the local models, the pink lines the average for G2G models.

Performance maps illustrating some of the operational statistics are provided in Figures Figure 7.29 to Figure 7.31. From these it appears that G2G is less accurate on timing than local models at many locations. However, G2G shows good levels of forecast Confidence in western and northern areas. In Figure 7.29 the spatial distribution of performance has clear similarities to the Overall Performance Measure for forecasts in Figure 7.25, suggesting that timing is an important factor for successful forecasting.

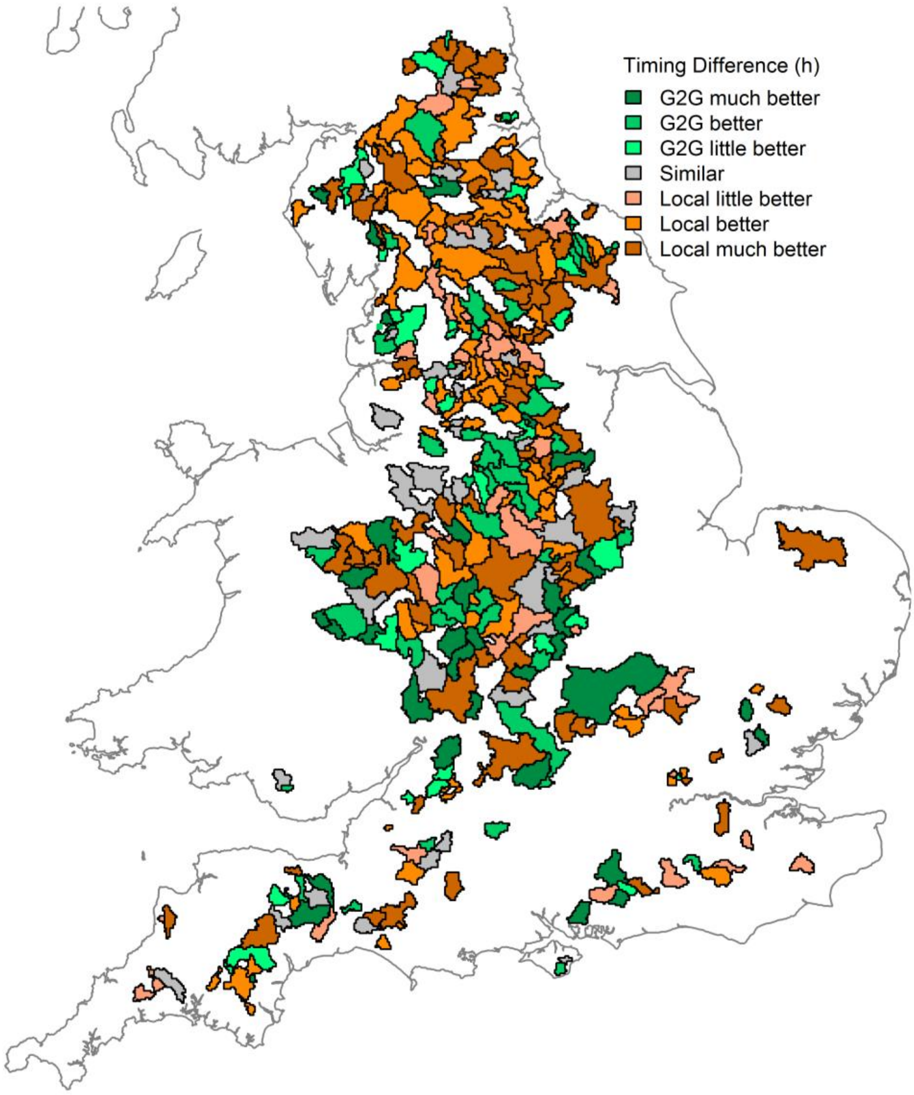


Figure 7.29 Performance map comparing timing of G2G and local models for sites which have both models available

Notes: There would appear to be some link between where event timing is best and where model behaviour is best; see also Figure 7.11 to Figure 7.13.

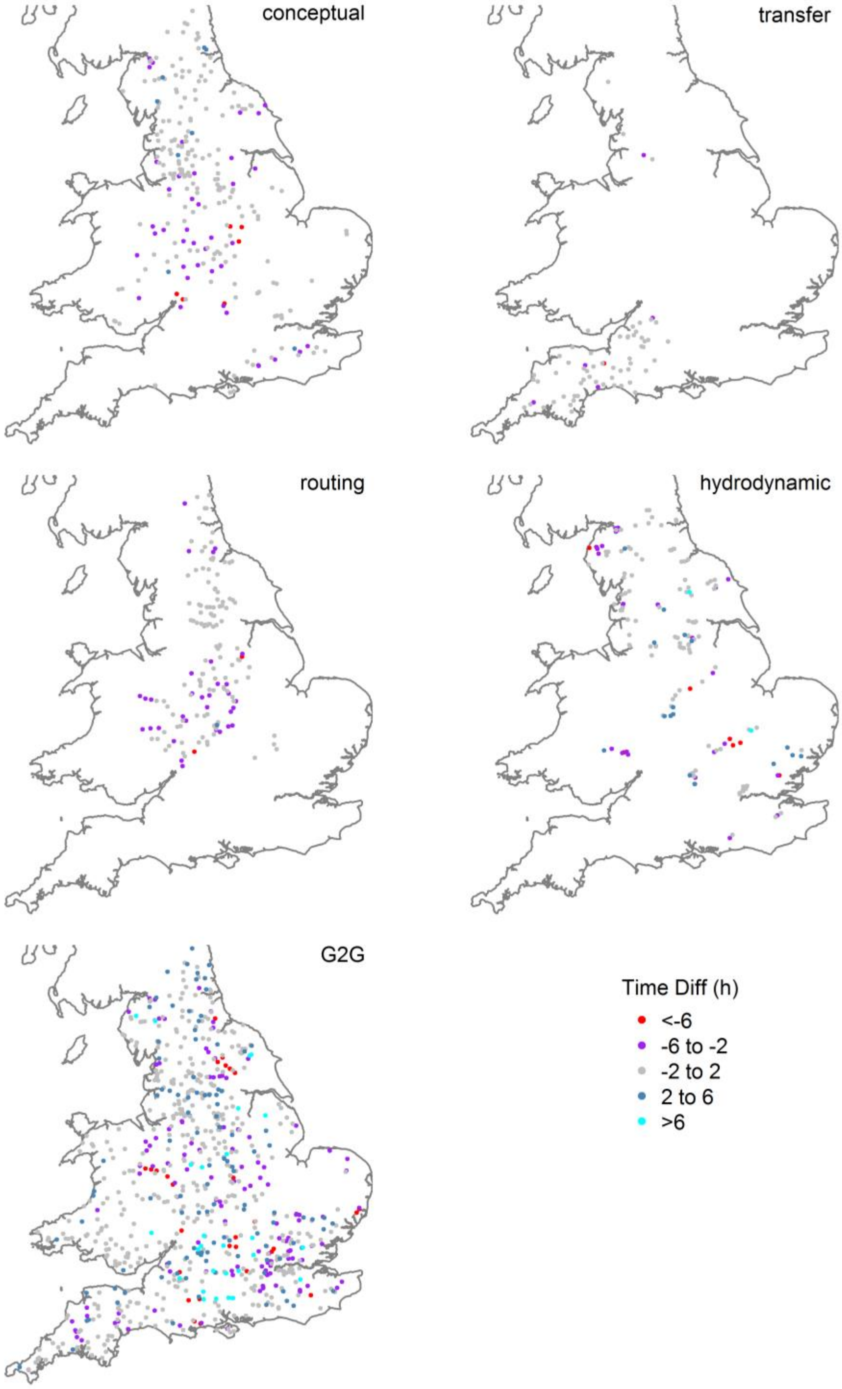


Figure 7.30 Performance map of average site time differences for each of the model groupings

Notes: Grey points are sites where average differences are within 2 hours.
Red and purple points show early forecasts.
Blue points show late forecasts.

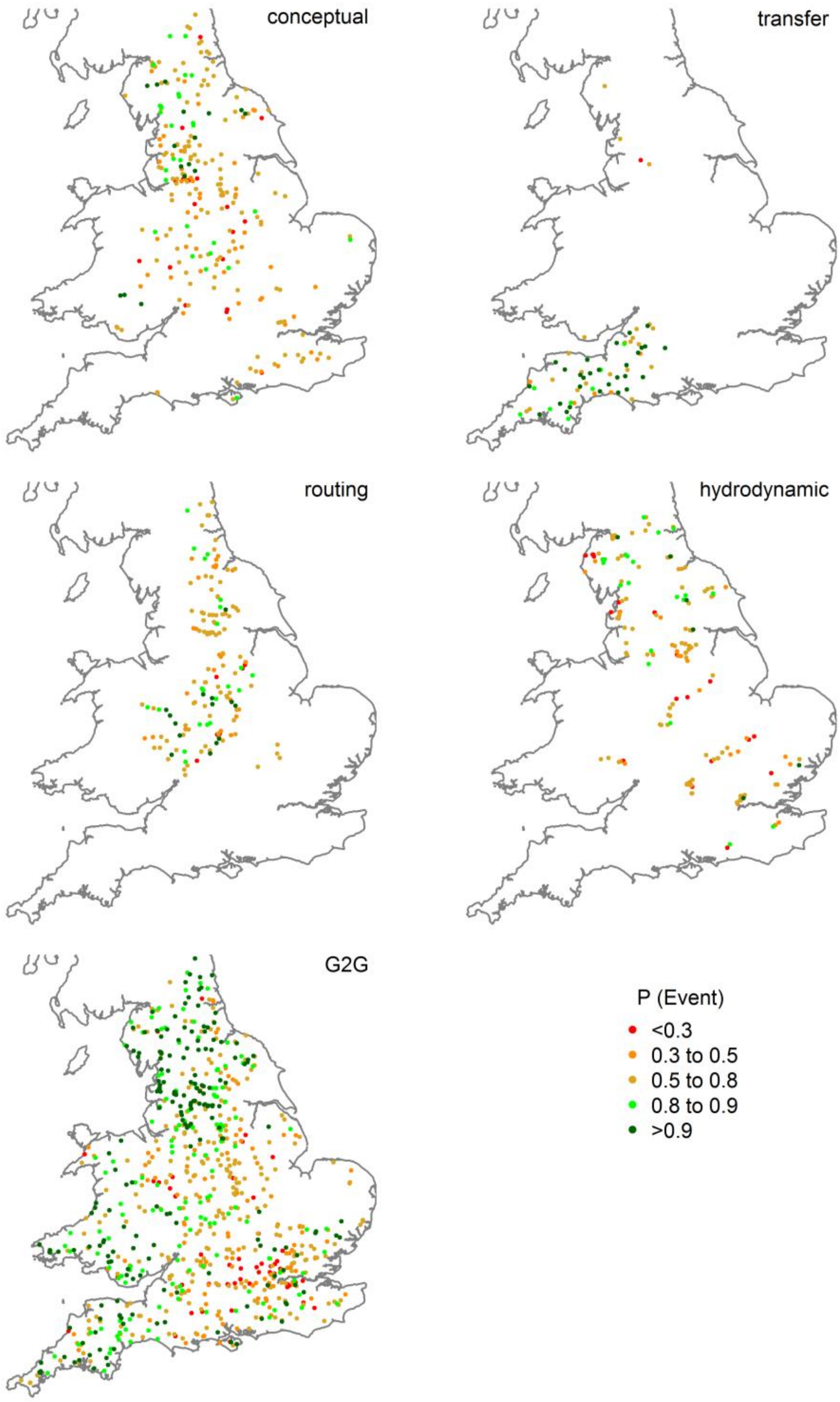


Figure 7.31 Performance map of model Confidence for each of the model groupings

Notes: G2G shows high model Confidence especially in northern and western areas.

7.4 Summary

This section has presented the results of the analyses of the local model datasets produced by consultants along with the G2G datasets maintained by CEH. In doing so it has, for the first time, combined local model and national model assessments into a common and consistent national framework for FFMP appraisal and reported on the outcome of its application.

The assessment has provided information, through the use of multi box plots, on how performance varies with model type for different forecast lead-imes and its variability across sites. Performance maps of colour-coded skill scores reveal the geographical variation in performance. Collations of these grouped by model category and lead-time provide further understanding of performance variations.

A line plot of average skill for a given model against lead-time for all models allows the performance of different models to be compared. A performance comparison of each local model with the national G2G model, for short and long lead-times for three skill scores, allows tabulation of when the local model is better on average than G2G, and vice versa.

Multi box plots have been used, for sites in common, to compare the skill of a local model type with that of G2G as a function of lead-time. Scatter plots of skill of a local model type against that of G2G collated for different lead-times on a single (‘postage stamp’) display again reveal the comparative performance of the two models. Performance maps that employ a performance comparison rating between the local model and G2G provide a geographical insight into which is better for a given lead-time. In some cases, two local models may exist and scatter plots of their relative performance, for a given skill score and lead-time, can be used to compare them.

Multi box plots of local model skill in each region as a function of lead-time, for different skill scores, have revealed regional differences in performance and of its variability. A line plot of average skill for a given region against lead-time, for local models and G2G separately, has revealed comparative performance of local models across regions and also of G2G.

The sensitivity of skill scores with magnitude tolerance when a 20% tolerance on flow threshold is converted to level through a rating (the ideal) to the expedient of using a standard 0.2m tolerance (when no rating is available) has been mapped. However, it can be quite significant and introduce biases affecting model comparison, favouring local models over G2G. Thus a clearer model comparison is obtained without use of magnitude tolerance.

Consideration of the Overall Performance Measure has examined the interrelation between its 9 components through matrix scatter plots for local and G2G models, and how best to treat missing values. Multi box plots of different Overall Performance Measure components for local and G2G models stratified by region, and by local model type along with G2G, have enabled comparative performance across models and regions to be determined. For sites where local and G2G model performance can be compared, a comparative performance map has classified the two models by descriptors of the type: ‘much better’, ‘better’, ‘little better’ and ‘similar’.

Statistics seen as being of especial operational relevance – POD, Confidence, event timing uncertainty (average time difference and spread) – have been summarised through box plots stratified by model type and geographical region. A comparative performance map of local model and G2G in terms of event timing difference has been produced along with performance maps of average event timing difference and Confidence for the different model groups.

The overall outcome is an extensive evidence-base of flood forecasting model performance. This takes account of differences in site, model type, model group and geographical region and provides information on comparative performance where a choice of model forecast exists. A range of statistics are employed, some highlighted as of particular operational relevance. An integration of selected statistics into an Overall Performance Measure (partitioned into forecast and simulation components) yields a synthesised appraisal of performance that can be used for comparison across sites stratified in various ways.

8 Recommendations and conclusions

This section presents recommendations based on the findings of this study and draws some broad conclusions. The recommendations concern:

- local and national (G2G) modelling, including dependencies on river gauging
- how flood forecasting model assessments should be managed in the future
- the creation and maintenance of a model assessment database
- the choice of Overall Performance Measure
- how the Performance Summary should guide operational forecasting
- how the results of this base level assessment can guide improvements in flood forecasting in the future

8.1 Recommendations for modelling

This study indicates that different models have different strengths and weaknesses. It is unlikely to be the case that one model outperforms another in all respects. An important point to consider is that having multiple models (at a site) may well provide the best information. This is especially true if each model's strengths and weaknesses are understood.

For the future, the aspiration could be to have multiple model forecasts available at each location, as is already becoming the case for many locations where there are both forecasts from local and G2G models available.

8.1.1 Recommendations for local models

There is a clear case for some degree of standardisation across regions as to how models are implemented, selected, calibrated and assessed. However, this should not be at the expense of regional expertise and regional tailoring.

By standardising approaches it should be possible to improve model assessment and comparison and thus, in the longer term, flood forecasting ability. Although it may require more inter-regional collaboration and sharing of expertise, it should allow for best practice to be spread across all regions. This is likely to be helped by the move within the Environment Agency from regional management to national flood modelling and forecasting teams supported by local centres with regional expertise.

Items which would assist comparison include:

- using a standard model time-interval – 15 minutes is recommended to align to the normal interval used in telemetry data capture (versions of MCRM and DODO code are available for operational use that can operate at a 15-minute time-step)
- considering some rationalisation of model types across regions – it could well be possible to get better results with a smaller set of models

- implementing models that go beyond transfer function models for the South West and hence to improve forecasting at longer lead-times
- checking the longer lead-time model behaviour for MCRM, TCM and DODO using only datasets using a Perfect Rainfall scenario.
- carrying out further work to determine whether the less well performing models could be replaced by something that would perform better, or whether all models would likely encounter similar problems due to local challenging circumstances (Appendix C provides some guidance on this)

Some further points of standardisation that relate to the creation of Performance Summary datasets are included in Section 8.2.

It is not possible to conclude from this study whether some models outperform others as a standard, and thus could be used to replace others. However, models such as PDM, KW and ISIS clearly perform strongly across several regions. It is therefore recommended that these models be considered as an initial choice when applying or improving models in all regions. Other models should be used if a good case can be made that they are more applicable to the specific situation.

The results from this study are best considered alongside outputs from previous inter-comparison studies. Where there are gaps, some further direct model comparison studies may be justified.

8.1.2 Recommendations for G2G models

In general, the G2G model is not expected to produce as good results as locally calibrated models. This is because it is a countrywide distributed hydrological (rainfall-runoff and routing) model and effectively, for its domain of application, has fewer parameters than the local models. The G2G model is broadly calibrated across England and Wales, whereas the local models are calibrated to a specific site.

While in many respects G2G compares relatively well with the local models applied on a regional basis, there are areas where improvement may be targeted. This includes:

- invest in improving the timing of peaks for G2G
- conducting case study examples to understand why G2G does better/worse than local models at selected locations

In addition, it is recommended that the Flood Forecasting Performance Summary produced here is incorporated into the existing G2G Performance Summary in operational use by the Flood Forecasting Centre.

8.1.3 Recommendations for gauging and rating

The issue of how to create well-gauged and well-rated flow locations is complex but one that requires attention.

Ideally, all river gauging station locations would have good gauging and good rating curves that are regularly maintained. Model calibration and implementation systems would be easily and rapidly updated to incorporate changes or additional ratings.

This study has noted:

- significant differences in the rating equations used operationally at sites between local models on regional national flood forecasting systems and G2G on the FFC's national flood forecasting system – this is a feature of the past performance assessments analysed in this study and is thought to be less of a problem now

- a problem with updating rating equations that may then mean that previously calibrated models are no longer valid

These issues suggest that, although challenging, more could be done to keep ratings and models up to date and consistent across different platforms, including maintaining time-stamped ratings across NFFS implementations.

The lack of rating equations at many forecast (level-only) sites hinders cross-comparison and interpretation of model results: for example, G2G cannot be compared with level-based outputs. It is accepted that some level-only sites will not have unique ratings on account of backwater effects, inducing hysteresis behaviour and looped ratings; a hydrodynamic river routing approach is suggested as more suitable for these.

8.2 Recommendations for future flood forecasting model assessments

Future assessment of flood forecasting model performance has the potential to be made considerably faster, cheaper and more meaningful. For this, the most important requirement will be to standardise and quality control, as much as possible, how model performance datasets are generated. Specific requirements include the following.

- All time-series data (observed and modelled) should be supplied as both flows and levels where possible.
- Data files should be standardised as much as practical in their collation, formatting and naming.
- Thresholds and tolerances used should be standardised.
- The same rainfall scenarios should be used in FFMP studies. The Perfect Rainfall forecast (that is, one based on foreknowledge of rainfall observations) is the minimum necessary and ideally Forecast Rainfall scenarios should also be used. These should be aligned to mirror how these rainfall sources are configured in the NFFS.
- The model forecast length should extend to what is operationally possible, with out to 5 days being a future goal for local models.
- All observed and modelled forecasts should employ a 15-minute time-step.
- All model time series should be produced and documented in a consistent way that allows for meaningful comparison.

8.3 Recommendations for creating and maintaining a model assessment database

It is recommended that, as a minimum, a text-based model database be created to collect forecast model performance outputs. Because a model forecast dataset is quite extensive, selection of an efficient format is vital so that analysis is practicable. For example, XML is an extremely verbose file format, especially when forecasts are considered and is not suited to this purpose.

Appendix B outlines a possible structure for such a database. The suggestions are initial ones and refinement is likely and advisable. It is possible that a more sophisticated storage system could be used and there is scope for adjustment. However, standard databases such as WISKI or ORACLE are not considered suited to this task.

The proposed approach is to:

- define carefully the file structure, file naming scheme and file format
- require consultants performing future forecast performance assessments to adhere strictly to this scheme

All data entered into the database should have been previously subject to quality control, so that data noise and any step changes are corrected before the data are included in the database.

Care will be necessary when setting up the database to ensure that as many important metadata variables as possible are included.

It is recommended that the Environment Agency and Natural Resources Wales create a national register of flood warning sites and sites with models. As a starting point, this needs to include catchment area. Ideally updates to rating equations, models available at a site and so on would also be stored here. The register should be housed centrally and updated regularly by region. This would make it easier to carry out all studies on a national basis and reduce the need to consult each local centre individually on regional details.

8.4 Recommendations for Overall Performance Measure

It is recommended that the Overall Performance Measure be based only on the forecast model results. Although the Overall Performance Measure for forecasts used here allows model cross-comparison, some remaining points require attention.

First, it is hard to know how the Overall Performance Measure for forecasts relates to site performance. This is because it is an aggregate of several aspects.

Second, whether and how magnitude tolerance is included in the measure is likely to make a difference to the conclusions that are drawn. In this report, magnitude tolerances have not been used in the Overall Performance Measure for forecasts.

The measures of simulation performance are difficult to use and vulnerable to choice of with or without levels. As these measures are more relevant to model calibration performance than to assessment of flood forecasting performance, it is not recommended that they play a large part in evaluating model forecast performance.

8.5 Recommendations for operational forecasting

It is recommended that:

- the Forecast Model Performance Summary is made available to NFFS flood forecasting staff
- NFFS flood forecasting staff are trained to understand the meaning of the statistics and how they may be used in an operational setting

The most important information is the likely timing of the event and the Confidence of the forecast.

Local centre staff should note locations where G2G outperforms the local model and make use of G2G forecasts at these locations.

8.6 Recommendations for the Performance Summary template, analyses and access

Two distinct types of assessment outputs are presented in this report.

First, the Flood Forecasting Model Performance Summary provides a concise summary of performance at each site for each model and is discussed in detail in Section 6.

Second, this at-site Performance Summary is complemented by regional and national analyses over many sites and/or models in the form of performance maps and grouped statistics. These are discussed in Section 7 and summarised in Section 7.4.

Accessing, viewing and assessing the wealth of performance assessment information in appropriate ways is challenging and depends on the intended use: for example, supporting real-time decision making or guiding offline strategic investment decisions. Various options are discussed below.

8.6.1 Via NFFS

Flood Forecasting Model Performance Summary

The template for the Flood Forecasting Model Performance Summary has been designed to summarise a variety of site and model performance information on one A4 page, to be accessed as a PDF via the NFFS tooltip function – as is currently done for the G2G Performance Summary within NFFS-FFC. Although this design requirement is quite constraining, it allows a flood duty officer to quickly view and assess a range of relevant model performance information to guide decision-making on flood warning.

Regional and national analysis of Performance Summary statistics

The NFFS could be configured or developed to include some, but not all, of the regional and national analysis information presented in Section 7. One potential drawback is that only the NFFS-FFC has national coverage while the local centre NFFS configurations have regional coverage. Also, the main perceived use of these analyses is to support offline strategic investment decisions and so there is less need for integration within a real-time forecasting system.

8.6.2 Directly via the Performance Summary PDFs and this report

Flood Forecasting Model Performance Summary

Accessing the PDFs directly from a computer folder is possible, but time consuming and not efficient.

Regional and national analysis of Performance Summary statistics

The regional and national analyses presented in Section 7 are particularly useful for assessing model performance strategically: for example, identifying areas of the country with particularly poor model performance. However, a limitation of the static maps and plots in this report is that it is difficult to identify specific sites where further analysis would be useful.

8.6.3 Via CEH's web portal

Both of the options described above have recognised limitations and there is a desire for a more interactive method for viewing the outputs at site, regional and national scales. CEH has taken the first steps in exploring this by developing a prototype web portal which would complement the one page Flood Forecasting Model Performance Summary template and the regional and national analyses in this report. This portal utilises the generic web functionality of the CEH Environmental Information Platform (https://eip.ceh.ac.uk/) which is increasingly being used and further developed by CEH for other water industry applications.

The current prototype interfaces to the Performance Summary database developed under this project. It displays a performance map of sites analysed over England and Wales, which can be filtered by model type and/or lead time, with the performance measure (for example, CSI) presented as a colour-coded circle over each location. Using the mouse to select a given colour circle yields a pop-up display giving values of the performance measure for different lead-times at this location and a list of the models available at that site. The pop-up also contains a 'zoom to' function that moves into the location selected, exposing the river network in detail and neighbouring sites. Selecting the site ID and name currently gives access to the PDF of the one-page Flood Forecasting Model Performance Summary. Pan and zoom functionality via the mouse allows the user to interactively explore the map and identify specific sites. An example screenshot is given in Figure 8.1, which essentially shows the performance map information from Figure 7.6 in an interactive manner, complete with links to the Performance Summary PDFs.

The current web browser tool also gives document access, with this report configured in at present. This prototype is seen as a first step in giving access to components of the Performance Summary through appropriate menus, freeing the design from the current one page template (which could still be supported).

There are several advantages to the web portal approach.

- CEH can add any new sites/data as soon as they have been processed.
- There is more flexibility to roll-out changes or additions to templates or statistics.
- There is no reliance on Environment Agency or Natural Resources Wales IT systems for maintenance or upgrades – other than requiring internet access.
- The portal can potentially be accessed outside of Environment Agency and Natural Resources Wales networks if needed.

A downside to the approach is the reliance on an external website but, for offline strategic use, this is less of a concern.

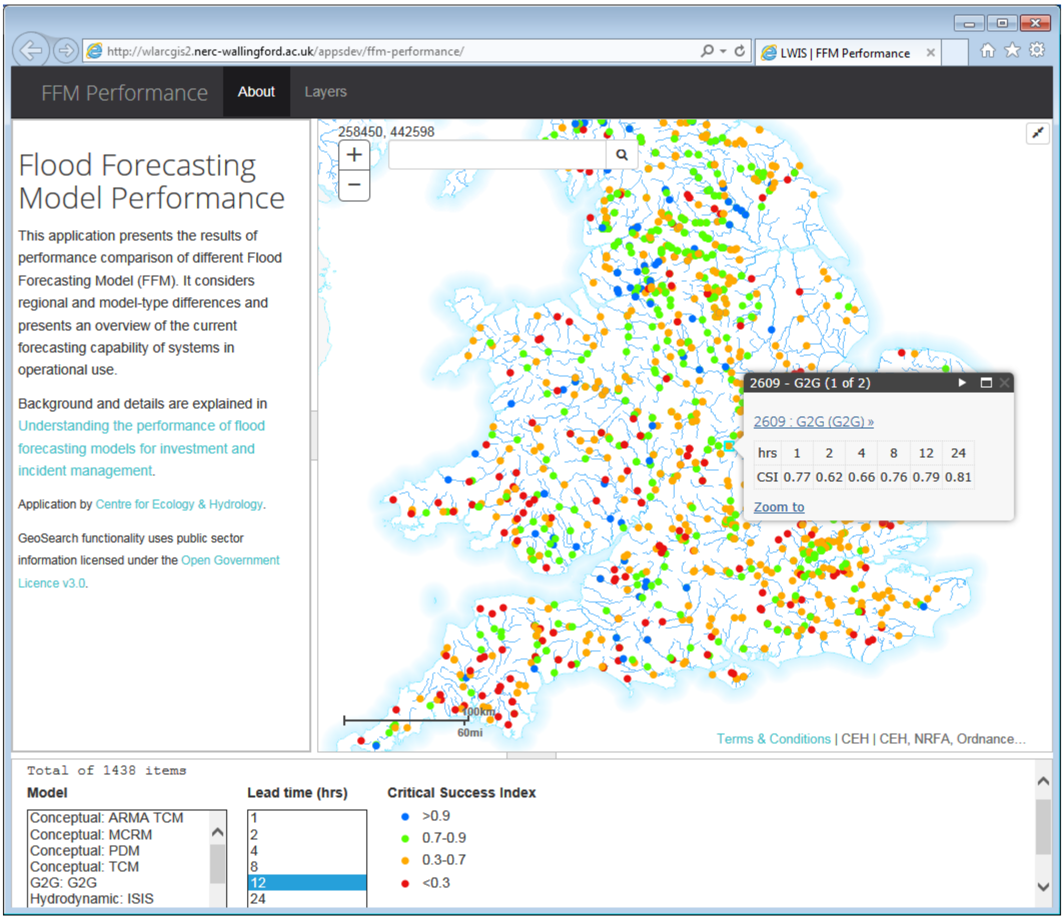


Figure 8.1 Screenshot from the prototype FFMP web portal developed by CEH

Notes: The screenshot shows data equivalent to Figure 7.6 in an interactive way.

8.6.4 Recommendations

- **Access via the NFFS.** It is recommended the PDF summary pages are included as tooltips within the local centre NFFS applications. This is particularly for real-time use.
- **Direct access.** This report and individual Performance Summary PDFs should be centrally available to users.
- **Access via CEH web portal.** CEH plans to make the prototype web portal accessible to Environment Agency and Natural Resources Wales staff. Based on user feedback, further development of the portal should be considered. This could extend to including more maps of different statistics and improving the interactivity.

8.7 Recommendations for improvement of flood forecasting

This study provides a base level for the assessment of flood forecasting model performance. As the first study to provide a national overview of flood forecasting performance it is an important milestone.

The question of how a study such as this can be used to identify weaknesses and to improve flood forecasting is not straightforward. It will always be the case that local knowledge and discernment will be required to determine whether poor model performance is due to complex local conditions or whether a model is a candidate for improvement. Nevertheless, the production of a report such as this should help local centre and national staff determine where efforts should be directed.

Addressing recommendations above, such as standardising approaches and models across regions and creating a database of model results, will inevitably increase comparability and ease decision-making in the future.

8.8 Conclusions

This study has, for the first time, developed a national approach for assessing the performance of local flood forecasting models along with the national G2G model. The approach has been implemented to bring together, in a nationally consistent way, datasets from local model performance studies held by consultants, usually for groups of gauged catchments within a river basin. It has also been applied to a G2G national dataset, created by running the G2G model offline over 5 water years to make forecasts at regular 1-hour forecast time-origins throughout the period.

A range of performance statistics, and ways of displaying them, have been selected or developed to summarise performance at different lead-times. These are complemented by hydrograph displays of forecast, simulated and observed river levels/flows, including an indication of the success in forecasting a threshold crossing. An Overall Performance Score, along with its component scores, gives a colour-coded performance grading for each site model. Comparison of two models at the same site is summarised through a display that assesses relative performance in terms of CSI, POD, Confidence and timing difference.

These statistics and displays are combined with hydrometric details of a given site to form a single A4 page Performance Summary for each site and model combination. This is produced as a PDF for every site/model combination and could potentially be accessed via an NFFS site map display using the tooltip function.

In addition, Section 7 of this report presents an extensive national evidence-base of model performance, stratified by model type, model group, geographical region and lead time. It also includes information on comparative performance where a choice of model forecast exists. A prototype web portal developed by CEH offers a flexible path to access information from this evidence-base and Performance Summary.

The Performance Summary framework has been designed to be readily refreshed to include new datasets from consultants as they become available or are commissioned. Recommendations have been made to make this process more efficient and the model assessments more meaningful and useful, both in incident management and for guiding strategic investment in flood forecasting models.

References

BAILEY, R.A. AND DOBSON, C., 1981. Forecasting for floods in the River Severn catchment. *Journal of the Institution of Water Engineers & Scientists*, 35 (2), 168-178.

BELL, V.A., KAY, A.L., JONES, R.G., MOORE, R.J. AND REYNARD, N.S., 2009. Use of soil data in a grid-based hydrological model to estimate spatial variation in changing flood risk across the UK. *Journal of Hydrology*, 377 (3-4), 335-350.

BOX, G.E.P. AND JENKINS, G.M., 1970. *Time Series Analysis Forecasting and Control.* San Francisco: Holden-Day.

CEH, 2012a. *PDM Rainfall-Runoff Model. Version 2.3.* Includes guide, practical user guides, user manual and training exercises. Wallingford: Centre for Ecology & Hydrology.

CEH, 2012b. *PSM Rainfall-Runoff Model. Version 2.3.* Includes guide, practical user guides, user manual and training exercises. Wallingford: Centre for Ecology & Hydrology.

CEH, 2012c. *KW Channel Flow Routing Model. Version 2.3*. Includes guide, practical user guides, user manual and training exercises. Wallingford: Centre for Ecology & Hydrology.

CEH, 2013. *Performance assessment of the G2G Model: a guide to the Performance Summary.* Report to the Flood Forecasting Centre, Wallingford: Centre for Ecology & Hydrology [first published 2010].

CLUCKIE, I.D. AND OWENS, M.D., 1987. Real-time rainfall-runoff models and use of weather radar information. In: *Weather Radar and Flood Forecasting* (ed. V.C. Collinge and C. Kirby), pp. 171-190. Chichester: J. Wiley & Sons.

COLE, S.J., HOWARD, P.J. AND MOORE, R.J., 2009. *Hydrological modelling for the rivers Lavant and Ems.* Report to the Environment Agency Southern Region, Wallingford: Centre for Ecology & Hydrology.

CRANSTON, M., MAXEY, R., TAVENDALE, A., BUCHANAN, P., MOTION, A., COLE, S., ROBSON, A., MOORE, R.J. AND MINETT, A., 2012. Countrywide flood forecasting in Scotland: challenges for hydrometeorological model uncertainty and prediction. In: *Weather Radar and Hydrology* (ed. by R.J Moore, S.J. Cole and A.J. Illingworth), Proceedings of Exeter Symposium, April 2011, IAHS Publication No. 351, pp. 538-543. Wallingford: International Association of Hydrological Sciences.

DOUGLAS, J.R. AND DOBSON, C., 1987. Real-time flood forecasting in diverse drainage basins. *Weather Radar and Flood Forecasting* (ed. V.C. Collinge and C. Kirby), pp. 153-169. Chichester: J. Wiley & Sons.

ENVIRONMENT AGENCY, 2001a. *Comparison of rainfall-runoff models for flood forecasting. Part 1: Literature review of models.* R&D Technical Report W241. Research contractor: Institute of Hydrology (authors: R.J Moore and V.A Bell). Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2001b. *Comparison of rainfall-runoff models for flood forecasting. Part 2: Calibration and evaluation of models.* R&D Technical Report W242. Research contractor: Institute of Hydrology (authors: V.A. Bell, D.S. Carrington and R.J. Moore).Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2007. *Rainfall-runoff and other modelling for ungauged/low-benefit locations.* Science Report SC030227/SR1. Research contractor:

Centre for Ecology and Hydrology (authors: R.J.Moore, V.A. Bell, S.J.Cole and D.A. Jones), Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2010. *Hydrological modelling using convective scale rainfall modelling – phase 3*. Science Report SC060087/R3. Research contractor: Centre for Ecology and Hydrology (authors: R.J.Moore, V.A. Bell, S.J.Cole and D.A. Jones), Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2014. *Evaluating G2G for use in rapid response catchments: final report.* R&D Project Report SC110003/R1. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management programme. Research contractor: Deltares and CEH (authors: J. Schellekens, A.R.J. Minett, P. Reggiani and A.H. Weerts (Deltares); R.J. Moore, S.J. Cole, A.J. Robson and V.A. Bell (CEH)). Bristol: Environment Agency.

GREENFIELD, B.J., 1984. *The Thames Water Catchment Model.* Internal report, Technology and Development Division, Thames Water.

HAN, D., 1991. *Weather radar information processing and real-time flood forecasting.* PhD thesis, Water Resources Research Group, Department of Civil Engineering, University of Salford.

HARDING, R.J. AND MOORE, R.J., 1988. *Assessment of snowmelt models for use in the Severn Trent flood forecasting system*. Report by the Institute of Hydrology to Severn Trent Water Authority.

JBA CONSULTING, 2015. *2014s1299 Midlands Performance Measures.* Report to the Environment Agency, draft report, 17 March 2015. Skipton: Jeremy Benn Associates Ltd.

JONES, D.A. AND MOORE, R.J., 1980. A simple channel flow routing model for real-time use. In: *Hydrological Forecasting*, Proceedings of Oxford Symposium, April 1980. IAHS Publication No. 129, pp. 397-408. Wallingford: International Association of Hydrological Sciences.

MOORE, R.J., 1985. The probability-distributed principle and runoff production at point and basin scales. *Hydrological Sciences Journal*, 30 (2), 273-297.

MOORE, R.J., 1999. Real-time flood forecasting systems: perspectives and prospects. In: *Floods and Landslides: Integrated Risk Assessment* (ed. R. Casale and C. Margottini), Chapter 11, pp. 147-189. Berlin: Springer.

MOORE, R.J., 2007. The PDM rainfall-runoff model. *Hydrology and Earth System Sciences*, 11 (1), 483-499.

MOORE, R.J. AND JONES, D.A., 1978. An adaptive finite-difference approach to real-time channel flow routing. In: *Modelling, Identification and Control in Environmental Systems* (ed. G.C. Vansteenkiste), pp. 153-170. Amsterdam: North-Holland.

MOORE, R.J. AND BELL, V.A., 2002. Incorporation of groundwater losses and well level data in rainfall-runoff models illustrated using the PDM. *Hydrology and Earth System Sciences*, 6 (1), 25-38.

MOORE, R.J., HARDING, R.J., AUSTIN, R.M., BELL, V.A. AND LEWIS, D.R., 1996. *Development of improved methods for snowmelt forecasting.* R&D Note 402. Research contractor: Institute of Hydrology. Bristol: National Rivers Authority.

MOORE, R.J., BELL, V.A. AND CARRINGTON, D.S., 2000. Intercomparison of rainfall-runoff models for flood forecasting. In: *Flood Forecasting: What Does Current Research Offer the Practitioner? (*ed. M. Lees and P. Walsh), Occasional Paper No. 12, pp. 69-76. British Hydrological Society.

MOORE, R.J., COLE, S.J., BELL, V. A. AND JONES, D.A., 2006. Issues in flood forecasting: ungauged basins, extreme floods and uncertainty. In: *Frontiers in Flood Research* (ed. I. Tchiguirinskaia, K.N.N. Thein and P. Hubert), Proceedings of the 8th Kovacs Colloquium, UNESCO, Paris, June/July 2006, IAHS Publication No. 305, pp. 103-122. Wallingford: International Association of Hydrological Sciences.

O'CONNOR, K.M., 1982. Derivation of discretely coincident forms of continuous linear time-invariant models using the transfer function approach. *Journal of Hydrology*, 59 (1-2), 1-48.

PENMAN, H.L., 1950. The dependence of transpiration on weather and soil conditions. *Journal of Soil Science*, 1 (1), 74-89.

POLLARD, O. AND HAN, D., 2012. Making calibration objectives relevant to flood forecasting. *Water Management*, 165 (WM2), 121-136.

PRICE, D., HUDSON, K., BOYCE, G., SCHELLEKENS, J., MOORE, R.J., CLARK, P., HARRISON, T., CONNOLLY, E. AND PILLING, C., 2012. Operational use of a grid-based model for flood forecasting. *Water Management*, 165 (2), 65-77.

ROBSON, A.J. AND MOORE, R.J., 2009. *Midlands Catchment Runoff Model: Model Description and User Guide. Version 1.0.* Report to the Environment Agency. Wallingford: Centre for Ecology and Hydrology.

WALLINGFORD WATER, 1995. *A flood forecasting and warning system for the River Soar: Stage 2 Report*. Report to the National Rivers Authority Severn Trent Region, Version 2.0 (available from Centre for Ecology & Hydrology, Wallingford).

WILBY, R., GREENFIELD, B. AND GLENNY, C., 1994. A coupled synoptic hydrological model for climate change impact assessment. *Journal of Hydrology*, 153 (1-4), 265-290.

YANG, Z. AND HAN, D. 2006. Derivation of unit hydrograph using a transfer function approach. *Water Resources Research*, 42 (1), W01501. DOI:10.1029/2005WR004227.

List of abbreviations

ARMA	autoregressive moving average
CEH	Centre for Ecology & Hydrology
CSI	Critical Success Index
CWI	Catchment Wetness Index
FAR	False Alarm Ratio (Confidence is 1 – FAR)
FFMP	Flood Forecasting Model Performance
FWLoS	Flood Warning Level of Service
G2G	Grid-to-Grid [model]
FFC	Flood Forecasting Centre
KW	Kinematic Wave [model]
MCRM	Midlands Catchment Runoff Model
NFFS	National Flood Forecasting System
NRFA	National River Flow Archive
OPS	Overall Performance Score
PDM	Probability Distributed Model
PRTF	Physically Realisable Transfer Function [model]
POD	Probability of Detection
ResFW	Residential Flood Warning [alarm level]
SMI	Soil Moisture Index
TCM	Thames Catchment Model
TFN	Transfer Function Noise [model]

Appendix A: Performance guidelines

This appendix provides the original Environment Agency guidelines for creation of model performance results. Note that the format has evolved considerably from that originally proposed. In addition, it was not possible to include some of the aspects below because of the requirement that the process be automated and non-subjective.

PERFORMANCE CATEGORISATION GUIDELINES

Indicators that performance is well assessed

- Development environment assessment with:
  - more than 10 years of data that are reasonably representative of current/future conditions
  - more than 5 observed ResFW threshold exceedances
  - highest peak substantially above ResFW threshold
  - more than 2 significant rainfall events on relatively dry catchment conditions
- Reasonable consistency between development environment and operational environment performance
- Thresholds used in development and operational environments are similar (not necessarily identical)

Note: ResFW is the Residential Flood Warning alarm level at which a river first affects a nearby property.

Indicators that performance is not well assessed

- Above criteria not met

Indicators that performance is good

- Development environment assessment with:
  - more than 80% of peaks within magnitude tolerance
  - more than 80% of peaks within timing tolerance
  - R^2 (Nash-Sutcliffe) Efficiency above 0.85
  - Magnitude and timing errors not increasing with magnitude of observed peaks
  - ‘As forecast’ POD for ResFW above 0.7
  - ‘As forecast’ FAR for ResFW below 0.3
- Operational environment performance statistics do not contradict the development environment statistics
- Model is a reasonable conceptualisation of the real world

Indicators that performance is moderate

- Development environment assessment with:
  - more than 60% of peaks within magnitude tolerance
  - more than 60% of peaks within timing tolerance
  - R^2 (Nash-Sutcliffe) Efficiency above 0.70
  - Only limited indications of magnitude and timing errors increasing with magnitude of observed peaks
  - 'As forecast' POD for ResFW above 0.5
  - 'As forecast' FAR for ResFW below 0.5
- Operational environment performance statistics do not contradict the development environment statistics

Indicators that performance is poor

- Above criteria not met

Moveable structures

- Some sites are affected by structures that are operated manually or automatically. This will be site-specific and may mean performance of a model affected by such structures is variable, particularly around levels or flows where structures operate. In some cases, especially at higher flows, some structures influence may be drowned out.
- Although performance statistics will be carried out at all modelled forecast locations, it may be in some cases that performance statistics will never be viable.
- Structures vary from simple trash screens to large automatic gates used for navigation.

Appendix B: Recommended format for Flood Forecasting Model Performance database

B.1 Introduction

The purpose of Appendix B is to provide an outline specification to be followed by consultants when submitting Flood Forecasting Model Performance (FFMP) studies, and their associated local model datasets, to the Environment Agency. The intention is that the datasets will be in a form that allows CEH to readily take on and integrate these local model datasets into the national database it maintains for the purposes of creating a consistent national analysis and report of flood forecasting model performance across England and Wales. Future FFMP local studies and their collation into a national analysis/report have the potential to be made considerably quicker, cheaper and more meaningful if specified consistently when commissioned.

The approach taken to achieving a nationally consistent performance assessment is to gather the 'raw' data from local model performance studies – observations, model forecasts and historical model simulations of river flow/level along with relevant metadata. Collation of the underlying data from local model studies, and not the performance statistics themselves, ensures standardisation – along with flexibility in choice – of the performance metrics to be used subsequently for the national analysis and reporting.

The outline database specification considered here recognises that the local model datasets were provided under this project by three consultants (JBA Consulting, Plan B UK and CH2M) in different forms and thus a rigid specification is not appropriate. However, it has been possible to define an outline file storage (see Section B.3) structure to be followed as a guide by any consultant contracted to supply local model datasets.

B.2 Broader requirements

There are also broader requirements to be met by future FFMP studies that, in part, follow from the recommendations of this project. These are summarised below.

The main **overall requirement** is to standardise, as far as possible, how model performance datasets are generated and supplied in a quality-controlled way. Specific requirements include the following.

- All time-series data (observed and modelled) are to be supplied as both flows and levels where possible.
- Data files should be standardised as much as practical in their collation, formatting and naming.
- Thresholds and tolerances used should be standardised.
- The same rainfall scenarios should be used in FFMP studies. The Perfect Rainfall forecast (that is, one based on foreknowledge of rainfall observations) is the minimum necessary and ideally Forecast Rainfall

scenarios should also be used. These should be aligned to mirror how these rainfall sources are configured in the NFFS.

- The model forecast length should extend to what is operationally possible – out to 5 days being a future goal for local models.
- All observed and modelled time-series should employ a 15-minute time-step.
- All model time-series should be produced and documented in a consistent way that allows for meaningful comparison.

A model forecast dataset can be extensive in terms of data volumes and so selection of an efficient format is needed so that analysis is practicable. Datasets should be supplied in simple, easy-to-read text-based form. Verbose file formats, such as XML, should not be used and standard databases, such as WISKI or ORACLE, are not considered suitable.

The approach to database design is to:

- define carefully the file structure, file naming scheme and file format (see Section B.3)
- require consultants performing future FFMP studies to adhere strictly to this scheme

All observed data included in the dataset should have been previously been subjected to a quality-control procedure, so that data noise and any step changes are corrected prior to inclusion. Some care will be needed to ensure that as many important metadata variables as possible are included.

To help in achieving consistency of approach in FFMP studies, CEH has recommended that the Environment Agency and Natural Resources Wales create a national register of flood warning sites and sites with models that contains relevant metadata. This should include the catchment area and other relevant information such as updates to rating equations and models available at a site. The national register should be stored centrally and updated regularly. This would allow all FFMP studies to be commissioned on a national basis and reduce the need to consult with each local centre individually on regional details.

Basic and more detailed requirements to be met by consultants are summarised below.

B.2.1 Basic requirements

- Datasets to be supplied as text files to include:
  - observed flows or levels, and both if available
  - modelled forecasts as flows or levels, and both if available
  - historical simulation data as flows or levels, and both if available
  - metadata (such as thresholds, or events used)
- Consistency in naming of sites, model type (and form of data assimilation if included), forecast type and rainfall scenario
- Consistency in forecast length, time-step and time between forecast origins
- Forecast generation – the 'all-available' forecast approach is preferred over the one-event-per-forecast approach

B.2.2 Detailed requirements

- All observed and modelled time-series should employ a standard 15 minute time-step.
- Ensure that the longer lead-time performance of models is assessed using a Perfect Rainfall scenario as the minimum necessary and ideally also Forecast Rainfall scenarios to capture operational performance.
- Ensure that appropriate rating equations are used for river flow and level transformations, recording source details where possible (for example, NFFS configuration version).

B.3 File storage structure outline specification

It is recommended that, at a minimum, a text-based model database be created. However, a model forecast dataset is quite extensive and selection of an efficient format is necessary such that analysis is practicable.

The suggestions listed below constitute a minimum and refinement is likely and advisable.

All data should have been previously quality-controlled, so that data noise and any step changes are corrected prior to their inclusion in the database.

B.3.1 File storage structure

```
FFMP_Database/
  NFFSID/
    ModelName/
        StudyDate_ConsultantName_StudyID/
            NFFSID_Variable_StartDate_EndDate_RainScenario_TimeStep_FORC.csv
            NFFSID_Variable_StartDate_EndDate_RainScenario_SIM.csv
            NFFSID_Variable_StartDate_EndDate_OBS.csv
            NFFSID.meta
            NFFSID_COMMENTS.txt
```

where:

NFFSID = NFFS site ID

All dates (StartDate EndDate StudyDate) should be in standard form YYYYMMDD.

The StudyDate will be the date assigned to the Performance Study in which the dataset was gathered.

The StudyID must be unique and not contain special characters.

All files and directories should be named according to a strict protocol with care taken not to include underscore (_) characters in anything other than the NFFSID. Examples are given in Table B.1.

A separate set of data documenting each Performance Study should be created and maintained.

Table B.1 Examples of file and directory names

	Options	Notes
RainScenario	PERFECT	
	FORECAST	
ModelName	PDM	Names to be consistent and standardised
	KW	
Variable	LEVEL	
	FLOW	
FileDataType	FORC	
	OBS	
	SIM	
	META	
	COMMENTS	
TimeStep	15MIN	
	HOUR	

B.3.2 File naming structure and file naming

Observed

Observed river flow and level time-series data files to use the following naming scheme:

NFFSID_Variable_StartDate_EndDate_OBS.csv

For example:

2001_Flow_20010101_20100303_OBS.csv

Time-series data to be in the following column format:

Date, Value

For example:

```
...
19/02/02 22:45, 13.545
19/02/02 23:00, 13.543
19/02/02 23:15, 13.541
19/02/02 23:30, 13.540
19/02/02 23:30, -999.999
...
```

A standard date format should be used within all the files: DD/MM/YY HH:MM. For example:

26/02/02 10:30

Missing values should be entered as -999.999

Simulation

Historical simulation flow and level time-series data files to use the following naming scheme:

NFFSID_Variable_StartDate_EndDate_SIM.csv

For example:

2001_Flow_20010101_20100303_SIM.csv

The contents of this file will use the same format as the observed data.

Forecast

Forecast flow should use the standard naming scheme:

NFFSID_Variable_StartDate_EndDate_RainScenario_TimeStep_FORC.csv

For example:

2001_Flow_20010101_20100303_PERECT_15MIN_FORC.csv

Data to be in the following column format (one forecast per row):

Forecast origin (t_0), Forecast value at t_1, … , Forecast value at t_n

For example:

```
...
26/02/02 10:30,14.622,14.545,14.419,14.253,... ,12.477,12.184,-999.999
25/02/02 16:45,13.400,13.371,13.289,...,12.608,12.380,12.138,11.886
26/02/02 06:15,11.379,11.342...,13.048,12.766,12.477,12.184
...
```

Here the initial data item is the time-origin of the forecast. The first value will then be one model time-step after the time-origin.

Missing values should be entered as -999.999. Forecasts should be padded out to have the same line length in each file – this will act as a quality-control check.

B.3.3 Metadata files

NFFSID.meta

This section is expected to require additions.

The purpose of the metadata file(s) will be to store information about the site that is needed for analyses. It is likely that these data will be split across more than one file. For example, general site data such as location and grid coordinates would be in one file. Data specific to a Performance Study would be in another.

An example of a general site metadata file is:

[Location]

ID = '2001'

River Name= 'Thames'

Location Name= ‘Days Lock’

Northing = 673000

Easting = 450000

Area = 174.3

An example of a study specific file is:

```
[Forecast]
TimeStepMins=15
MaximumForcastLengthMins=1660
ErrorCorrection=0
ARMA=0
WithLevels=1
Type= Forecast Rated
Rainfall Input=Forecast

[Simulation]
Levels=0


[Thresholds and Tolerances]
QMED_level=3.5
QMED_flow=12.6
QMED_2_level=3.1
QMED_2_flow=10.5
```

B.3.4 Additional options:

It should be considered whether additional names should be included in the Forecast and Simulation naming schemes, for example, to indicate WITH/WITHOUT levels or whether ARMA error prediction or state updating is to be used.

Appendix C: Overall Performance Scores and the Performance Summary

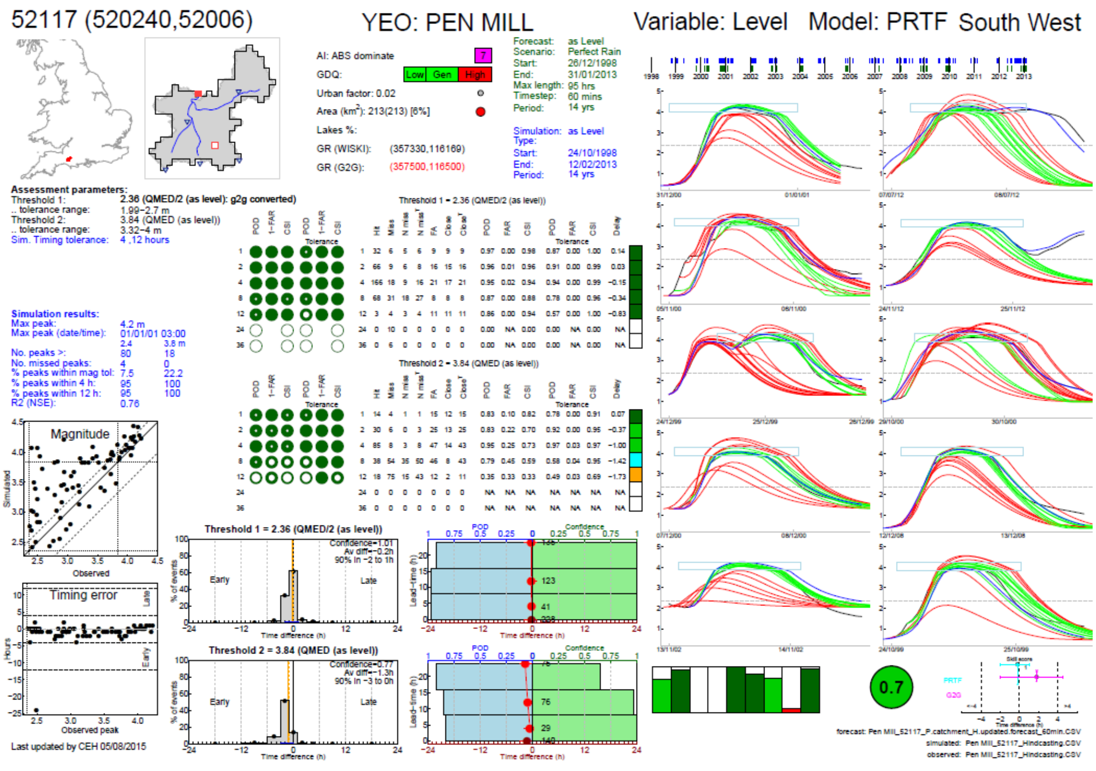
Below are examples of the Performance Summary for particular sites in various regions and using different models, illustrating the behaviour of the component displays when sites are organised by the Overall Performance Score (OPS). These examples are followed by a tabulation of sites with OPS in the lowest 10% for each region so as to highlight sites that may deserve closer inspection.

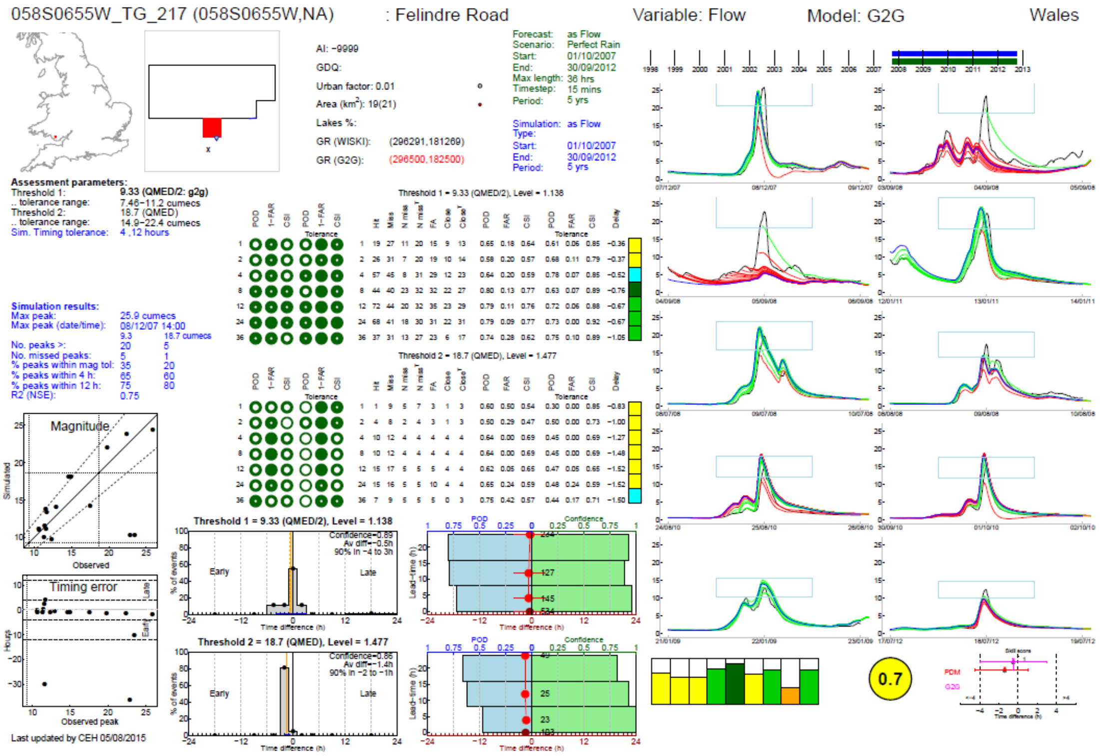
Following from Sections 5.6 and 7.2, the OPS is the average of the six forecast sub-components of the Overall Performance Measure, such that:

$$OPS = \frac{1}{6}\sum_{k=1}^{6} I_k \; .$$

Overall Performance Score = 0.7

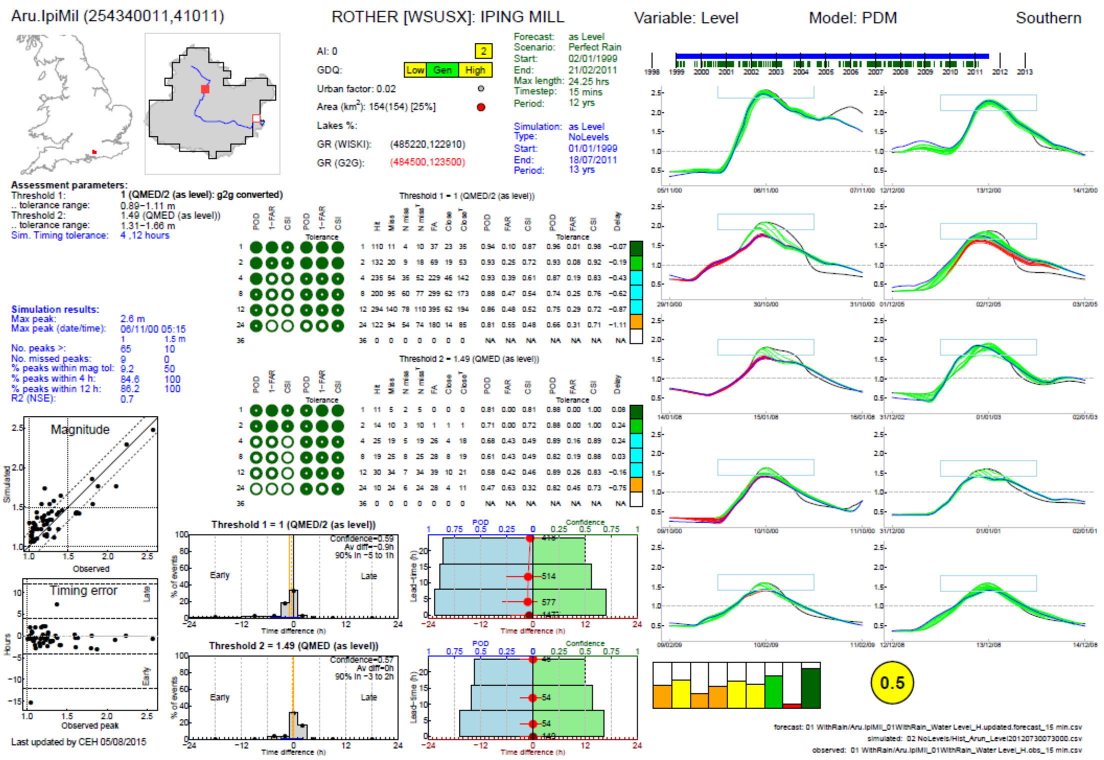
Two examples of a Performance Summary where the OPS = 0.7 are given below.

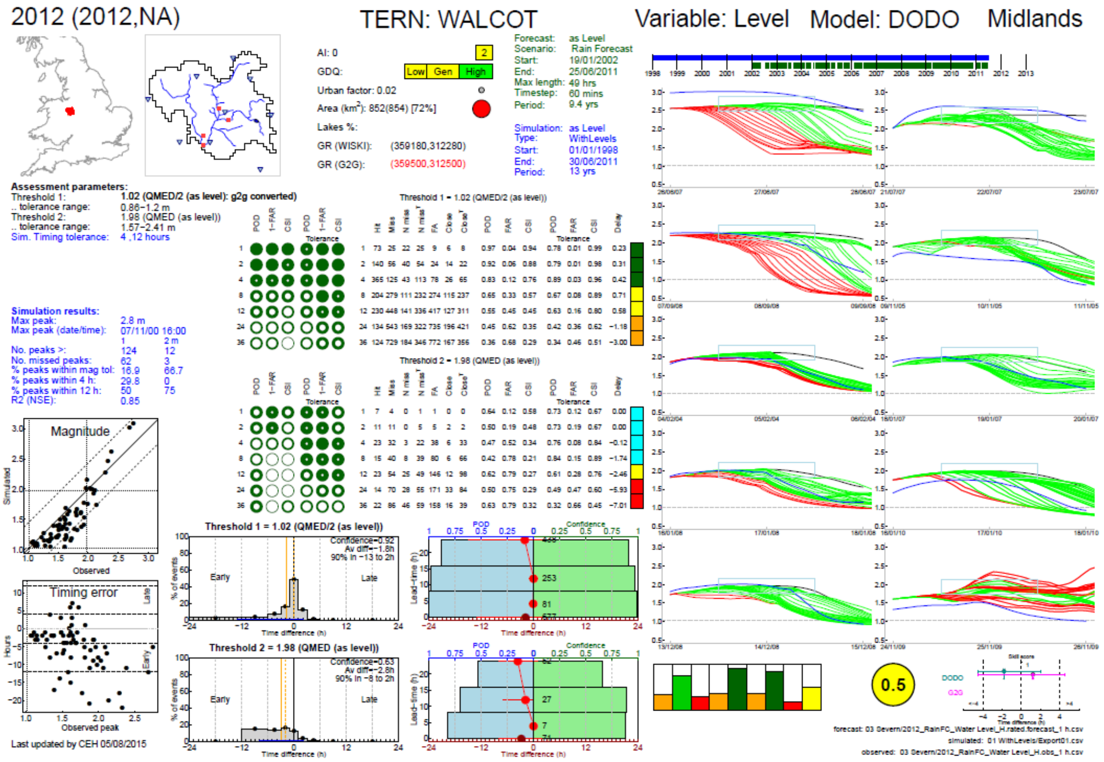




Overall Performance Score = 0.5

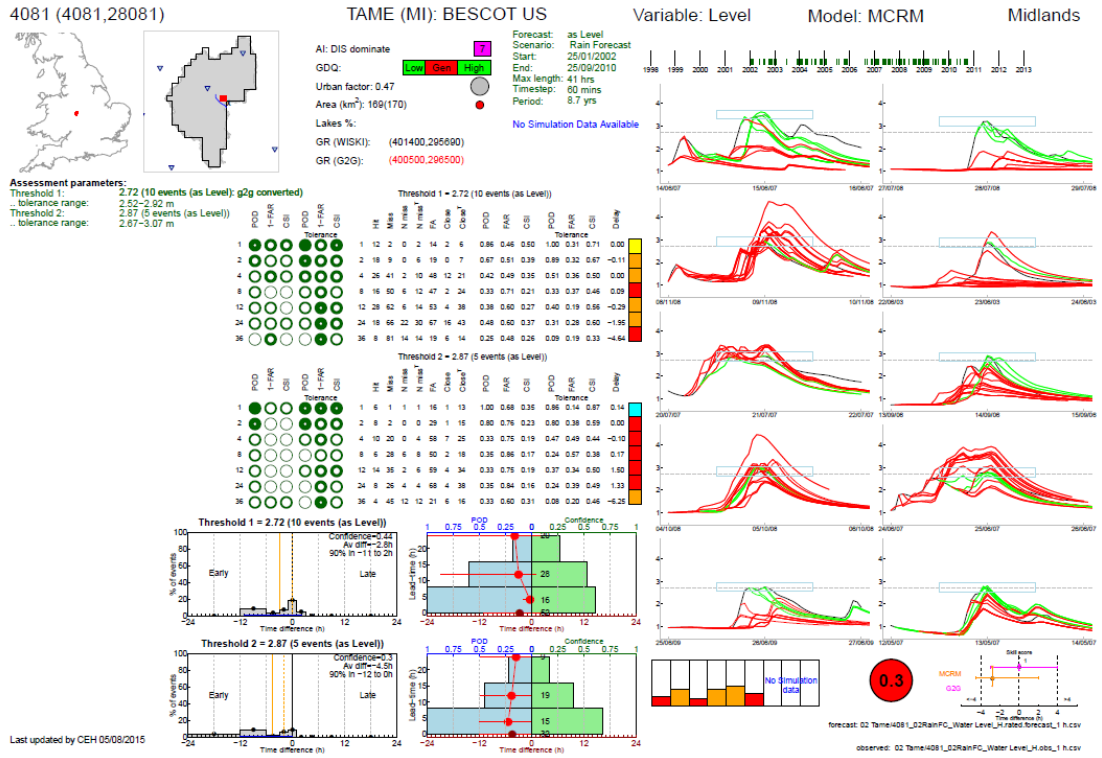
Two examples of a Performance Summary where the OPS = 0.5 are given below.

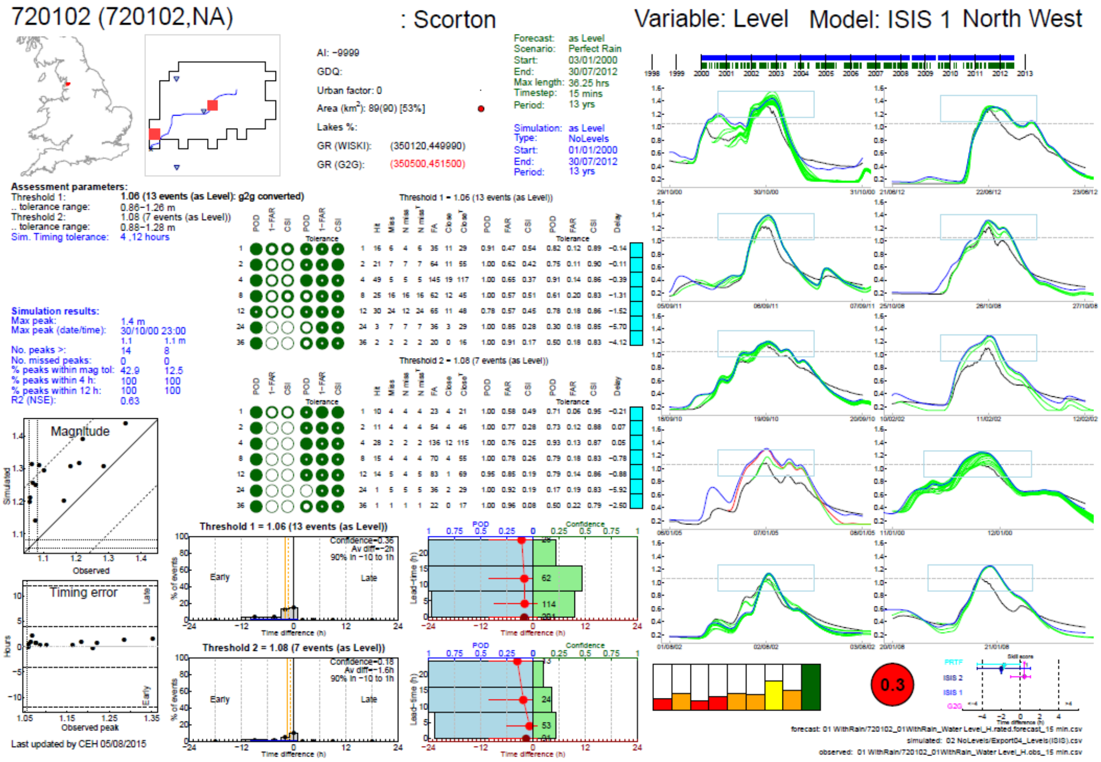




Overall Performance Score = 0.3

Two examples of a Performance Summary where the OPS = 0.3 are given below.





Sites with Overall Performance Score in lowest 10%

Table C.1 lists site models with an OPS among the lowest 10% for each region and which may deserve closer inspection.

Table C.1 Site models with an OPS among the lowest 10% for their region

Anglian

ID	Model	OPS
E22727	ISIS	0.01
E22761	ISIS	0.01
E22744	ISIS	0.02
E21732	ISIS	0.03

North East

ID	Model	OPS
PATLYB1	KW	0.02
BUTTCR1	KW	0.09
Snainton	PDM	0.13
WESTAY1	ISIS	0.14
Snaygill	ISIS	0.21
Hollins_Bridge	ISIS	0.22
STOCKB2	ISIS	0.22
NUNNYKIRK	PDM	0.25
BRADBY5	KW	0.25
PRESTL5	KW	0.26
Rowell_Bridge	ISIS	0.26
Lev_Mill	PDM	0.27
WALDEN1	PDM	0.28
Myton_on_Swale	ISIS	0.28
MaltonA64	ISIS	0.29
Cundy_Cross	ISIS	0.29
MIDDLT5	KW	0.31
Malin_Bridge	KW	0.32

South West

ID	Model	OPS
47119	PRTF	0.05
45209	PRTF	0.19
53136	PRTF	0.27
46135	PRTF	0.28
52111	PRTF	0.29
45159	PRTF	0.32

Southern

ID	Model	OPS
Med.Hendal	PDM	0.04
Aru.Lodsbr	PDM	0.19

North West

ID	Model	OPS
720105	ISIS	0.06
753050	ISIS	0.06
752020	ISIS	0.12
690140	PRTF	0.16
692115	PDM	0.21
692800	PDM	0.21
720120	ISIS 2	0.21
720780	ISIS	0.24
692422	ISIS 1	0.24
720120	ISIS 1	0.25
692830	PDM	0.25
693115	PDM	0.28
720102	ISIS 1	0.30
692190	PDM	0.30

Midlands/Wales

ID	Model	OPS
2216	MCRM	0.02
4086	DODO	0.08
055003_TG 316	ISIS	0.08
2036	DODO	0.09
2083	DODO	0.16
4036	DODO	0.16
2639	MCRM	0.16
4143	MCRM	0.17
2218	DODO	0.18
055SW004	MCRM	0.19
4873	MCRM	0.19
2661	MCRM	0.20
4007	ISIS	0.21
2215	DODO	0.21
4205	MCRM	0.21
4161	MCRM	0.22
055807_TG 320	ISIS	0.23

Thames

ID	Model	OPS
1290TH	TCM	0.10
1100TH	TCM	0.20
1790TH	TCM	0.22

Appendix D: Communications with regional experts on individual sites

Following the production of preliminary results on a site-by-site basis in the form of draft Performance Summary pages, contact was made with the regional experts to query any notable spurious results and request any additional comments that could help improve presentation.

For each site, queries were made:

- where it was suspected there might be a data issue
- where data appeared to be missing
- where there was a question over the correct time-series to use

Since these issues may have affected the quality of the sites for a region, it was felt judicious to gain the insight of the regional experts on this. Draft outputs for each site were provided, along with a detailed overview of the Performance Summary, and comments for each site that were believed to require further discussion.

The following tables present, for each region, the comments sent out to the regional experts, along with their responses (blue) and any actions taken by CEH as a result. Only those sites with queries have been included in the tables; all sites deemed to be satisfactory have been omitted.

ANGLIAN

NOTE: No useable historical simulation data were provided for any sites in Anglian. Following correspondence with JBA, it has been possible to recover historical data associated with the Bedford Ouse and analyse these; however, all other sites in Anglian remain without historical data.

ID	Model	Comments
E21136	MIKE 11	Poor forecasts. Performance is very poor as is a sluice
E21163	MIKE 11	Odd forecast data in flood plots.
E21724	unknown	No model selected: No plot produced. Model has since been recalibrated
E21732	unknown	Poor forecasts
E22511	unknown	Poor forecasts
E22712	ISIS	Poor forecasts. A routing model links two ungauged PDM models that simulate the flow at Hadleigh
E22727	ISIS	Poor forecasts
E22744	ISIS	Poor forecasts
E22761	ISIS	Poor forecasts. Observed data contain some occasional low values which have been excluded.
E22843	ISIS	Poor forecasts. Observed data contain some occasional low values which have been excluded.
E22869	ISIS	Poor forecasts. Observed data contain some occasional low values which have been excluded.
E22889	ISIS	Poor forecasts
E22897	ISIS	Poor forecasts
E24829	PDM	Observed data very messy. Multiple spikes/steps.
E61101	MIKE 11	Poor forecasts. This is a sluice though so model performance is not great

MIDLANDS

ID	Model	Comments
2034, 2039 2067	MCRM, MCRM, DODO	Cap on simulation series: may be due to the validation rules/or upper limits on the ratings as I suspect the historical levels need to pass back through the ratings to be calculated in NFFS.
2165	DODO	Yes this site is heavily influenced by tidal activity and should be excluded from analysis. On the River Severn now (from Worcester and downstream) we use the Lower Severn ISIS model. This was not included in analysis during the 2012 performance measures. Therefore there are other sites which should also be considered for exclusion (or possibly just include a ‘disclaimer’ to say tidal and fluvial influenced sites). These sites are Saxons Lode (2032), Mythe (2087) and Haw Bridge (2057). Excluded from analysis
2169	MCRM	Constant value for simulation. This is a minor site and can be excluded from analysis.
2642	DODO	Poor observed data. Corrupted data. Diglis data can be used as reference. Excluded from analysis
4xxx	Numerous	No simulation data available

NORTH EAST

<table>
<tr><th>ID</th><th>Model</th><th>Comments</th></tr>
<tr><td>ALDWRK2</td><td>ISIS</td><td>Some data spikes were removed from Obs series</td></tr>
<tr><td>BARNSL1</td><td>PDM</td><td>Simulation data looks suspect No obvious reason for this result that I can come up with. The model is quite reasonable in NFFS and the JBA analysis gives it a fairly good performance result. The data feeds to use in the analysis are consistent with other PDM models. For completeness more than anything else I’ve added the current rating (below) and attached the current INP file to my return. Q = a(h+b)^c
ratingCurveEquation (4)
<table>
<tr><th></th><th>lowerLevel</th><th>upperLevel</th><th>flag</th><th>equation</th><th>a</th><th>b</th><th>c</th></tr>
<tr><td>1</td><td>0.03</td><td>0.244</td><td></td><td>Power</td><td>6.57523</td><td>0.068783</td><td>1.93347</td></tr>
<tr><td>2</td><td>0.244</td><td>0.867</td><td></td><td>Power</td><td>19.9483</td><td>-0.037458</td><td>2.12806</td></tr>
<tr><td>3</td><td>0.867</td><td>2.02</td><td></td><td>Power</td><td>0.0005954</td><td>2.68714</td><td>7.9028</td></tr>
<tr><td>4</td><td>2.02</td><td>999.9</td><td>3</td><td>Power</td><td>0.0005954</td><td>2.68714</td><td>7.9028</td></tr>
</table></td></tr>
<tr><td>BEDBRN1</td><td>PDM</td><td>Some PDM forecasts go negative</td></tr>
<tr><td>BORBRG2</td><td>ISIS</td><td>Odd data from original data choice. Changed from 02 NoLevels H.sim to 02 NoLevels Updated (based on JBA usage)
This site is a key forecasting location and we really do need performance statistics for it – and I know that the JBA analysis had results as we expected – good to 8–10 hour lead times.</td></tr>
<tr><td>BROADW1</td><td>PDM</td><td>Some forecasts go negative</td></tr>
<tr><td>CLKHTN1</td><td>ISIS</td><td>Record may be too short for inclusion.
That’s fine – it is a newish model with little history.</td></tr>
<tr><td>COWGRN5</td><td>FIXED FLOW</td><td>Please ignore the model as it is a constant flow model. Model not analysed</td></tr>
<tr><td>Cundy_Cross</td><td>ISIS</td><td>Some constant simulation data.
Due to a minimum flow setting in the ISIS model to keep it stable.</td></tr>
<tr><td>Dalton</td><td>PDM</td><td>Some strange forecasts. We import ultrasonic flow data and run the model and update with that. However a rating curve is used to produce the forecast water level. Significant backwater effects from the Swale compromise the rating and so the model is really of little use. It is not a key forecast location so hasn’t really come up as an issue operationally.</td></tr>
<tr><td>Darfield_Br</td><td>ISIS</td><td>Odd forecasted event. This same issue is apparent at several other sites for the same event. Maybe there is some spurious data that has got into the analysis and then propagated downstream through the Don model network? Event removed</td></tr>
<tr><td>DEWSBY1</td><td>KW</td><td>Some data spikes in observed were removed</td></tr>
<tr><td>DONCST1</td><td>ISIS</td><td>Odd forecasted event. This same issue is apparent at several other sites for the same event. Maybe there is some spurious data that has got into the analysis and then propagated downstream through the Don model network? Event removed</td></tr>
<tr><td>ELVING1</td><td>KW</td><td>Will not be included. That’s fine – significant backwater effects apparent that swamp the rating</td></tr>
<tr><td>FLEETW1</td><td>NO MODEL</td><td>Will not be included. The model has been removed from NFFS</td></tr>
<tr><td>GOUTHW1</td><td>ISIS</td><td>Model looks like constant flow – should it be included? Is this modelled outflow from Gouthwaite Reservoir?
In January 2014 this model was changed from a fixed flow model to a PDM followed by ISIS (routing) that incorporated a</td></tr>
</table>

ID	Model	Comments
		reservoir. We now use the reservoir telemetry to update level and so the forecast output at the telemetry site (Gouthwaite) is from the ISIS model. Our return spreadsheet in Oct specified ISIS output for this location. Remove from analysis
GRASTN1	NO MODEL	Will not be included. That's fine – telemetry has been removed from the location but we are as yet to remove the forecast model from NFFS. It is not used at all however.
HARTBN1	PDM	Some forecasts go negative
HARWOD5	PDM	Some forecasts go negative
HIGHFD1	PDM	Some data spikes removed from Obs series
KEIGHL1	PDM	Some forecasts go negative
Killamarsh	ISIS	Odd forecasted event. This same issue is apparent at several other sites for the same event. Maybe there is some spurious data that has got into the analysis and then propagated downstream through the Don model network? Event removed
KIRKHM1	KW	Significant backwater effects apparent that swamp the rating
Lev_Mill	PDM	Some forecasts go negative
Lev_Station	PDM	Some forecasts go negative
Malin_Bridge	KW	Some forecasts go negative
MaltonA64	ISIS	Simulation somewhat inconsistent Hydraulically complex close to the confluence with the Derwent.
Mexborough_Lock	ISIS	Odd forecasted event. This same issue is apparent at several other sites for the same event. Maybe there is some spurious data that has got into the analysis and then propagated downstream through the Don model network? Event removed
MIDDLT5	KW	Some forecasts go negative
MITFRD1	KW	Some forecasts go negative
MONKTN1	KW	Some forecasts go negative
MOORHS5	PDM	Some forecasts go negative
Morpeth	KW	Some forecasts go negative
NESS001	ISIS	Some strange forecasts. Not sure what happened in the 2005 event. No results or plots of the June 2005 event in the JBA analysis so I presume they stripped it out for some reason? Event removed
RIPON01	ISIS	Some forecasts go negative
ROTHBY1	KW	Some forecasts go negative
RPNURE1	KW	Some forecasts go negative
RUTHBR5	PDM	Some forecasts go negative
Sheffield_Station	KW	Some data spikes removed from Obs series
SKELTN1	KW	Some forecasts go negative
Snainton	PDM	Odd observed data. Possible effect on the rating by backwater effects from the Derwent.
SOWRBY1	KW	Some forecasts go negative
Spr_Gdns_Dam	ISIS	Forecast looks identical to simulation. The Gaunless models have been identified for review as forecast performance through the storage reservoir is poor. The work has not been

ID	Model	Comments
		done however. At the moment, the forecast time series is H.simulated – direct from ISIS model with no updating.
STAVLY1	PDM	Some forecasts go negative
STOKES5	KW	Some forecasts go negative
TADCST1	KW	Some data spikes removed from Obs series
UGLYDB1	~~FIXED FLOW~~ ISIS	Remove. Will not be included. We replaced the fixed flow model early 2014 year and the Ugly Dub forecast is now an output of one of the string of Tyne ISIS models (Tyne3). The forecast flow then goes through the Deltares error correction process to become a Q.updated.forecast and, after the rating, H.rated.forecast.
VIKING1	KW	Some forecasts go negative
WESTAY1	ISIS	Some forecasts go negative
WESTWK1	KW	Some forecasts go negative
Wharncliffe	ISIS	Some forecasts go negative
WHITTN1	KW	Some forecasts go negative
Wincobank	KW	Some forecasts go negative
WOODHS1	ISIS	Strange observed data. Possible source of the problems of the other sites on the Don for the first event. Don't know what is wrong with the Obs data. In NFFS we run by default an ISIS model that NEVER operates any of the regulators. During an event, the MFDO is able to switch ISIS data files and run the forecasts with a version that does have the regulators running to standard rules. However, those rules are not followed by Ops staff, so we are never able to match the forecast with the actual regulator operation. This is a long-running problem and does affect the performance of the Don models. Event removed

NORTH WEST

ID	Model	Comments
681006	PDM	Forecast is very close to observed. This is a state updated PDM. When the original performance testing was carried out, NFFS was configured to supply the PDM with observed flows up to T+24 hours. In real-time, observed flow will not exist beyond time-now, so this minor slip was never noticed. However JBA carry out performance testing using an NFFS with observed data throughout the period, so the Congleton PDM will unfortunately appear as perfect out to 24 hours as the observed flows are available and therefore applied to the model. This has been corrected in the current configuration, so will not be a problem in future performance tests. Site removed
690140	PRTF	No simulation data
690140	PDM	No simulation data
690140	UNKNOWN	No model picked – won't be used
690207	PRTF	No simulated data
690510	UNKNOWN	No model picked – won't be used
692119	PRTF	Forecasts do not start from simulated or from observed**.** These datasets are not as expected. Looking at the forecast traces, although the forecasts do not start from the simulated or observed, the shape of where they start from is very similar to the observed trace. In this ISIS model location, a minimum level of 0.43 m is applied, which isn't apparent in these traces. There was a datum change at site in June/July 2011 of around 40 cm (new datum is lower), which might explain the offset. However, the issue seems to exist in the traces both before and after this date. Site removed
692190	ISIS1	The inflows for this ISIS model were PRTF at the time the performance testing was done. The inflows have now been replaced by PDMs. The odd dips in the simulated traces are due to the way the PRTF inflows updated themselves when a new historical simulation was run. This won't have affected the forecast traces (as can be seen).
692422	PRTF	Forecasts do not always start from simulated or from observed. This model is ISIS with ARMA updating, also with a minimum flow applied. The explanation is probably similar as for Brinskway (692524) below. Site removed anyway as PRTF
692524	PRTF	Forecasts do not always start from simulated or from observed. A minimum flow is applied at this location to ensure ISIS model stability. For the simulated this equates to around 1.1m and for the updated equates to around 1m. I would therefore expect forecasts to start from the observed only when levels are higher than this. I'm not entirely sure why there is inconsistent behaviour though. Site removed anyway as PRTF
693132	UNKNOWN	No model picked – no plot produced
694039	ISIS	No simulation data
694041	ISIS	Appears to be tidal. Will not be included in analyses
694042	ISIS1 (rated)	Are data as expected – forecast does not start at either obs or simulated? This forecast series is rated ISIS flow, and is not updated, so I would not expect it to tie in with observed levels. The historical time series selected was the 'no levels' one, to look at the base performance of the model. There is only one forecast

ID	Model	Comments
		time series, which I assume was run 'with levels'. Therefore I can see that there could be a mismatch between the historical and forecast.
694042	ISIS 2 (Simulated)	The upstream inflows for this model are the Causey Bridge PDM (694039) and a couple of smaller ungauged PDMs. The Causey Bridge PDM was configured to use observed flow until T+24 hours (similar to Congleton Park), so it is probable that the forecasts are looking so consistent and good because the model is more or less using observed upstream flows as inputs throughout the forecast period. Site removed.
700309	PDM	Curious simulation which affects forecasts for 1 event. These two locations are only a few miles apart on the same river. The forecasts that look suspect are 16 and 20 January 2008. As the forecasts are run with perfect rainfall and the locations are close to each other, I suspect some dodgy raingauge data may have crept in, affecting the forecasts at both sites. I have had a quick look through WISKI and haven't been able to pin-point a raingauge with issues at this time, but as we run with a raingauge catchment average rather than specific raingauge weightings, it could be any raingauge in the region. Events removed.
700311	PDM	
710301	ISIS	Simulation data look wrong. The bottom of the PDF indicates that this is forecast information for the PRTF, mixed with historical information for the ISIS. I agree that the historical looks wrong. As we have recently had the whole ISIS cascade re-done and re-tested, I suggest that this location is removed for the local performance assessments at the moment. Remove site from analysis.
713120	PDM	Simulation is same as observed? This is a state updated PDM. When the original performance testing was carried out, NFFS was configured to supply the PDM with observed flows up to T+24 hours. In real-time, observed flow will not exist beyond time-now, so this minor slip was never noticed. However JBA carry out performance testing using an NFFS with observed data throughout the period, so the Ewood PDM will unfortunately appear as perfect out to 24 hours as the observed flows are available and therefore applied to the model. This has been corrected in the current configuration, so will not be a problem in future performance tests. Remove site from analysis.
720102	PRTF	No simulation data
720105	ISIS	Simulation and Forecasts look truncated? Output limited as no peaks are ever forecast to be above thresholds. The observed trace should be from gauge 720150 (Garstang Intake Weir) not 720105 (Garstang Upstream Gate). The first gauge is just downstream of a flood basin, while the latter is inside it. The ISIS model location is just downstream of the basin and simulates the action of the gates being operated according to the rules used by field staff and hence the hydrograph is truncated as the flood basin begins to fill. The key operational threshold here is 2.31m. Perhaps in this case, this would be a more suitable assessment level, rather than a converted QMed?
720517	ISIS 2	Forecasts don't always appear to tie in with simulation – are the datasets correct? For 11 December 2006 event, data from the upstream site of A6 Brock Upstream (720215) appear to be dubious around the event peak. The ISIS1 time-series is ARMA

ID	Model	Comments
		updated at St Michaels (720517) itself, which would have mainly removed the effect of Brock Upstream A6 being too low. However the problem at the upstream gauge would have propagated through in the simulated forecast time-series (ISIS2). As the historical simulation would have been run with no observed levels anywhere, the gauge problems again would not have been an issue. So, I think the suspect data upstream is the cause of the disparity in this case. Remove event
720780	ISIS	Poor observed data. This is a pumped catchment and the model attempts to replicate the action of the pumps. The observed data are therefore 'good', even though they look a mess. The model is poor as the pumping rules are not captured very effectively. This needs to remain in as a forecast location to ensure the poor model performance is captured.
722421	ISIS1	Two sets of thresholds in threshold file. Use 2.34m. As discussed, this is due to the use of different ratings as models for the same site are updated at different times.
722421	ISIS 1	Two sets of thresholds in threshold file. Use 2.34m. As discussed, this is due to the use of different ratings as models for the same site are updated at different times.
724320	PDM	Some strange looking observed data in 2006. The 'events' in early March 2006 do not look real. The gauge was relatively new at this time and wasn't being formally QA'ed so the data are not marked as either good or suspect in WISKI. Looking at a downstream site though, there are no peaks apparent on these dates, so please disregard these events.
724528	PDM	No simulated data
724735	ISIS	Looks tidal. This site will be removed
724836	PDM	Forecasts extremely tight and almost identical to observed – is this correct? This is a state updated PDM. When the original performance testing was carried out, NFFS was configured to supply the PDM with observed flows up to T+24 hours. In real-time, observed flow will not exist beyond time-now, so this minor slip was never noticed. However JBA carry out performance testing using an NFFS with observed data throughout the period, so the Galgate PDM will unfortunately appear as perfect out to 24 hours as the observed flows are available and therefore applied to the model. Remove site from analysis.
725139	ISIS	Looks tidal. This site will be removed This is a flat area which suffers tide locking. The main risk is when tides are high, preventing river outflow.
744312	ISIS	Several forecasts identical to simulation run. The upstream inflow of this ISIS model is a PDM at Egremont. The Egremont gauge was only installed in 2004. The events that have identical simulated and forecast traces at Braystones (744312) are all pre-2004. Without observed data to state-update the PDM, the historical simulation and forecast simulation with perfect rain should be the same. It's possibly not ideal for assessing the performance of the model consistently as some forecasts are affected by state-updating and others aren't. Remove data pre 2004?
750504	PDM	No simulated data
750806	PRTF	No simulation data

ID	Model	Comments
751612	ISIS 2	Forecast appears identical to simulation. Remove site from analysis.
764009		Site decommissioned – no plot produced
Various	PDM	No simulation data for 760101, 760112, 760502, 761104, 761706, 763308, 764010, 764050, 765512, 765850

SOUTH WEST

ID	Model	Comments
44139	PDM	Restrict performance review between 4 November 2007 and 5 September 2012 due to concerns about hydrometric data quality outside of this period: 2005 to 2006 – minimum river levels are routinely below 0.5m and appear inconsistent with minimum river levels in the period 18 November 2007 to 5 September 2012. 2007 – Bridport North Mills – suspect data prior to 18 November 2007 with large data spikes/dropouts. Step change in minimum river levels from <0.5m to >0.5m between 18 November 2007 and 28 November 2007. Baseflows after 18 November 2007 did not drop below 0.5m. 2012 – Bridport North Mills – good data prior to 5 September 2012 Suspect data removed. Site visit on 5 February 2013 found the gauge board reading was 0.695m and logger 0.779m. PTx buried in silt. Ticket in to Ops for silt removal at site. Flow record also affected. 2014 – Bridport North Mills. Level sensor is buried in silt, gauge unable to calculate level and flow accurately. All the data are currently unvalidated. The customer should exercise caution when using the data, particularly in the low flow range.

SOUTHERN

ID	Model	Comments
3240TH	ARMA TCM	No overlap between forecast and simulation series
Aru.Alfold	PDM	All level forecasts are produced by an ISIS model, simulated and updated flows are produced by the PDM. We recommend that any testing is carried out on the flow outputs from the PDM. Using PDM forecast updated and PDM 02 Nolevels H.Rat from Princes Marsh
Aru.Lodsbr	PDM	Forecasts do not start at either simulation or observed series. Using Princes Marsh instead but some forecasts still not starting in simulation or observed.
Aru.Tanbri	PDM	Observed data for the top flood peak plot look suspicious. This error is replicated in our hydrometric archive, possibly gauge error. Poor event removed
Dar.Hawley	ISIS	Some strange data. The model at Hawley is known to significantly overforecast, we are currently running a project to improve the outputs. Site removed
Dar.Otford	N/A	Model is being rebuilt. Site removed
Dar.PaFarm	PDM	As with Hawley, this site has serious problems with the forecast which we are aiming to improve with the Darent Model Improvements project. Site removed

ID	Model	Comments
Dar.Wester	PDM	As with Hawley, this site has serious problems with the forecast which we are aiming to improve with the Darent Model Improvements project. Site removed
IWS.BembRiver	ISIS	Appears to be tidal. Site removed
Med.Darman	ISIS	Observed data too poor. Site removed
Med.Edenbr	PDM	Forecast identical to simulated (except 2008 to 2009). No error correction and no forecast rain. Difficult catchment regarding rainfall quality may explain discrepancy.
Med.EstFar.Dns	ISIS	Forecast identical to simulated. Some forecasts do not start on observed. Forecasts on this network take a historical run with error correction at the upstream boundaries (but not at this site) as starting point.
Med.Hendal	PDM	Forecasts look pretty bad for some flood peaks. Poor simulation data. Observed data from forecasts used. PDM has large soil store and since been recalibrated but not input to NFFS. After dry periods, possible to absorb most of rain without generating runoff. Site affected by rainfall data issues.
Med.Lamber	PDM	Poor observed data. Site removed
Med.LiMill	ISIS	Poor event removed
Med.Pens	ISIS	Low flow site which we don't use for flood warning purposes. Site removed.
Med.Smurf	ISIS	Tidal site – Site removed
Med.TownL	ISIS	Observed data are too noisy and spiky to be used (Town Lock). Site will not be analysed. Site removed
Med.Vexour	PDM	Simulation series very poor. Model and rating are being rebuilt by JBA as part of Medway model improvements. Site removed
Med.Yaldin.Dns	ISIS	Poor event removed

THAMES

ID	Model	Comments
1201TH_T	ISIS	The peak on 29 May 2008 should be removed the level recorder had problems throughout this period and the data are not accurate.
1290TH	TCM	Choice of observed data. Q.merged should be the default option in the Thames NFFS config whenever it is available. Where special arrangements have been made (for example, hybrid or switchover ratings) the different elements are brought together by the merging process and this should be therefore be the default for forecasting purposes. At this site Q.rated represents in channel flow, there is extensive bypassing of the gauging station via a wide floodplain, Q.merged represents total flow that includes an estimate of bypassing.
1420TH	TCM (old)	Will not be analysed
1460_w1TH	TCM (old)	Will not be analysed
1465TH	ISIS (old)	Will not be analysed
1489TH	ISIS	This site has a history of poor data quality, more recent data are considered more reliable after equipment upgrades have been made. Lower order events can be complicated by gate operations nearby.

ID	Model	Comments
1490TH	ISIS (old)	Will not be analysed
1491TH	ISIS (old)	Will not be analysed
1501TH_T	ISIS (old)	Will not be analysed
1503TH_T	ISIS (old)	Will not be analysed
1799TH_T	ISIS	Some noisy observed data.
2210TH	TCM (old)	Will not be analysed
2700TH	ISIS	Flat flood peaks. ISIS is the default model at this location now, but there is also a TCM. No simulated flows from ISIS as detailed performance analysis has not been conducted. Could either use the TCM or probably preferable not to conduct analysis here. Will not be analysed
3804TH	PDM	Flat forecast levels are due to zero rainfall; of the 2 raingauges that served this model one was decommissioned in April 2011 and the other in April 2012. They were temporary closures but the situation still persists. We will be updating our config to use different gauges for this model.
3815TH	PDM	Observed data between November 2001 and November 2003 considered unreliable and should be disregarded. Unsure of the cause – could have been blockage or instrumentation error.
3823TH	PDM	Odd observed levels are due to trash screen blockage (and subsequent clearance) at the site. 10 March 2001 was caused by a sensor problem and should be disregarded.
3838TH		No model selected – no plot produced.
3839TH	ISIS	Offset between simulation and forecast. There is a minimum flow specified in the model to aid stability (2.5 cumecs).

Appendix E: Sites omitted from the analysis of model performance

The table below lists the sites omitted from the analysis of flood forecasting model performance, arranged by region and including a commentary on the reason for a site's omission. In some cases the reasoning was complex; further information is given in Appendix D on communications with regional experts on individual sites.

NFFS ID	Site name	Region	Model	Reason for omission
E21136	Hemingford	Anglian	MIKE 11	Severe abstraction
E61101	St Neots	Anglian	MIKE 11	Severe abstraction
E22511	Sturmer	Anglian	PDM	Poor data
E24829	Riseley	Anglian	PDM	Poor observed data
E21724	Linton	Anglian	Unknown	Old model
2165	Gloucester	Midlands	DODO	Tidal
2642	Worcester	Midlands	DODO	Poor/corrupted data
2169	Ludlow (Corve)	Midlands	MCRM	Poor data. Minor site.
COWGRN5	Cow Green Reservoir	North East	Fixed Flow	Constant flow model
CLKHTN1	Cleckheaton Thornton St	North East	ISIS	Too short a record
GOUTHW1	Gouthwaite	North East	ISIS	Old model
UGLYDB1	Ugly Dub	North East	ISIS	Old model
ELVING1	Elvington Sluices	North East	KW	Severe abstraction
KIRKHM1	Kirkham Sluices	North East	KW	Severe abstraction
FLEETW1	Fleet Weir, Leeds	North East	Unknown	Old model
GRASTN1	Grassington	North East	Unknown	Old model
681003	Hug Bridge	North West	PRTF – not used	Old model
681006	Congleton Park	North West	PRTF – not used	Old model
681210	Rudheath	North West	PRTF – not used	Old model
684027	Bridge Trafford	North West	PRTF – not used	Old model
685519	Great Culvert Entrance	North West	PRTF – not used	Old model
690150	Stubbins	North West	PRTF – not used	Old model
690160	Bury Grounds	North West	PRTF – not used	Old model
690203	Rochdale	North West	PRTF – not used	Old model
690205	Blackford Bridge	North West	PRTF – not used	Old model
690408	Farnworth	North West	PRTF – not used	Old model
690510	Manch Racecourse	North West	PRTF – not used	Old model
692115	Lancashire Chemical Works	North West	PRTF – not used	Old model
692418	Uppermill	North West	PRTF – not used	Old model
692825	Brighton Grove Debris Screen	North West	PRTF – not used	Old model
692830	Cringle Brook	North West	PRTF – not used	Old model
693115	Northern Moor	North West	PRTF – not used	Old model
693333	Stanneylands	North West	PRTF – not used	Old model

NFFS ID	Site name	Region	Model	Reason for omission
693421	Old Mill Lane	North West	PRTF – not used	Old model
694039	Causey Bridges	North West	PRTF – not used	Old model
694744	Kirkby	North West	PRTF – not used	Old model
700325	Wigan	North West	PRTF – not used	Old model
700408	Croston	North West	PRTF – not used	Old model
712052	Oxford Road	North West	PRTF – not used	Old model
712153	Reedyford	North West	PRTF – not used	Old model
713056	New Jumbles Rock	North West	PRTF – not used	Old model
720101	Abbeystead	North West	PRTF – not used	Old model
720105	Garstang FCS	North West	PRTF – not used	Old model
724629	Caton	North West	PRTF – not used	Old model
724836	Galgate	North West	PRTF – not used	Old model
730203	Sprint Mill	North West	PRTF – not used	Old model
730507	Victoria Bridge	North West	PRTF – not used	Old model
744130	Egremont	North West	PRTF – not used	Old model
751613	Southwaite Bridge	North West	PRTF – not used	Old model
765013	Cummersdale	North West	PRTF – not used	Old model
681006	Congleton Park	North West	PDM	Old model
692119	Woolley Bridge Gates	North West	ISIS 1	Poor data
694041	Liverpool Road	North West	ISIS	Tidal
694042	Higham Avenue	North West	ISIS 2	See comments table
710301	Low Moor	North West	ISIS	Old model
713120	Ewood Blackburn	North West	PDM	Old model
724735	Lancaster Quay	North West	ISIS	Tidal
724836	Galgate	North West	PDM	Old model
725139	Pilling (Broadfleet Br)	North West	ISIS	Tidal
751612	Scalehill	North West	ISIS 2	Poor data
764009	Harraby Green	North West	Unknown	Site decommissioned
764009	Harraby Green	North West	PDM	Site decommissioned
764009	Harraby Green	North West	PRTF	Site decommissioned
690140	Irwell Vale	North West	ISIS	Old model
690510	Manch Racecourse	North West	ISIS	Old model
690150	Stubbins	North West	ISIS	Old model
690203	Rochdale	North West	ISIS	Old model
690207	Albert Royds Bridge	North West	ISIS	Old model
690160	Bury Grounds	North West	PDM	No forecast
690205	Blackford Bridge	North West	PDM	No forecast
690408	Farnworth	North West	ISIS	Old model
692119	Woolley Bridge Gates	North West	ISIS 2	No forecast
692190	Compstall	North West	ISIS	No forecast
692370	Marple Bridge	North West	ISIS 2	No forecast
692422	Broomstairs Bridge	North West	ISIS 2	No forecast
692524	Brinksway	North West	ISIS 2	No forecast
713019	Samlesbury Pgs	North West	ISIS	No forecast

NFFS ID	Site name	Region	Model	Reason for omission
713056	New Jumbles Rock	North West	ISIS	No forecast
693132	Partington	North West	ISIS	No forecast
690611	Collyhurst Weir	North West	PDM	No forecast
690713	London Road	North West	PDM	No forecast
692330	Taxal	North West	PDM	No forecast
692366	Watford Bridge	North West	PDM	No forecast
692423	Portwood	North West	PDM	No forecast
692727	Flixton Bridge	North West	PDM	No forecast
693031	Little Woolden Hall	North West	PDM	No forecast
693515	Bollington Mill	North West	PDM	No forecast
711610	Hodder Place	North West	PDM	No forecast
710151	Locks Weir	North West	PDM	No forecast
692800	Mauldeth Road	North West	PDM	No forecast
Dar.PaFarm	Park Farm	Southern	ISIS	Old model
IWS.BembRiver	Bembridge Gs	Southern	ISIS	Tidal
Med.Darman	Darmans Bridge	Southern	ISIS	Poor observed data
Med.Pens	Penshurst	Southern	ISIS	Low flow site: not used
Med.Smurf	Smurfit	Southern	ISIS	Tidal
Med.TownL	Town Lock	Southern	ISIS	Poor observed data
Dar.Hawley	HAWLEY	Southern	PDM	Old model
Dar.PaFarm	PARK FARM	Southern	PDM	Old model
Dar.Wester	WESTERHAM GS	Southern	PDM	Old model
Med.Lamber	Lamberhurst	Southern	PDM	Poor observed data
Med.Vexour	Vexour Bridge	Southern	PDM	Old model
Dar.Otford	Otford	Southern	Unknown	Old model
2700TH	Windsor	Thames	ISIS	No performance analysis
1465TH	Thrupp	Thames	ISIS (old)	Old model
1490TH	Oxford G.Stn	Thames	ISIS (old)	Old model
1491TH	Kings Mill	Thames	ISIS (old)	Old model
1501TH_T	Iffley Lock (Tail)	Thames	ISIS (old)	Old model
1503TH_T	Abingdon Lock (Tail)	Thames	ISIS (old)	Old model
1420TH	BANBURY G.STN	Thames	TCM (old)	Old model
1460_w1TH	Enslow Weir A	Thames	TCM (old)	Old model
2210TH	Marlborough G.Stn	Thames	TCM (old)	Old model
3838TH	Kenton Lane	Thames	Unknown	Old model

Appendix F: Model information and Overall Performance Measure

This appendix collates, in table form for each region, the following site information:

- Site ID
- Model type
- Catchment area (km^2) [if known]
- Interval of time (minutes) between successive data points in time-series/forecast
- Rainfall scenario (P = Perfect Rainfall, F = Forecast Rainfall)
- Length of record in years
- Measurement variable: flow, level or mixed (forecast level + simulation flow or vice versa)
- Overall Performance Score
- T_l Flow: lower threshold as flow ($m^{-3}s^{-1}$) [if known]
- T_l Level: lower threshold as level (m) [if known]
- T_l 2h: colour-coded skill performance grade combining POD and FAR scores as described in Table 6.1, for a 2-hour lead-time with lower threshold
- T_l 12h: colour-coded skill performance grade combining POD and FAR scores as described in Table 6.1, for a 12-hour lead-time with lower threshold
- T_u Flow: upper threshold as flow ($m^{-3}s^{-1}$) [if known]
- T_u Level: upper threshold as level (m) [if known]
- T_u 2h: colour-coded skill performance grade combining POD and FAR scores as described in Table 6.1, for a 2-hour lead time with upper threshold
- T_u 12h: colour-coded skill performance grade combining POD and FAR scores as described in Table 6.1, for a 12-hour lead-time with upper threshold

In the tables, NA indicates ‘not available’.

ANGLIAN

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
E19023	KW	NA	15	P	5.38	Level	0.57	9.22	26.64998			18.45	26.92311		
E21042	MIKE 11	91	15	P	12.56	Level	0.40	12.78	1.398			25.56	1.511		
E21163	MIKE 11	NA	15	P	13.97	Level	0.16	NA	8.1475			NA	8.1935		
E21187	PDM	76	15	P	12.47	Level	0.31	6.78	1.1175			13.55	1.3945		
E21227	ISIS	287	15	P	6.43	Level	0.38	15.98	1.35			31.95	1.6065		
E21270	MIKE 11	NA	15	P	12.84	Level	0.33	NA	44.666			NA	44.7915		
E21324	PDM	NA	15	P	12.40	Level	0.40	NA	1.2605			NA	1.5235		
E21445	MIKE 11	534	15	P	12.56	Level	0.45	40.52	1.2655			81.04	1.3375		
E21449	MIKE 11	NA	15	P	12.56	Level	0.51	40.52	54.5675			81.04	54.621		
E21505	KW	146	15	P	12.56	Level	0.45	15.33	1.064			30.65	1.607		
E21609	MIKE 11	978	15	P	13.97	Level	0.15	61.08	0.5925			122.15	0.7075		
E21647	KW	291	15	P	12.40	Level	0.60	11.29	0.779			22.59	1.189		
E21657	MIKE 11	1113	15	P	13.97	Level	0.14	46.53	1.056			93.05	1.547		
E21732	ISIS	NA	15	P	13.10	Level	0.03	NA	8.527			NA	8.718		
E21747	MIKE 11	NA	15	P	13.97	Level	0.15	NA	3.9045			NA	4.0065		
E21862	KW	79	15	P	12.40	Level	0.47	7.91	1.841379			15.81	2.525281		
E21987	PDM	31	15	P	10.83	Level	0.41	5.64	1.423			11.28	1.5905		
E22088	MIKE 11	NA	15	P	10.47	Level	0.37	NA	60.9275			NA	61.0275		
E22344	PDM	41	15	P	12.40	Level	0.56	1.88	0.262			3.75	0.41		
E22351	PDM	71	15	P	12.40	Level	0.49	5.65	0.751			11.30	1.019		
E22518	PDM	21	15	P	6.12	Mixed	0.41	4.10	NA			5.79	NA		
E22539	ISIS	137	15	P	6.43	Level	0.27	8.30	1.303			16.60	1.464		
E22678	ISIS	344	15	P	1.06	Level	0.43	12.82	1.0405			25.65	1.3335		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
E22712	ISIS	82	15	P	6.86	Mixed	0.31	7.69	NA			8.93	NA		
E22727	ISIS	44	15	P	16.11	Level	0.01	5.40	44.58			10.80	44.7095		
E22744	ISIS	106	15	P	16.20	Level	0.02	12.95	26.5185			25.90	26.615		
E22761	ISIS	154	15	P	16.20	Level	0.01	6.18	9.7895			12.35	9.958		
E22843	ISIS	52	15	P	12.16	Level	0.10	4.07	53.2675			8.14	53.371		
E22869	ISIS	128	15	P	16.87	Level	0.10	7.10	23.8905			14.20	23.9495		
E22889	ISIS	169	15	P	18.00	Level	0.15	16.48	25.2435			32.95	25.4155		
E22897	ISIS	57	15	P	15.35	Level	0.04	6.61	20.6465			13.21	20.7975		
E23726	PDM	NA	15	P	12.56	Level	0.46	NA	102.3815			NA	102.5185		
E24267	MIKE 11	NA	15	P	12.61	Level	0.05	NA	5.979			NA	6.0295		
E24451	MIKE 11	NA	15	P	13.97	Level	0.37	NA	38.6585			NA	38.9025		
E60701	MIKE 11	NA	15	P	12.56	Level	0.16	NA	65.038			NA	65.1785		
E1245	PDM	29	15	P	12.24	Mixed	0.51	1.66	NA			3.33	NA		
E1657	PDM	12	15	P	12.28	Mixed	0.45	0.46	NA			0.91	NA		
E1839	PDM	19	15	P	10.43	Mixed	0.62	1.29	NA			2.59	NA		
E19862	PDM	244	15	P	8.39	Mixed	0.37	7.90	NA			15.80	NA		
E22727	ISIS	44	15	P	7.42	Mixed	0.63	7.53	NA			8.53	NA		
E22744	ISIS	106	15	P	8.54	Mixed	0.69	8.43	NA			10.35	NA		
E22889	ISIS	169	15	P	12.38	Mixed	0.79	16.48	NA			32.95	NA		
E23073	PDM	NA	15	P	9.54	Mixed	0.38	14.88	NA			19.06	NA		
E2862	PDM	47	15	P	7.42	Mixed	0.36	4.51	NA			5.84	NA		
E2901	PDM	123	15	P	7.43	Mixed	0.44	8.50	NA			17.00	NA		
E4222	PDM	17	15	P	12.26	Mixed	0.51	2.46	NA			4.93	NA		
E1013	G2G	32	15	P	5.00	Flow	0.46	1.35	NA			1.65	NA		
E1056	G2G	38	15	P	5.00	Flow	0.37	2.07	NA			2.44	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
E1147	G2G	24	15	P	5.00	Flow	0.34	1.09	NA			2.18	NA		
E1163	G2G	9	15	P	5.00	Flow	0.24	0.33	NA			0.65	NA		
E1228	G2G	10	15	P	5.00	Flow	0.43	1.16	NA			1.84	NA		
E1491	G2G	11	15	P	5.00	Flow	0.25	2.19	NA			2.97	NA		
E1533	G2G	61	15	P	5.00	Flow	0.39	3.90	NA			5.34	NA		
E1652	G2G	21	15	P	5.00	Flow	0.30	2.91	NA			4.61	NA		
E1660	G2G	134	15	P	5.00	Flow	0.33	11.15	NA			22.29	NA		
E1742	G2G	18	15	P	5.00	Flow	0.44	1.52	NA			1.76	NA		
E1750	G2G	21	15	P	5.00	Flow	0.18	0.92	NA			1.84	NA		
E1759	G2G	21	15	P	5.00	Flow	0.40	2.31	NA			3.00	NA		
E1788	G2G	44	15	P	5.00	Flow	0.55	4.07	NA			6.08	NA		
E19862	G2G	244	15	P	4.00	Flow	0.23	12.40	NA			14.60	NA		
E2097	G2G	27	15	P	4.86	Flow	0.35	4.80	NA			4.96	NA		
E21005	G2G	44	15	P	5.00	Flow	0.40	2.85	NA			3.28	NA		
E21058	G2G	13	15	P	5.00	Flow	0.04	2.65	NA			3.48	NA		
E21187	G2G	76	15	P	5.00	Flow	0.34	7.59	NA			11.17	NA		
E21408	G2G	41	15	P	5.00	Flow	0.15	9.42	NA			11.20	NA		
E21505	G2G	146	15	P	5.00	Flow	0.30	23.85	NA			29.60	NA		
E21511	G2G	187	15	P	5.00	Flow	0.37	15.55	NA			18.99	NA		
E21647	G2G	291	15	P	5.00	Flow	0.58	17.36	NA			20.37	NA		
E21657	G2G	1113	15	P	5.00	Flow	0.21	54.00	NA			73.05	NA		
E21713	G2G	123	15	P	4.79	Flow	0.02	33.55	NA			46.35	NA		
E21724	G2G	31	15	P	5.00	Flow	0.44	2.46	NA			4.91	NA		
E21737	G2G	101	15	P	5.00	Flow	0.30	4.85	NA			6.58	NA		
E21778	G2G	80	15	P	5.00	Flow	0.37	5.06	NA			6.46	NA		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
E21987	G2G	31	15	P	5.00	Flow	0.03	6.59	NA			9.43	NA		
E22041	G2G	49	15	P	5.00	Flow	0.31	2.30	NA			2.87	NA		
E22137	G2G	62	15	P	5.00	Flow	0.44	3.27	NA			4.56	NA		
E22344	G2G	41	15	P	5.00	Flow	0.49	2.61	NA			3.35	NA		
E22351	G2G	71	15	P	5.00	Flow	0.43	5.98	NA			7.99	NA		
E22511	G2G	19	15	P	5.00	Flow	0.23	4.69	NA			7.14	NA		
E22518	G2G	21	15	P	5.00	Flow	0.27	3.09	NA			6.18	NA		
E22548	G2G	57	15	P	5.00	Flow	0.40	6.41	NA			8.25	NA		
E22563	G2G	31	15	P	5.00	Flow	0.28	2.93	NA			3.88	NA		
E22697	G2G	23	15	P	5.00	Flow	0.25	2.30	NA			4.00	NA		
E22720	G2G	96	15	P	5.00	Flow	0.45	5.41	NA			10.82	NA		
E22727	G2G	44	15	P	5.00	Flow	0.03	7.48	NA			8.53	NA		
E22744	G2G	106	15	P	5.00	Flow	0.16	9.48	NA			13.70	NA		
E22761	G2G	154	15	P	5.00	Flow	0.33	8.35	NA			11.05	NA		
E22832	G2G	30	15	P	5.00	Flow	0.63	2.46	NA			4.25	NA		
E22843	G2G	52	15	P	5.00	Flow	0.53	5.27	NA			7.64	NA		
E2285	G2G	59	15	P	5.00	Flow	0.32	8.08	NA			11.82	NA		
E22862	G2G	90	15	P	5.00	Flow	0.38	9.99	NA			15.65	NA		
E22869	G2G	128	15	P	5.00	Flow	0.39	7.81	NA			12.00	NA		
E22885	G2G	94	15	P	5.00	Flow	0.37	7.62	NA			11.95	NA		
E22889	G2G	169	15	P	5.00	Flow	0.38	18.25	NA			24.40	NA		
E2296	G2G	146	15	P	5.00	Flow	0.14	21.65	NA			21.95	NA		
E23028	G2G	29	15	P	5.00	Flow	0.28	6.17	NA			6.69	NA		
E23081	G2G	23	15	P	5.00	Flow	0.45	1.65	NA			3.31	NA		
E23151	G2G	36	15	P	5.00	Flow	0.20	9.03	NA			14.38	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
E23186	G2G	86	15	P	5.00	Flow	0.37	3.98	NA			4.74	NA		
E23218	G2G	78	15	P	5.00	Flow	0.32	14.45	NA			15.90	NA		
E23277	G2G	72	15	P	5.00	Flow	0.44	10.50	NA			12.35	NA		
E23316	G2G	34	15	P	5.00	Flow	0.46	4.44	NA			5.26	NA		
E24068	G2G	207	15	P	5.00	Flow	0.52	11.40	NA			16.70	NA		
E2655	G2G	47	15	P	5.00	Flow	0.45	4.54	NA			9.19	NA		
E2662	G2G	127	15	P	3.96	Flow	0.41	10.03	NA			12.22	NA		
E2694	G2G	8	15	P	5.00	Flow	0.26	1.42	NA			1.83	NA		
E2699	G2G	45	15	P	5.00	Flow	0.33	3.90	NA			5.40	NA		
E2734	G2G	45	15	P	5.00	Flow	0.40	3.20	NA			6.40	NA		
E2846	G2G	48	15	P	5.00	Flow	0.30	7.70	NA			15.40	NA		
E2862	G2G	47	15	P	5.00	Flow	0.47	3.78	NA			5.51	NA		
E2901	G2G	123	15	P	5.00	Flow	0.53	10.90	NA			14.40	NA		
E4222	G2G	17	15	P	5.00	Flow	0.41	2.40	NA			4.18	NA		
E4427	G2G	46	15	P	5.00	Flow	0.29	5.45	NA			10.89	NA		

MIDLANDS

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^{3}s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^{3}s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
2001	G2G	3266	15	P	5.00	Flow	0.29	243.53	NA			269.95	NA		
2002	G2G	1439	15	P	5.00	Flow	0.42	129.48	NA			174.04	NA		
2004	G2G	166	15	P	5.00	Flow	0.57	23.74	NA			29.26	NA		
2005	G2G	1717	15	P	5.00	Flow	0.09	200.70	NA			292.39	NA		
2008	G2G	865	15	P	5.00	Flow	0.43	74.71	NA			149.42	NA		
2010	G2G	220	15	P	5.00	Flow	0.40	32.25	NA			51.99	NA		
2011	G2G	122	15	P	5.00	Flow	0.61	12.15	NA			24.29	NA		
2012	G2G	544	15	P	5.00	Flow	0.47	18.15	NA			36.31	NA		
2014	G2G	492	15	P	5.00	Flow	0.43	176.57	NA			205.32	NA		
2015	G2G	112	15	P	5.00	Flow	0.49	14.92	NA			29.84	NA		
2016	G2G	168	15	P	5.00	Flow	0.52	6.74	NA			13.49	NA		
2017	G2G	200	15	P	5.00	Flow	0.24	37.87	NA			51.90	NA		
2018	G2G	140	15	P	5.00	Flow	0.62	10.14	NA			20.28	NA		
2019	G2G	218	15	P	5.00	Flow	0.39	12.31	NA			24.63	NA		
2020	G2G	112	15	P	5.00	Flow	0.31	7.33	NA			8.33	NA		
2023	G2G	72	15	P	5.00	Flow	0.39	7.88	NA			11.26	NA		
2024	G2G	136	15	P	5.00	Flow	0.29	3.02	NA			6.05	NA		
2025	G2G	39	15	P	5.00	Flow	0.61	12.83	NA			25.66	NA		
2027	G2G	98	15	P	5.00	Flow	0.50	9.47	NA			13.72	NA		
2028	G2G	702	15	P	5.00	Flow	0.63	211.62	NA			248.80	NA		
2029	G2G	1165	15	P	5.00	Flow	0.50	145.21	NA			195.28	NA		
2032	G2G	5075	15	P	5.00	Flow	0.36	204.81	NA			409.61	NA		
2034	G2G	35	15	P	5.00	Flow	0.41	6.61	NA			10.84	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^{3}s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^{3}s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
2036	G2G	61	15	P	5.00	Flow	0.34	13.23	NA			16.45	NA		
2038	G2G	208	15	P	5.00	Flow	0.47	57.00	NA			62.82	NA		
2039	G2G	143	15	P	5.00	Flow	0.42	37.56	NA			41.44	NA		
2040	G2G	106	15	P	5.00	Flow	0.21	1.65	NA			3.30	NA		
2041	G2G	125	15	P	5.00	Flow	0.43	6.60	NA			13.19	NA		
2048	G2G	62	15	P	5.00	Flow	0.38	9.87	NA			14.06	NA		
2049	G2G	225	15	P	5.00	Flow	0.46	11.93	NA			23.86	NA		
2050	G2G	195	15	P	5.00	Flow	0.46	18.05	NA			36.10	NA		
2054	G2G	189	15	P	5.00	Flow	0.58	30.78	NA			39.89	NA		
2057	G2G	7098	15	P	5.00	Flow	0.20	415.89	NA			471.66	NA		
2067	G2G	37	15	P	5.00	Flow	0.57	5.15	NA			10.30	NA		
2076	G2G	370	15	P	5.00	Flow	0.66	171.53	NA			234.48	NA		
2077	G2G	1891	15	P	5.00	Flow	0.12	200.08	NA			265.57	NA		
2084	G2G	111	15	P	5.00	Flow	0.58	16.37	NA			21.59	NA		
2085	G2G	3694	15	P	5.00	Flow	0.28	211.91	NA			423.83	NA		
2088	G2G	80	15	P	5.00	Flow	0.42	6.18	NA			12.36	NA		
2090	G2G	156	15	P	5.00	Flow	0.50	12.74	NA			25.48	NA		
2091	G2G	635	15	P	5.00	Flow	0.43	51.92	NA			77.37	NA		
2092	G2G	118	15	P	5.00	Flow	0.35	25.24	NA			38.25	NA		
2093	G2G	813	15	P	5.00	Flow	0.39	44.51	NA			89.03	NA		
2094	G2G	62	15	P	5.00	Flow	0.56	8.54	NA			17.08	NA		
2095	G2G	94	15	P	5.00	Flow	0.32	26.41	NA			27.96	NA		
2104	G2G	209	15	P	5.00	Flow	0.27	51.71	NA			59.33	NA		
2107	G2G	114	15	P	5.00	Flow	0.28	30.72	NA			35.07	NA		
2124	G2G	23	15	P	5.00	Flow	0.66	3.29	NA			5.43	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^3s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
2132	G2G	331	15	P	5.00	Flow	0.44	27.08	NA			54.17	NA		
2134	G2G	2860	15	P	5.00	Flow	0.14	254.62	NA			281.95	NA		
2156	G2G	159	15	P	5.00	Flow	0.43	97.53	NA			140.15	NA		
2159	G2G	116	15	P	5.00	Flow	0.72	93.49	NA			134.16	NA		
2167	G2G	164	15	P	5.00	Flow	0.47	7.70	NA			15.39	NA		
2169	G2G	118	15	P	5.00	Flow	0.43	11.31	NA			22.61	NA		
2175	G2G	1657	15	P	5.00	Flow	0.30	237.11	NA			324.86	NA		
2176	G2G	778	15	P	5.00	Flow	0.36	241.69	NA			267.23	NA		
2180	G2G	3050	15	P	5.00	Flow	0.16	274.68	NA			301.33	NA		
2603	G2G	21	15	P	5.00	Flow	0.52	4.36	NA			6.84	NA		
2607	G2G	13	15	P	5.00	Flow	0.04	3.89	NA			5.77	NA		
2609	G2G	67	15	P	5.00	Flow	0.55	4.61	NA			9.23	NA		
2613	G2G	60	15	P	5.00	Flow	0.34	9.12	NA			18.25	NA		
2621	G2G	14	15	P	5.00	Flow	0.04	15.89	NA			21.99	NA		
2625	G2G	713	15	P	5.00	Flow	0.49	58.38	NA			116.76	NA		
2629	G2G	32	15	P	5.00	Flow	0.59	2.73	NA			5.47	NA		
2636	G2G	49	15	P	5.00	Flow	0.05	24.98	NA			32.03	NA		
2639	G2G	56	15	P	5.00	Flow	0.45	14.99	NA			16.54	NA		
2642	G2G	3691	15	P	5.00	Flow	0.40	157.58	NA			315.15	NA		
2649	G2G	19	15	P	5.00	Flow	0.22	5.07	NA			10.15	NA		
4003	G2G	186	15	P	5.00	Flow	0.65	39.02	NA			78.04	NA		
4006	G2G	205	15	P	5.00	Flow	0.42	11.41	NA			22.83	NA		
4007	G2G	2855	15	P	5.00	Flow	0.41	94.54	NA			189.08	NA		
4008	G2G	257	15	P	5.00	Flow	0.55	39.07	NA			78.14	NA		
4009	G2G	4763	15	P	5.00	Flow	0.45	167.49	NA			334.98	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^{3}s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^{3}s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
4011	G2G	385	15	P	5.00	Flow	0.59	88.02	NA			114.73	NA		
4012	G2G	789	15	P	5.00	Flow	0.22	30.15	NA			60.29	NA		
4014	G2G	366	15	P	5.00	Flow	0.16	12.40	NA			24.79	NA		
4018	G2G	667	15	P	5.00	Flow	0.56	52.17	NA			104.33	NA		
4019	G2G	1889	15	P	5.00	Flow	0.26	82.23	NA			164.46	NA		
4022	G2G	5253	15	P	5.00	Flow	0.32	297.08	NA			323.18	NA		
4023	G2G	54	15	P	5.00	Flow	0.64	8.23	NA			16.47	NA		
4024	G2G	282	15	P	5.00	Flow	0.42	31.21	NA			34.35	NA		
4026	G2G	218	15	P	5.00	Flow	0.36	21.85	NA			43.70	NA		
4031	G2G	117	15	P	5.00	Flow	0.44	45.46	NA			51.92	NA		
4032	G2G	29	15	P	5.00	Flow	0.50	3.21	NA			3.93	NA		
4033	G2G	8	15	P	5.00	Flow	0.20	2.40	NA			4.80	NA		
4039	G2G	40	15	P	5.00	Flow	0.53	18.62	NA			28.72	NA		
4040	G2G	36	15	P	5.00	Flow	0.44	8.09	NA			10.39	NA		
4041	G2G	30	15	P	5.00	Flow	0.04	18.40	NA			23.29	NA		
4043	G2G	264	15	P	5.00	Flow	0.44	71.78	NA			92.57	NA		
4046	G2G	32	15	P	5.00	Flow	0.53	5.23	NA			10.46	NA		
4048	G2G	95	15	P	5.00	Flow	0.35	24.05	NA			28.73	NA		
4049	G2G	38	15	P	5.00	Flow	0.37	2.74	NA			5.49	NA		
4050	G2G	63	15	P	5.00	Flow	0.27	2.73	NA			5.46	NA		
4052	G2G	94	15	P	5.00	Flow	0.56	3.92	NA			7.84	NA		
4053	G2G	161	15	P	5.00	Flow	0.36	20.52	NA			31.18	NA		
4055	G2G	37	15	P	5.00	Flow	0.49	10.03	NA			12.48	NA		
4056	G2G	55	15	P	5.00	Flow	0.56	4.78	NA			9.56	NA		
4058	G2G	28	15	P	5.00	Flow	0.52	5.90	NA			11.80	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^3s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
4061	G2G	121	15	P	5.00	Flow	0.53	31.99	NA			37.41	NA		
4066	G2G	69	15	P	5.00	Flow	0.38	15.33	NA			17.62	NA		
4067	G2G	698	15	P	5.00	Flow	0.45	130.19	NA			183.99	NA		
4074	G2G	847	15	P	5.00	Flow	0.37	55.55	NA			74.53	NA		
4079	G2G	53	15	P	5.00	Flow	0.53	2.17	NA			4.35	NA		
4080	G2G	442	15	P	5.00	Flow	0.41	56.78	NA			113.57	NA		
4081	G2G	68	15	P	5.00	Flow	0.61	18.00	NA			36.00	NA		
4082	G2G	118	15	P	5.00	Flow	0.45	14.26	NA			21.21	NA		
4083	G2G	109	15	P	5.00	Flow	0.22	31.95	NA			38.60	NA		
4085	G2G	619	15	P	5.00	Flow	0.62	105.84	NA			133.64	NA		
4086	G2G	70	15	P	4.90	Flow	0.31	9.67	NA			11.95	NA		
4087	G2G	83	15	P	5.00	Flow	0.33	30.04	NA			37.68	NA		
4091	G2G	105	15	P	5.00	Flow	0.42	8.53	NA			12.79	NA		
4093	G2G	714	15	P	5.00	Flow	0.25	34.31	NA			68.63	NA		
4115	G2G	14	15	P	5.00	Flow	0.27	2.37	NA			4.74	NA		
4116	G2G	57	15	P	5.00	Flow	0.33	5.80	NA			6.14	NA		
4118	G2G	41	15	P	5.00	Flow	0.27	2.66	NA			3.09	NA		
4142	G2G	186	15	P	5.00	Flow	0.35	27.54	NA			31.60	NA		
4143	G2G	33	15	P	5.00	Flow	0.41	7.84	NA			9.23	NA		
4146	G2G	11	15	P	5.00	Flow	0.39	4.07	NA			6.69	NA		
4158	G2G	30	15	P	5.00	Flow	0.57	2.19	NA			4.39	NA		
4161	G2G	16	15	P	5.00	Flow	0.27	3.93	NA			5.62	NA		
4163	G2G	2	15	P	5.00	Flow	0.21	3.78	NA			4.32	NA		
4164	G2G	173	15	P	5.00	Flow	0.30	9.30	NA			11.25	NA		
4174	G2G	238	15	P	5.00	Flow	0.30	18.64	NA			24.60	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^3s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
4186	G2G	63	15	P	5.00	Flow	0.33	12.32	NA			24.64	NA		
4195	G2G	10	15	P	5.00	Flow	0.38	1.54	NA			2.30	NA		
4196	G2G	32	15	P	5.00	Flow	0.59	2.48	NA			4.97	NA		
4197	G2G	16	15	P	5.00	Flow	0.46	5.30	NA			10.61	NA		
4205	G2G	8	15	P	3.44	Flow	0.29	0.98	NA			1.07	NA		
4427	G2G	124	15	P	5.00	Flow	0.30	7.53	NA			15.07	NA		
4435	G2G	46	15	P	5.00	Flow	0.32	10.67	NA			13.44	NA		
4873	G2G	175	15	P	5.00	Flow	0.23	19.83	NA			22.14	NA		
2001	DODO	3266	60	F	9.43	Level	0.74	172.07	2.405			344.14	4.039		
2005	DODO	1717	60	F	9.43	Level	0.54	178.07	4.636			356.15	6.275		
2008	DODO	865	60	F	9.43	Level	0.43	74.71	2.267			149.42	3.898		
2010	DODO	220	60	F	9.43	Level	0.54	29.86	1.512			59.72	1.617		
2011	MCRM	122	60	F	9.43	Level	0.37	12.15	1.458			24.29	2.282		
2012	DODO	544	60	F	9.43	Level	0.50	18.15	1.022			36.31	1.978		
2015	MCRM	112	60	F	9.43	Level	0.34	14.92	2.204			29.84	2.595		
2016	MCRM	168	60	F	9.43	Level	0.42	6.74	0.797			13.49	1.17		
2017	MCRM	200	60	F	9.43	Level	0.25	29.73	2.5595			59.46	2.619		
2018	MCRM	140	60	F	9.43	Level	0.31	10.14	0.979			20.28	1.41		
2019	DODO	218	60	F	9.43	Level	0.56	12.31	0.873			24.63	1.374		
2020	MCRM	112	60	F	9.43	Level	0.47	4.28	0.476			8.57	0.73		
2024	MCRM	136	60	F	9.43	Level	0.50	3.02	0.417			6.05	0.655		
2027	MCRM	98	60	F	9.43	Level	0.27	7.72	0.638			15.45	0.93		
2028	DODO	702	60	F	9.43	Level	0.40	156.71	4.302			313.41	4.4205		
2029	DODO	1165	60	F	9.43	Level	0.47	98.83	2.909			197.65	5.123		
2032	DODO	5075	60	F	9.43	Level	0.57	204.81	1.965			409.61	4.844		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^3s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
2034	MCRM	35	60	F	9.43	Level	0.46	6.19	0.773			12.38	1.112		
2036	DODO	61	60	F	9.43	Level	0.09	9.90	1.838			19.80	2.894		
2038	MCRM	208	60	F	9.43	Level	0.45	38.84	1.295			77.68	1.825		
2039	MCRM	143	60	F	9.22	Level	0.28	25.94	1.9075			51.87	2.2205		
2041	MCRM	125	60	F	9.43	Level	0.57	6.60	0.7			13.19	1.11		
2048	MCRM	62	60	F	9.43	Level	0.27	10.48	0.834			20.95	1.236		
2050	DODO	195	60	F	9.43	Level	0.36	18.05	2.042			36.10	2.357		
2054	MCRM	189	60	F	9.43	Level	0.47	24.75	2.3775			49.49	2.631		
2057	DODO	7098	60	F	9.43	Level	0.40	237.13	2.97			474.26	4.983		
2067	DODO	37	60	F	9.43	Level	0.33	5.15	1.641			10.30	2.064		
2077	DODO	1891	60	F	9.43	Level	0.67	173.09	2.415			346.18	4.055		
2083	DODO	35	60	F	9.43	Level	0.16	11.36	1.2725			22.72	1.447		
2084	DODO	111	60	F	9.43	Level	0.27	11.19	1.153			22.39	2.229		
2085	DODO	3694	60	F	9.43	Level	0.70	211.91	1.51			423.83	4.065		
2087	DODO	5159	60	F	9.43	Level	0.50	207.78	2.156			415.57	4.128		
2088	DODO	80	60	F	9.43	Level	0.41	6.18	0.889			12.36	1.382		
2090	DODO	156	60	F	9.43	Level	0.29	12.74	1.516			25.48	2.106		
2091	DODO	635	60	F	9.43	Level	0.60	41.69	1.936			83.38	2.561		
2092	MCRM	118	60	F	9.43	Level	0.39	21.88	3.021			43.76	3.242		
2093	DODO	813	60	F	9.43	Level	0.49	44.51	0.904			89.03	1.383		
2094	MCRM	62	60	F	9.43	Level	0.31	8.54	1.079			17.08	1.526		
2095	DODO	94	60	F	9.43	Level	0.37	14.51	2.368			29.02	2.888		
2104	DODO	209	60	F	9.43	Level	0.46	34.50	1.192			69.00	1.809		
2107	DODO	114	60	F	8.57	Level	0.27	18.42	1.101			36.85	1.479		
2132	DODO	331	60	F	9.43	Level	0.26	27.08	1.043			54.17	1.494		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^3s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
2134	DODO	2860	60	F	9.43	Level	0.80	182.71	3.202			365.43	5.166		
2167	DODO	164	60	F	9.43	Level	0.32	7.70	1.227			15.39	1.781		
2175	DODO	1657	60	F	9.43	Level	0.42	173.13	5.125			346.25	6.286		
2180	DODO	3050	60	F	9.43	Level	0.74	214.27	2.519			428.54	4.294		
2609	MCRM	67	60	F	9.43	Level	0.45	4.61	1.315			9.23	2.098		
2613	MCRM	60	60	F	9.43	Level	0.27	9.12	1.443			18.25	1.757		
2621	MCRM	14	60	F	8.19	Level	0.36	13.74	1.061			27.48	1.274		
2625	DODO	713	60	F	8.94	Level	0.41	58.38	2.187			116.76	2.987		
2639	MCRM	56	60	F	5.36	Level	0.16	10.01	1.274			20.01	1.356		
2649	MCRM	19	60	F	5.19	Level	0.41	5.07	1.542			10.15	1.947		
4003	DODO	186	60	F	8.67	Level	0.46	39.02	1.634			78.04	2.466		
4008	DODO	257	60	F	8.74	Level	0.54	39.07	0.984			78.14	1.454		
4018	DODO	667	60	F	8.74	Level	0.57	52.17	1.221			104.33	1.855		
4026	MCRM	218	60	F	8.67	Level	0.44	21.85	1.179			43.70	1.708		
4031	DODO	117	60	F	8.74	Level	0.46	28.55	1.007			57.10	1.538		
4033	MCRM	8	60	F	8.74	Level	0.24	2.40	0.674			4.80	0.909		
4039	MCRM	40	60	F	8.67	Level	0.36	17.33	1.132			34.67	1.457		
4041	MCRM	30	60	F	8.74	Level	0.36	14.03	1.017			28.07	1.436		
4046	DODO	32	60	F	8.74	Level	0.40	5.23	0.676			10.46	0.952		
4058	MCRM	28	60	F	8.74	Level	0.37	5.90	0.76			11.80	1.095		
4061	DODO	121	60	F	8.74	Level	0.42	24.60	2.28			49.20	2.351		
4066	MCRM	69	60	F	8.67	Level	0.39	9.03	0.652			18.06	1.104		
4069	DODO	45	60	F	8.67	Level	0.40	66.19	1.481			132.37	1.954		
4078	DODO	552	60	F	8.74	Level	0.64	56.98	1.886			113.96	2.538		
4080	DODO	442	60	F	8.67	Level	0.46	56.78	1.116			113.57	1.571		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^3s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
4081	MCRM	68	60	F	8.67	Level	0.30	18.00	2.716			36.00	2.87		
4087	DODO	83	60	F	8.67	Level	0.55	19.66	1.64			39.33	2.511		
4094	MCRM	134	60	F	8.67	Level	0.38	21.53	1.9945			43.07	2.089		
4121	MCRM	NA	60	F	8.74	Level	0.32	2.98	0.654			5.97	0.926		
4142	DODO	186	60	F	8.74	Level	0.49	16.27	1.141			32.54	2.443		
4143	MCRM	33	60	F	8.74	Level	0.17	7.09	0.987			14.18	1.119		
055002_TG 301	ISIS	NA	15	P	10.41	Level	0.33	NA	5.2865			NA	5.456		
055003_TG 316	ISIS	NA	15	P	10.41	Level	0.08	NA	2.7525			NA	2.7625		
055013_TG 326	MCRM	NA	15	P	10.43	Mixed	0.43	26.31	1.517			32.23	1.588		
055018_TG 327	DODO	NA	15	P	10.43	Mixed	0.39	23.84	2.4945			24.21	2.511		
055021_TG 305	DODO	NA	15	P	10.43	Mixed	0.44	58.82	3.143			63.05	3.2675		
055028_TG 9302	DODO	NA	15	P	10.43	Mixed	0.46	20.75	1.4825			27.16	1.717		
055804_TG 314	MCRM	NA	60	P	10.43	Level	0.34	NA	3.318			NA	3.51		
055807_TG 320	ISIS	NA	15	P	10.41	Level	0.23	NA	4.6815			NA	4.771		
055811_TG 9303	ISIS	NA	15	P	10.41	Level	0.39	NA	5.465			NA	5.7815		
055816_TG 319	ISIS	NA	15	P	10.41	Level	0.32	NA	4.8515			NA	4.942		
055L010SG	DODO	NA	15	P	5.78	Mixed	0.43	32.47	1.0805			34.27	1.114		
055SW004	MCRM	NA	15	P	4.91	Mixed	0.19	15.50	1.822			17.59	1.9465		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^3s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
2004	DODO	166	15	P	10.50	Mixed	0.36	15.29	1.424			30.58	1.537		
2067	DODO	37	15	P	10.50	Mixed	0.41	5.15	1.641			10.30	2.064		
2083	DODO	35	15	P	10.26	Mixed	0.26	11.36	1.1435			22.72	1.202		
2084	DODO	111	15	P	10.50	Mixed	0.34	11.19	1.544			22.39	1.6755		
2129	MCRM	NA	15	P	10.50	Mixed	0.53	2.51	0.888			5.03	1.1115		
2167	DODO	164	15	P	10.50	Mixed	0.36	7.70	1.5855			15.39	1.6155		
2207	DODO	NA	15	P	5.60	Mixed	0.40	11.37	1.268			15.22	1.514		
2209	MCRM	NA	15	P	5.44	Mixed	0.41	8.23	1.2205			10.32	1.385		
2213	DODO	NA	15	P	5.35	Mixed	0.27	22.03	1.737			24.62	1.8665		
2215	DODO	NA	15	P	4.92	Mixed	0.21	2.81	1.0245			3.61	1.1685		
2216	MCRM	NA	15	P	5.21	Mixed	0.02	3.01	0.9555			3.37	1.0385		
2218	DODO	NA	15	P	5.33	Mixed	0.18	18.66	1.227			26.35	1.515		
2221	DODO	NA	15	P	3.57	Mixed	0.35	3.19	1.1675			4.31	1.341		
2425	MCRM	NA	15	P	3.06	Mixed	0.41	4.29	1.0185			5.32	1.113		
2516	MCRM	NA	15	P	6.61	Mixed	0.58	10.33	1.146			12.42	1.256		
2627	MCRM	NA	15	P	10.50	Mixed	0.44	7.86	1.713			9.73	1.8715		
26303	MCRM	NA	15	P	10.50	Mixed	0.30	13.39	1.478			17.17	1.585		
2641	MCRM	NA	15	P	8.19	Mixed	0.36	3.99	0.787			4.46	0.832		
2661	MCRM	NA	15	P	6.61	Mixed	0.20	5.03	0.6715			6.07	0.8345		
2662	MCRM	NA	15	P	6.61	Mixed	0.23	2.22	0.4925			3.00	0.5525		
2706	MCRM	NA	15	P	5.87	Mixed	0.49	5.36	0.808			6.81	0.9575		
4003	ISIS	186	15	P	10.53	Level	0.51	39.02	1.634			78.04	2.466		
4006	DODO	205	60	P	10.56	Mixed	0.37	11.41	2.255			22.83	2.571		
4007	DODO	2855	60	P	10.54	Mixed	0.40	94.54	2.498			189.08	2.7535		
4009	DODO	4763	60	P	10.56	Mixed	0.51	167.49	3.411			334.98	3.6095		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^3s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
4011	DODO	385	60	P	10.54	Mixed	0.43	62.09	2.5365			124.18	2.654		
4012	DODO	789	60	P	10.56	Mixed	0.49	30.15	2.1695			60.29	2.36		
4014	DODO	366	60	P	10.56	Mixed	0.61	12.40	2.0895			24.79	2.1945		
4019	DODO	1889	60	P	10.55	Mixed	0.59	82.23	2.811			164.46	3.003		
4022	DODO	5253	60	P	10.56	Mixed	0.70	174.71	2.396			349.43	2.6655		
4023	DODO	54	60	P	10.54	Mixed	0.50	8.23	0.881			16.47	0.9205		
4024	DODO	282	60	P	10.54	Mixed	0.26	17.41	2.9435			34.82	3.0255		
4032	MCRM	29	60	P	10.54	Mixed	0.58	2.12	0.717			4.24	0.745		
4036	DODO	43	60	F	10.48	Flow	0.16	1.65	NA			2.07	NA		
4040	MCRM	36	60	P	10.56	Mixed	0.31	5.20	1.0135			10.39	1.106		
4043	DODO	264	60	P	10.54	Mixed	0.41	46.86	2.7535			93.72	2.9435		
4044	MCRM	12	60	P	10.54	Mixed	0.46	0.36	0.299			0.71	0.344		
4048	MCRM	95	60	P	10.54	Mixed	0.44	15.81	2.495			31.61	2.5495		
4049	MCRM	38	60	P	10.54	Mixed	0.35	2.74	0.86			5.49	0.985		
4052	MCRM	94	60	P	10.45	Mixed	0.43	3.92	1.1255			7.84	1.2345		
4053	MCRM	161	60	P	10.54	Mixed	0.44	17.33	1.835			34.66	1.9		
4055	DODO	37	60	P	10.54	Mixed	0.49	6.43	1.0835			12.85	1.2305		
4056	DODO	55	60	P	10.54	Mixed	0.40	4.78	1.181			9.56	1.3705		
4064	MCRM	NA	60	P	3.28	Mixed	0.45	9.86	1.1675			13.90	1.4845		
4065	ISIS	NA	15	P	10.16	Level	0.35	NA	5.5595			NA	5.8205		
4067	DODO	698	60	P	10.54	Mixed	0.50	96.33	2.135			192.66	2.25		
4069	ISIS	45	15	P	10.53	Level	0.34	66.19	1.481			132.37	1.954		
4071	ISIS	NA	15	P	10.56	Level	0.32	NA	1.472			NA	1.712		
4074	DODO	847	60	P	10.42	Mixed	0.36	37.53	0.9875			75.05	1.047		
4080	ISIS	442	15	P	10.53	Level	0.44	56.78	1.116			113.57	1.571		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^{3}s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^{3}s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
4082	DODO	118	60	P	10.54	Mixed	0.46	11.28	2.3425			22.57	2.4275		
4083	DODO	109	60	P	10.56	Mixed	0.28	23.85	2.548			47.70	2.611		
4084	ISIS	NA	15	P	10.56	Level	0.34	NA	2.451			NA	2.6865		
4085	DODO	619	60	P	10.54	Mixed	0.52	69.43	1.8415			138.85	1.923		
4086	DODO	70	60	P	10.54	Mixed	0.08	6.30	2.5535			12.60	2.661		
4087	ISIS	83	15	P	10.53	Level	0.50	19.66	1.64			39.33	2.511		
4091	DODO	105	60	P	10.54	Mixed	0.59	7.10	1.552			14.20	1.699		
4093	DODO	714	60	P	10.54	Mixed	0.41	34.31	1.8065			68.63	1.9095		
4095	ISIS	NA	15	P	10.53	Level	0.52	74.83	2.4955			149.65	2.551		
4109	DODO	818	60	P	10.56	Mixed	0.47	38.01	2.5885			76.01	2.744		
4115	DODO	14	15	P	10.53	Mixed	0.51	2.37	1.143			4.74	1.2455		
4116	DODO	57	60	P	10.56	Mixed	0.45	4.12	0.821			8.23	0.8815		
4118	DODO	41	60	P	10.54	Mixed	0.57	1.57	0.5315			3.13	0.603		
4126	ISIS	NA	15	P	10.53	Level	0.48	NA	2.6935			NA	2.8415		
4127	ISIS	NA	15	P	10.53	Level	0.48	NA	3.6075			NA	3.709		
4131	DODO	2698	60	P	10.54	Mixed	0.55	119.76	3.114			239.53	3.1995		
4145	MCRM	11	60	P	10.54	Mixed	0.60	0.94	1.109			1.88	1.218		
4146	MCRM	11	60	P	10.54	Mixed	0.36	3.59	1.3245			7.17	1.5415		
4155	MCRM	NA	60	P	10.54	Mixed	0.31	3.83	1.6845			7.66	1.8365		
4158	MCRM	30	60	P	10.54	Mixed	0.66	2.19	2.0345			4.39	2.0965		
4161	MCRM	16	60	P	10.54	Mixed	0.22	3.02	2.611			6.04	2.888		
4164	DODO	173	60	P	10.54	Mixed	0.38	6.37	0.7955			12.74	0.891		
4171	ISIS	NA	15	P	10.53	Level	0.52	NA	2.098			NA	2.148		
4174	DODO	238	60	P	10.54	Mixed	0.42	12.51	0.4405			25.02	0.487		
4186	DODO	63	60	P	8.03	Mixed	0.43	12.32	2.9165			24.64	2.9965		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_1 Flow (m^3s^{-1})	T_1 Level (m)	T_1 2h	T_1 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
4189	ISIS	NA	15	P	10.14	Level	0.41	NA	1.525			NA	1.5815		
4191	DODO	NA	60	P	10.56	Mixed	0.54	14.75	3.6485			29.51	3.7145		
4195	MCRM	10	60	P	10.54	Mixed	0.40	1.26	1.0235			2.53	1.104		
4196	MCRM	32	60	P	10.54	Mixed	0.47	2.48	1.811			4.97	1.8945		
4197	MCRM	16	60	P	10.54	Mixed	0.33	5.30	1.1285			10.61	1.2165		
4199	ISIS	NA	15	P	10.16	Level	0.25	NA	6.711			NA	6.965		
4205	MCRM	8	60	P	5.22	Mixed	0.21	0.87	0.488			1.74	0.602		
4207	MCRM	NA	60	P	4.13	Mixed	0.60	3.84	0.587			6.70	0.8475		
4238	MCRM	NA	15	P	10.54	Mixed	0.47	2.44	0.42			3.25	0.4805		
4427	DODO	124	60	P	10.56	Mixed	0.45	7.53	0.973			15.07	1.2875		
4755	ISIS	NA	15	P	3.18	Level	0.49	NA	2.1665			NA	2.2665		
4873	MCRM	175	60	P	10.54	Mixed	0.19	11.91	3.536			23.83	3.5575		
4878	ISIS	NA	15	P	10.53	Level	0.29	NA	2.5735			NA	2.799		
055804_TG 314	ISIS	NA	15	P	10.41	Level	0.27	NA	3.328			NA	3.5125		
4007	ISIS	2855	15	P	10.53	Level	0.21	94.54	2.4985			189.08	2.7535		
4009	ISIS	4763	15	P	10.56	Level	0.40	167.49	3.4155			334.98	3.6165		
4019	ISIS	1889	15	P	10.55	Level	0.36	82.23	2.8125			164.46	3.0065		
4022	ISIS	5253	15	P	10.56	Level	0.44	174.71	2.399			349.43	2.668		
4131	ISIS	2698	15	P	10.53	Level	0.27	119.76	3.115			239.53	3.2005		

NORTH EAST

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
ADDGHM1	G2G	337	15	P	5.00	Flow	0.60	240.74	NA			257.45	NA		
ADWICK1	G2G	204	15	P	5.00	Flow	0.60	19.33	NA			38.65	NA		
ALDWRK2	G2G	1941	15	P	5.00	Flow	0.20	279.96	NA			314.99	NA		
Allen_Mill_Bridge	G2G	57	15	P	5.00	Flow	0.64	19.12	NA			26.58	NA		
ALSTON1	G2G	95	15	P	5.00	Flow	0.38	86.41	NA			172.83	NA		
ALWNTN1	G2G	159	15	P	5.00	Flow	0.30	77.62	NA			134.53	NA		
ARMLEY1	G2G	491	15	P	5.00	Flow	0.63	71.01	NA			142.02	NA		
ARTHNG1	G2G	529	15	P	5.00	Flow	0.55	222.13	NA			249.24	NA		
BARNRD5	G2G	467	15	P	5.00	Flow	0.60	259.61	NA			300.21	NA		
BARNSL1	G2G	82	15	P	5.00	Flow	0.46	12.31	NA			24.62	NA		
BEDBRN1	G2G	53	15	P	5.00	Flow	0.36	26.45	NA			40.12	NA		
BLACKS1	G2G	52	15	P	5.00	Flow	0.02	39.39	NA			51.85	NA		
BOYNTN1	G2G	39	15	P	5.00	Flow	0.08	0.83	NA			0.90	NA		
BRADBY5	G2G	38	15	P	5.00	Flow	0.31	4.78	NA			5.55	NA		
BRIGHS2	G2G	271	15	P	5.00	Flow	0.49	118.64	NA			152.23	NA		
BROADW1	G2G	91	15	P	5.00	Flow	0.43	33.81	NA			42.39	NA		
BROKSC5	G2G	716	15	P	5.00	Flow	0.45	311.30	NA			434.80	NA		
BROTON1	G2G	44	15	P	5.00	Flow	0.40	21.66	NA			25.29	NA		
BURNHL1	G2G	128	15	P	5.00	Flow	0.54	30.27	NA			39.78	NA		
BUTTCR1	G2G	1048	15	P	5.00	Flow	0.37	49.58	NA			99.16	NA		
BYWELL1	G2G	1889	15	P	5.00	Flow	0.43	695.57	NA			799.41	NA		
CASTLF1	G2G	1293	15	P	5.00	Flow	0.65	205.19	NA			410.37	NA		
CATTER1	G2G	426	15	P	5.00	Flow	0.55	237.19	NA			311.10	NA		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
CHERRY1	G2G	33	15	P	5.00	Flow	0.68	12.70	NA			15.17	NA		
CHESLS1	G2G	774	15	P	5.00	Flow	0.63	196.77	NA			264.89	NA		
CHESTF1	G2G	20	15	P	5.00	Flow	0.62	2.30	NA			4.60	NA		
CLDENE1	G2G	152	15	P	5.00	Flow	0.63	64.48	NA			74.98	NA		
COLLNG1	G2G	563	15	P	5.00	Flow	0.49	214.77	NA			249.30	NA		
COLNEB1	G2G	172	15	P	5.00	Flow	0.52	46.69	NA			93.38	NA		
COPLEY1	G2G	11	15	P	5.00	Flow	0.41	4.52	NA			4.95	NA		
COTTNL1	G2G	394	15	P	5.00	Flow	0.58	65.06	NA			130.12	NA		
CRAGHL1	G2G	33	15	P	5.00	Flow	0.43	8.71	NA			9.92	NA		
CRAKEH1	G2G	1072	15	P	5.00	Flow	0.30	142.86	NA			152.03	NA		
Cross_Hills	G2G	32	15	P	5.00	Flow	0.30	25.10	NA			29.05	NA		
CROWNP1	G2G	530	15	P	5.00	Flow	0.62	65.28	NA			130.57	NA		
Dalton	G2G	170	15	P	4.99	Flow	0.47	11.70	NA			23.40	NA		
DENBYD1	G2G	19	15	P	5.00	Flow	0.37	6.11	NA			12.21	NA		
DEWSBY1	G2G	532	15	P	5.00	Flow	0.56	117.15	NA			234.31	NA		
DONCST1	G2G	842	15	P	5.00	Flow	0.65	72.52	NA			145.03	NA		
DRONFD1	G2G	6	15	P	5.00	Flow	0.31	1.03	NA			1.17	NA		
EARBY01	G2G	17	15	P	5.00	Flow	0.32	9.35	NA			12.17	NA		
EASBY05	G2G	14	15	P	5.00	Flow	0.50	3.80	NA			4.57	NA		
EASTGT1	G2G	32	15	P	5.00	Flow	0.52	26.80	NA			38.79	NA		
Ecclesfield	G2G	3	15	P	5.00	Flow	0.55	1.41	NA			2.01	NA		
ELLAND1	G2G	269	15	P	5.00	Flow	0.48	118.88	NA			159.41	NA		
FARRER1	G2G	16	15	P	5.00	Flow	0.48	1.08	NA			2.15	NA		
FEATHS1	G2G	272	15	P	5.00	Flow	0.37	238.70	NA			281.36	NA		
FLINTM1	G2G	596	15	P	5.00	Flow	0.51	223.73	NA			255.96	NA		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
Foxton_Br4	G2G	157	15	P	5.00	Flow	0.55	20.79	NA			41.57	NA		
GARGRV1	G2G	66	15	P	5.00	Flow	0.38	41.73	NA			46.65	NA		
Gosforth	G2G	21	15	P	4.84	Flow	0.50	3.38	NA			5.00	NA		
GRASTN1	G2G	152	15	P	5.00	Flow	0.57	139.13	NA			155.18	NA		
GREATA4	G2G	29	15	P	5.00	Flow	0.61	7.03	NA			8.42	NA		
HADFLD1	G2G	249	15	P	5.00	Flow	0.65	32.73	NA			65.46	NA		
HADYHL1	G2G	70	15	P	5.00	Flow	0.54	14.26	NA			18.57	NA		
HARTBN1	G2G	46	15	P	5.00	Flow	0.49	10.79	NA			21.58	NA		
HARWOD5	G2G	24	15	P	5.00	Flow	0.52	26.96	NA			40.20	NA		
HAWBK01	G2G	7	15	P	5.00	Flow	0.42	4.63	NA			5.49	NA		
HAYDNB1	G2G	654	15	P	5.00	Flow	0.43	409.97	NA			474.01	NA		
HEATON1	G2G	477	15	P	5.00	Flow	0.58	116.05	NA			232.10	NA		
HEBDBR1	G2G	65	15	P	5.00	Flow	0.70	33.93	NA			42.14	NA		
HEUGHM1	G2G	30	15	P	4.99	Flow	0.25	4.02	NA			7.67	NA		
HIGHFD1	G2G	37	15	P	5.00	Flow	0.43	14.21	NA			28.42	NA		
Hollins_Bridge	G2G	18	15	P	4.00	Flow	0.55	5.18	NA			6.20	NA		
HOWEBR1	G2G	593	15	P	5.00	Flow	0.37	44.96	NA			89.92	NA		
HUNSNG1	G2G	385	15	P	5.00	Flow	0.62	129.81	NA			147.17	NA		
ILKLEY1	G2G	355	15	P	5.00	Flow	0.59	231.94	NA			258.71	NA		
JSDARL5	G2G	122	15	P	5.00	Flow	0.49	15.89	NA			22.51	NA		
KEIGHL1	G2G	57	15	P	5.00	Flow	0.59	19.77	NA			39.54	NA		
KETTLW1	G2G	75	15	P	5.00	Flow	0.50	63.90	NA			67.45	NA		
Kielder_Burn	G2G	53	15	P	5.00	Flow	0.26	50.18	NA			60.60	NA		
KILDWK2	G2G	229	15	P	5.00	Flow	0.51	32.90	NA			65.79	NA		
KILGRM2	G2G	438	15	P	5.00	Flow	0.52	225.34	NA			276.25	NA		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
KIRKBY1	G2G	41	15	P	5.00	Flow	0.67	10.64	NA			19.19	NA		
KIRKST1	G2G	488	15	P	5.00	Flow	0.57	75.18	NA			150.35	NA		
KNARES1	G2G	271	15	P	5.00	Flow	0.67	94.89	NA			105.07	NA		
Lev_Mill	G2G	8	15	P	5.00	Flow	0.19	0.81	NA			1.14	NA		
Lev_Station	G2G	21	15	P	5.00	Flow	0.40	4.15	NA			6.08	NA		
LOWHSS1	G2G	11	15	P	5.00	Flow	0.55	14.12	NA			15.00	NA		
LOWLND1	G2G	25	15	P	5.00	Flow	0.65	4.90	NA			9.81	NA		
LOWMOR5	G2G	1015	15	P	5.00	Flow	0.57	348.60	NA			454.36	NA		
Malin_Bridge	G2G	57	15	P	5.00	Flow	0.33	13.87	NA			17.21	NA		
MALTON1	G2G	912	15	P	5.00	Flow	0.44	78.23	NA			98.67	NA		
MARISH1	G2G	275	15	P	5.00	Flow	0.23	19.00	NA			21.92	NA		
MASHAM1	G2G	450	15	P	5.00	Flow	0.49	218.73	NA			274.70	NA		
METHLY1	G2G	662	15	P	5.00	Flow	0.59	98.41	NA			196.82	NA		
MIDDLETON_BR	G2G	50	15	P	5.00	Flow	0.41	15.74	NA			31.49	NA		
MIDDLT5	G2G	220	15	P	5.00	Flow	0.38	175.30	NA			222.05	NA		
MITFRD1	G2G	227	15	P	5.00	Flow	0.43	67.65	NA			91.07	NA		
MONKTN1	G2G	2530	15	P	5.00	Flow	0.19	320.06	NA			350.47	NA		
MORTON1	G2G	530	15	P	5.00	Flow	0.47	171.68	NA			215.11	NA		
MORWCK1	G2G	480	15	P	5.00	Flow	0.54	121.22	NA			157.45	NA		
NESS001	G2G	141	15	P	5.00	Flow	0.50	38.93	NA			49.39	NA		
NORMAN1	G2G	93	15	P	5.00	Flow	0.29	36.98	NA			49.44	NA		
NORTHP1	G2G	29	15	P	5.00	Flow	0.70	6.30	NA			12.61	NA		
NTCLGH1	G2G	50	15	P	5.00	Flow	0.69	13.94	NA			27.88	NA		
Nunnington	G2G	30	15	P	5.00	Flow	0.59	5.30	NA			8.76	NA		
NUNNYKIRK	G2G	28	15	P	5.00	Flow	0.40	5.04	NA			10.07	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
OTLEY01	G2G	413	15	P	5.00	Flow	0.57	237.40	NA			272.45	NA		
OTTEUS1	G2G	183	15	P	5.00	Flow	0.45	112.37	NA			126.69	NA		
PARKBG1	G2G	56	15	P	5.00	Flow	0.34	45.69	NA			91.38	NA		
PATLYB1	G2G	130	15	P	5.00	Flow	0.20	38.56	NA			77.11	NA		
Penistone	G2G	34	15	P	5.00	Flow	0.51	18.94	NA			23.45	NA		
POOLBR1	G2G	500	15	P	5.00	Flow	0.54	237.22	NA			267.82	NA		
PRESTL5	G2G	82	15	P	5.00	Flow	0.35	9.67	NA			12.18	NA		
QUEENS1	G2G	69	15	P	5.00	Flow	0.61	21.58	NA			43.16	NA		
REAVHL1	G2G	926	15	P	5.00	Flow	0.48	269.61	NA			326.17	NA		
REDEBR1	G2G	310	15	P	5.00	Flow	0.36	117.05	NA			146.52	NA		
REETH01	G2G	59	15	P	5.00	Flow	0.49	46.93	NA			57.61	NA		
RICHLW1	G2G	329	15	P	5.00	Flow	0.63	202.77	NA			243.03	NA		
RIPON01	G2G	67	15	P	5.00	Flow	0.67	19.89	NA			24.80	NA		
ROTHBY1	G2G	297	15	P	5.00	Flow	0.52	94.32	NA			133.83	NA		
Rotherham_Tesco	G2G	571	15	P	5.00	Flow	0.47	56.25	NA			112.50	NA		
RPNURE1	G2G	577	15	P	5.00	Flow	0.51	262.14	NA			303.66	NA		
RUTHBR5	G2G	85	15	P	5.00	Flow	0.52	57.12	NA			82.28	NA		
SHEEPB1	G2G	39	15	P	5.00	Flow	0.50	10.32	NA			12.79	NA		
SHILMR1	G2G	24	15	P	5.00	Flow	0.67	10.16	NA			19.25	NA		
SINNIN1	G2G	67	15	P	5.00	Flow	0.49	21.88	NA			37.76	NA		
SKELTN1	G2G	2584	15	P	5.00	Flow	0.52	198.57	NA			397.14	NA		
SKINNG5	G2G	40	15	P	5.00	Flow	0.51	16.11	NA			19.48	NA		
SKPMOR1	G2G	20	15	P	5.00	Flow	0.62	7.51	NA			8.75	NA		
SOWRBY1	G2G	221	15	P	5.00	Flow	0.54	94.44	NA			123.09	NA		
STANHP1	G2G	159	15	P	5.00	Flow	0.68	103.61	NA			124.88	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
STAVLY1	G2G	52	15	P	5.00	Flow	0.36	8.49	NA			9.66	NA		
STHCH02	G2G	57	15	P	5.00	Flow	0.53	17.34	NA			20.47	NA		
STOCKB2	G2G	293	15	P	5.00	Flow	0.36	77.32	NA			81.45	NA		
SUNDBR1	G2G	531	15	P	5.00	Flow	0.69	168.19	NA			220.02	NA		
TADCST1	G2G	623	15	P	5.00	Flow	0.42	198.01	NA			285.45	NA		
TEAMVL1	G2G	37	15	P	5.00	Flow	0.67	7.49	NA			9.38	NA		
TODMDN1	G2G	18	15	P	5.00	Flow	0.64	8.67	NA			11.98	NA		
VIEWLY_BR	G2G	133	15	P	5.00	Flow	0.46	11.60	NA			23.21	NA		
VIKING1	G2G	2590	15	P	5.00	Flow	0.18	318.04	NA			356.70	NA		
WAKEFD1	G2G	619	15	P	5.00	Flow	0.56	128.72	NA			257.44	NA		
WALDEN1	G2G	49	15	P	5.00	Flow	0.40	3.97	NA			6.66	NA		
WALSDN1	G2G	7	15	P	5.00	Flow	0.72	3.71	NA			4.59	NA		
WEARHD1	G2G	23	15	P	5.00	Flow	0.61	9.86	NA			19.72	NA		
WESTWK1	G2G	737	15	P	5.00	Flow	0.44	259.61	NA			288.11	NA		
Wharncliffe	G2G	123	15	P	5.00	Flow	0.55	23.34	NA			46.68	NA		
WHITTN1	G2G	119	15	P	5.00	Flow	0.53	27.74	NA			32.49	NA		
Wincobank	G2G	30	15	P	5.00	Flow	0.65	5.21	NA			10.42	NA		
WITTNP1	G2G	387	15	P	5.00	Flow	0.70	162.57	NA			209.47	NA		
WOODHS1	G2G	254	15	P	5.00	Flow	0.57	24.59	NA			49.18	NA		
WOOLER1	G2G	42	15	P	5.00	Flow	0.33	28.71	NA			44.82	NA		
WOOLSN1	G2G	8	15	P	5.00	Flow	0.48	1.86	NA			3.72	NA		
ADDGHM1	KW	337	15	P	11.02	Mixed	0.60	153.28	1.641			306.55	2.222		
ADWICK1	ISIS	204	15	P	10.99	Mixed	0.34	19.33	0.943			38.65	1.288		
ALDWRK2	ISIS	1941	15	P	11.02	Mixed	0.67	166.90	2.18			333.80	4.045		
Allen_Mill_Bridge	PDM	57	15	P	10.24	Mixed	0.56	16.36	1.039			32.71	1.464		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
ALMAWR1	KW	97	15	P	10.70	Mixed	0.57	20.34	0.842			40.67	1.151		
ALSTON1	PDM	95	15	P	11.02	Mixed	0.45	86.41	1.661			172.83	2.211		
ALWNTN1	PDM	159	15	P	10.24	Mixed	0.53	85.25	1.6835			170.50	1.947		
ARMLEY1	KW	491	15	P	10.99	Mixed	0.51	71.01	1.924			142.02	2.9		
ARTHNG1	KW	529	15	P	11.02	Mixed	0.55	145.18	2.739			290.36	3.972		
BAINBR1	KW	124	15	P	11.04	Mixed	0.48	70.35	2.9555			140.70	3.275		
BARNSL1	PDM	82	15	P	11.01	Mixed	0.50	12.31	0.819			24.62	1.11		
BEALWR1	ISIS	1318	15	P	10.99	Mixed	0.43	203.52	4.072			407.03	4.096		
BEDBRN1	PDM	53	15	P	11.02	Mixed	0.50	21.94	1.202			43.88	1.703		
Bellingham	ISIS	422	15	P	9.78	Mixed	0.62	149.60	2.221			299.19	2.551		
BORBRG2	ISIS	745	15	P	11.01	Level	0.52	154.10	13.704			308.19	15.098		
Bower_Hill	ISIS	55	15	P	2.75	Mixed	0.47	14.46	0.7835			28.91	0.9135		
BRADBY5	KW	38	15	P	11.02	Mixed	0.25	3.22	0.749			6.45	1.266		
BROADW1	PDM	91	15	P	11.04	Mixed	0.55	21.58	0.881			43.16	1.531		
BROKSC5	KW	716	15	P	10.98	Mixed	0.53	240.14	2.106			480.29	2.797		
BROTON1	KW	44	15	P	11.01	Mixed	0.47	14.59	1.291			29.17	1.909		
BURNHL1	PDM	128	15	P	11.02	Mixed	0.49	20.57	1.008			41.13	1.404		
BUTTCR1	KW	1048	15	P	11.01	Mixed	0.09	49.58	1.148			99.16	1.801		
BYWELL1	ISIS	1889	15	P	11.02	Mixed	0.61	443.35	3.155			886.69	4.829		
CASTLF1	ISIS	1293	15	P	10.99	Mixed	0.42	205.19	2.399			410.37	3.079		
CATTER1	KW	426	15	P	11.02	Mixed	0.54	158.43	2.095			316.86	2.865		
CHERRY1	PDM	33	15	P	11.04	Mixed	0.72	12.78	1.3355			25.55	1.544		
CHESLS1	KW	774	15	P	11.00	Mixed	0.55	159.07	1.811			318.14	3.433		
CHESTF1	PDM	20	15	P	10.54	Mixed	0.47	2.30	0.625			4.60	0.868		
CLDENE1	KW	152	15	P	11.01	Mixed	0.46	46.92	3.259			93.84	3.5675		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^{3}s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^{3}s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
COLDGT1	PDM	37	15	P	10.80	Mixed	0.52	17.12	0.518			34.25	0.79		
COLLNG1	KW	563	15	P	11.02	Mixed	0.43	141.39	3.8615			282.78	4.1445		
COLNEB1	KW	172	15	P	11.01	Mixed	0.49	46.69	1.1			93.38	1.512		
COPLEY1	PDM	11	15	P	10.27	Mixed	0.49	2.65	0.476			5.30	0.753		
COTTNL1	KW	394	15	P	10.99	Mixed	0.48	65.06	1.469			130.12	2.173		
CRAGHL1	ISIS	33	15	P	11.02	Mixed	0.49	5.29	1.028			10.59	1.091		
CRAKEH1	ISIS	1072	15	P	11.01	Level	0.64	87.59	2.853			175.17	5.101		
CROWNP1	KW	530	15	P	9.05	Mixed	0.47	65.28	1.087			130.57	1.536		
Cundy_Cross	ISIS	NA	15	P	4.88	Level	0.29	12.42	1.2845			24.83	1.597		
Dalton	PDM	170	15	P	11.04	Mixed	0.45	11.70	2.357			23.40	3.734		
Darfield_Br	ISIS	NA	15	P	6.77	Level	0.54	NA	1.87			NA	2.1375		
DENBYD1	PDM	19	15	P	11.01	Mixed	0.65	6.11	0.882			12.21	1.175		
DEWSBY1	KW	532	15	P	11.03	Mixed	0.55	117.15	2.745			234.31	3.897		
DONCST1	ISIS	842	15	P	10.99	Mixed	0.62	72.52	1.894			145.03	3.654		
Dovecote_Hill	ISIS	57	15	P	8.61	Mixed	0.43	10.53	1.19			21.05	1.607		
DRONFD1	PDM	6	15	P	11.01	Mixed	0.36	0.59	0.171			1.19	0.315		
EARBY01	PDM	17	15	P	10.65	Mixed	0.38	6.41	0.93			12.82	1.215		
EASBY05	PDM	14	15	P	7.96	Mixed	0.47	2.88	0.495			5.76	0.71		
EASTGT1	PDM	32	15	P	10.90	Mixed	0.73	24.67	0.9555			49.35	1.1015		
Ecclesfield	PDM	3	15	P	3.91	Mixed	0.55	1.22	0.744			2.43	1.155		
ELLAND1	KW	269	15	P	11.01	Mixed	0.55	83.32	1.171			166.65	1.538		
FARRER1	PDM	16	15	P	11.01	Mixed	0.58	1.08	0.348			2.15	0.478		
FEATHS1	ISIS	272	15	P	11.02	Mixed	0.53	145.40	1.383			290.81	1.995		
Ferrybr_Lock	ISIS	NA	15	P	10.99	Level	0.44	NA	2.205			NA	2.268		
FLINTM1	KW	596	15	P	11.02	Mixed	0.63	151.39	1.803			302.78	2.606		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
Foxton_Br4	KW	157	15	P	5.13	Mixed	0.49	20.79	1.252			41.57	1.819		
GARGRV1	PDM	66	15	P	10.22	Mixed	0.42	25.38	0.738			50.76	1.003		
Gosforth	ISIS	21	15	P	3.13	Mixed	0.43	2.62	1.24			5.25	1.3275		
GREATA4	KW	29	15	P	9.79	Mixed	0.46	5.39	0.435			10.79	0.703		
GRINTN1	KW	3	15	P	11.04	Mixed	0.47	1.01	2.1845			2.02	2.3		
HADFLD1	KW	249	15	P	11.01	Mixed	0.44	32.73	0.847			65.46	1.2		
HADYHL1	PDM	70	15	P	11.01	Mixed	0.38	9.67	1.625			19.35	2.086		
HARTBN1	PDM	46	15	P	11.02	Mixed	0.45	10.79	0.645			21.58	0.919		
HARWOD5	PDM	24	15	P	11.02	Mixed	0.37	21.14	1.2325			42.28	1.3775		
HAWBK01	PDM	7	15	P	10.65	Mixed	0.33	3.73	0.675			7.45	0.9		
HAYDNB1	ISIS	654	15	P	11.02	Mixed	0.54	251.56	2.221			503.11	3.301		
HEATON1	KW	477	15	P	11.01	Mixed	0.56	116.05	1.124			232.10	1.782		
HEBDBR1	KW	65	15	P	11.01	Mixed	0.52	27.16	1.9825			54.32	2.239		
HEUGHM1	KW	30	15	P	11.02	Mixed	0.40	5.17	0.7865			10.34	1.0875		
HIGHFD1	PDM	37	15	P	11.01	Mixed	0.43	14.21	1.0905			28.42	1.451		
Hollins_Bridge	ISIS	18	15	P	9.27	Mixed	0.22	3.74	0.5195			7.49	0.565		
HORBRY1	KW	556	15	P	10.54	Mixed	0.62	115.92	1.881			231.83	2.967		
Houghton	ISIS	NA	15	P	10.99	Level	0.55	NA	1.24			NA	1.32		
HOWEBR1	ISIS	593	15	P	11.00	Mixed	0.40	44.96	3.662			89.92	4.617		
HUNSNG1	KW	385	15	P	11.02	Mixed	0.52	104.55	1.398			209.10	2.6		
ICI0001	KW	172	15	P	11.01	Mixed	0.61	46.69	0.989			93.38	1.687		
ILKLEY1	KW	355	15	P	11.02	Mixed	0.60	157.13	1.77			314.26	2.784		
JSDARL5	KW	122	15	P	11.02	Mixed	0.33	12.39	1.105			24.78	1.641		
KEIGHL1	PDM	57	15	P	11.01	Mixed	0.55	19.77	1.086			39.54	1.429		
KETTLW1	PDM	75	15	P	11.04	Mixed	0.59	35.95	1.505			71.91	2.183		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^{3}s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^{3}s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
Kielder_Burn	PDM	53	15	P	11.02	Mixed	0.62	34.08	1.252			68.17	1.824		
KILDWK2	ISIS	229	15	P	10.99	Mixed	0.51	32.90	1.293			65.79	2.452		
KILGRM2	PDM	438	15	P	11.04	Mixed	0.54	142.98	2.762			285.96	4.42		
Killamarsh	ISIS	NA	15	P	10.73	Level	0.38	NA	1.503			NA	1.7475		
Kilnhurst_Br	ISIS	NA	15	P	6.83	Level	0.46	NA	2.952			NA	3.474		
KIRBYW1	ISIS	172	15	P	11.01	Level	0.51	15.77	0.554			31.53	0.988		
KIRKBY1	PDM	41	15	P	11.04	Mixed	0.63	11.44	1.888			22.88	2.186		
KIRKST1	KW	488	15	P	10.12	Mixed	0.40	75.18	2.026			150.35	2.383		
KNARES1	KW	271	15	P	10.37	Mixed	0.44	55.59	1.149			111.17	1.657		
Knott_Bank	ISIS	NA	15	P	7.64	Level	0.39	NA	4.4855			NA	4.5925		
Ladys_Bridge	ISIS	49	15	P	10.65	Mixed	0.37	17.41	0.96			34.83	1.299		
Lanch_Front_St	PDM	20	15	P	7.86	Mixed	0.54	8.39	1.0295			11.09	1.272		
LEDGRD1	KW	482	15	P	10.64	Mixed	0.58	116.14	1.965			232.28	3.452		
Lev_Mill	PDM	8	15	P	11.03	Mixed	0.27	0.68	0.217			1.35	0.336		
Lev_Station	PDM	21	15	P	11.04	Mixed	0.47	4.70	1.212			9.41	1.598		
LOWHSS1	PDM	11	15	P	11.04	Mixed	0.56	7.50	0.807			15.00	1.147		
LOWLND1	KW	25	15	P	10.28	Mixed	0.57	4.90	0.479			9.81	0.778		
LOWMOR5	ISIS	1015	15	P	11.00	Level	0.55	247.15	4.017			494.31	5.913		
Malin_Bridge	KW	57	15	P	10.74	Mixed	0.32	8.76	0.925			17.52	1.336		
MALTON1	ISIS	912	15	P	11.01	Level	0.33	53.49	2.866			106.99	4.076		
MaltonA64	ISIS	900	15	P	9.30	Level	0.29	57.81	4.0315			115.62	4.281		
MASHAM1	KW	450	15	P	7.38	Mixed	0.34	141.58	2.839			283.15	3.079		
METHLY1	KW	662	15	P	9.07	Mixed	0.54	98.41	2.394			196.82	3.337		
Mexborough_Lock	ISIS	NA	15	P	10.99	Level	0.54	NA	2.7005			NA	2.9655		
MIDDLETON_BR	PDM	50	15	P	9.08	Mixed	0.42	15.74	1.134			31.49	1.712		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
MIDDLT5	KW	220	15	P	11.02	Mixed	0.31	119.02	1.929			238.04	2.568		
MITFRD1	KW	227	15	P	11.03	Mixed	0.48	54.19	1.764			108.37	2.332		
MONKTN1	KW	2530	15	P	11.02	Mixed	0.64	195.37	3.768			390.74	6.099		
MOORHS5	PDM	7	15	P	11.02	Mixed	0.47	3.86	0.551			7.72	0.718		
Morpeth	KW	NA	15	P	8.47	Mixed	0.48	54.46	25.5035			108.93	25.702		
MORWCK1	KW	480	15	P	11.03	Mixed	0.52	119.88	2.848			239.76	3.049		
Myton_on_Swale	ISIS	NA	15	P	11.01	Level	0.28	NA	5.6475			NA	6.004		
NEASHS5	ISIS	994	15	P	11.00	Level	0.61	241.40	20.564			482.81	22.264		
NESS001	ISIS	141	15	P	11.00	Mixed	0.51	26.48	1.414			52.95	2.015		
NORMAN1	ISIS	93	15	P	11.00	Mixed	0.58	42.95	3.343			85.90	3.831		
NORTHP1	KW	29	15	P	11.03	Mixed	0.58	6.30	0.578			12.61	0.896		
NTCLGH1	PDM	50	15	P	10.37	Mixed	0.56	13.94	0.901			27.88	1.358		
Nunnington	PDM	30	15	P	5.15	Mixed	0.34	4.96	1.39			9.91	1.657		
NUNNYKIRK	PDM	28	15	P	8.85	Mixed	0.25	5.04	0.996			10.07	1.303		
Oakbrook_Rd	PDM	NA	15	P	4.92	Mixed	0.45	2.08	0.443			4.17	0.506		
Oakley_Cross_Beck	PDM	44	15	P	6.06	Mixed	0.59	8.64	0.7545			17.28	0.828		
OTLEY01	KW	413	15	P	11.02	Mixed	0.57	175.56	1.116			351.12	1.614		
OTTEBR1	KW	13	15	P	11.02	Mixed	0.33	1.54	0.298			3.08	0.446		
OTTEUS1	PDM	183	15	P	10.55	Mixed	0.56	71.01	2.738			142.02	3.353		
PARKBG1	PDM	56	15	P	11.04	Mixed	0.52	45.69	1.734			91.38	2.418		
PATLYB1	KW	130	15	P	10.35	Mixed	0.02	38.56	1.235			77.11	2.275		
Penistone	ISIS	34	15	P	10.65	Mixed	0.38	13.63	1.091			27.26	1.429		
Pickering	ISIS	46	15	P	10.51	Mixed	0.59	5.39	0.736			10.78	1.139		
PONTLD1	PDM	48	15	P	10.78	Mixed	0.41	6.00	56.0525			8.74	56.3195		
POOLBR1	KW	500	15	P	10.32	Mixed	0.55	152.56	2.671			305.11	3.671		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
PRESTL5	KW	82	15	P	11.02	Mixed	0.26	6.44	0.807			12.88	1.295		
QUEENS1	PDM	69	15	P	11.01	Mixed	0.49	21.58	1.193			43.16	1.663		
REAVHL1	ISIS	926	15	P	11.02	Mixed	0.59	193.30	3.2595			386.61	3.5735		
REDEBR1	ISIS	310	15	P	11.02	Mixed	0.42	82.42	2.073			164.84	2.2515		
REETH01	PDM	59	15	P	10.54	Mixed	0.34	31.04	1.5855			62.07	1.634		
RICHLW1	KW	329	15	P	11.02	Mixed	0.52	122.89	1.902			245.77	2.98		
RIPON01	ISIS	67	15	P	10.70	Mixed	0.51	13.55	0.732			27.09	1.121		
RIPPND1	PDM	31	15	P	11.01	Mixed	0.50	6.25	0.537			12.51	0.748		
ROTHBY1	KW	297	15	P	11.03	Mixed	0.45	99.36	2.3235			198.72	2.4955		
Rotherham	ISIS	NA	15	P	10.99	Level	0.59	NA	1.5975			NA	1.894		
Rotherham_Tesco	ISIS	571	15	P	5.17	Level	0.47	56.25	0.747			112.50	1.155		
Rowell_Bridge	ISIS	37	15	P	9.27	Mixed	0.26	5.15	0.318			10.31	0.483		
RPNURE1	KW	577	15	P	11.02	Mixed	0.53	168.40	3.1215			336.80	3.275		
RUTHBR5	PDM	85	15	P	11.02	Mixed	0.40	46.36	1.607			92.73	1.702		
SCARBH1	PDM	9	15	P	11.00	Mixed	0.37	3.13	0.318			6.26	0.395		
SHEEPB1	PDM	39	15	P	11.01	Mixed	0.48	6.57	0.636			13.13	0.976		
Sheffield_Station	KW	49	15	P	10.89	Mixed	0.52	8.71	0.193			10.48	0.2375		
SHILMR1	PDM	24	15	P	11.02	Mixed	0.36	10.92	0.814			14.92	0.942		
SINNIN1	PDM	67	15	P	9.33	Mixed	0.62	32.07	1.629			65.06	2.16		
SKELTN1	KW	2584	15	P	11.02	Mixed	0.59	198.57	3.546			397.14	5.737		
SKINNG5	PDM	40	15	P	9.16	Mixed	0.47	11.03	5.244			22.07	5.309		
SKIRFAREBR	PDM	NA	15	P	9.21	Mixed	0.59	39.12	1.117919			78.25	2.031059		
SKPMOR1	PDM	20	15	P	10.41	Mixed	0.63	4.72	0.912			9.43	1.448		
Snainton	PDM	4	15	P	11.04	Mixed	0.13	0.33	0.099			0.66	0.147		
Snaygill	ISIS	NA	15	P	10.99	Level	0.21	NA	4.0785			NA	4.1865		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
SOUTHP5	KW	133	15	P	11.02	Mixed	0.37	14.85	1.0495			29.71	1.109		
SOWRBY1	KW	221	15	P	11.01	Mixed	0.54	70.03	0.843			140.06	1.389		
Spr_Gdns_Dam	ISIS	NA	15	P	5.74	Level	0.47	7.04	0.823			14.08	1.156		
STAMFM1	PDM	30	15	P	11.02	Mixed	0.47	5.17	1.638			10.34	1.974		
STANHP1	KW	159	15	P	11.02	Mixed	0.63	77.10	2.133			154.21	2.2755		
STAVLY1	PDM	52	15	P	11.01	Mixed	0.57	5.45	1.045			10.91	1.602		
STHCH02	ISIS	57	15	P	10.86	Mixed	0.58	10.53	0.81			21.05	1.287		
STOCKB2	ISIS	293	15	P	10.99	Mixed	0.22	51.21	1.8835			102.42	2.091		
STOKES5	KW	34	15	P	11.02	Mixed	0.38	6.73	1.537			13.47	2.157		
SUNDBR1	KW	531	15	P	11.00	Mixed	0.52	152.80	2.23			305.59	2.8805		
TADCST1	KW	623	15	P	11.02	Mixed	0.49	157.11	2.476			314.23	3.304		
TEAMVL1	PDM	37	15	P	11.02	Mixed	0.47	5.85	0.706			11.70	0.996		
TODMDN1	PDM	18	15	P	9.50	Mixed	0.55	6.91	1.334			13.82	1.899		
VIEWLY_BR	KW	133	15	P	11.04	Mixed	0.42	11.60	1.412			23.21	1.919		
VIKING1	KW	2590	15	P	11.02	Mixed	0.61	203.83	2.514			407.65	4.252		
WAKEFD1	KW	619	15	P	11.01	Mixed	0.58	128.72	0.611			257.44	0.963		
WALDEN1	PDM	49	15	P	11.01	Mixed	0.28	3.61	0.632			7.22	1.005		
WALSDN1	PDM	7	15	P	11.01	Mixed	0.49	2.63	0.402			5.27	0.663		
WEARHD1	PDM	23	15	P	10.94	Mixed	0.70	9.86	1.1155			19.72	1.158		
West_Auckland	ISIS	39	15	P	8.61	Mixed	0.32	7.50	0.918			10.00	1.0665		
WESTAY1	ISIS	92	15	P	11.00	Mixed	0.14	3.05	0.5385			6.11	0.5765		
WESTWK1	KW	737	15	P	11.01	Mixed	0.66	153.87	1.517			307.75	2.481		
Wharncliffe	ISIS	123	15	P	11.00	Mixed	0.42	23.34	1.709			46.68	2.157		
WHITTN1	KW	119	15	P	11.01	Mixed	0.45	16.82	1.222			33.65	2.022		
Wincobank	KW	30	15	P	10.74	Mixed	0.44	5.21	1.062			10.42	1.677		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
WITTNP1	KW	387	15	P	11.01	Mixed	0.68	134.24	3.0755			268.47	3.592		
WOODHS1	ISIS	254	15	P	10.99	Mixed	0.51	24.59	1.461			49.18	2.105		
WOOLSN1	PDM	8	15	P	11.02	Mixed	0.37	1.86	0.916			3.72	1.249		
Yarm5	ISIS	NA	15	P	11.00	Level	0.56	NA	3.093			NA	3.5925		

NORTH WEST

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
690160	PDM	124	15	P	8.74	Flow	0.74	58.02	NA			116.05	NA		
690205	PDM	133	15	P	8.99	Flow	0.54	73.26	NA			83.65	NA		
690207	PDM	48	15	P	9.00	Flow	0.83	8.54	NA			17.08	NA		
690611	PDM	41	15	P	3.07	Flow	0.75	27.28	NA			36.05	NA		
690713	PDM	31	15	P	3.57	Flow	0.82	6.94	NA			13.89	NA		
692115	PDM	NA	15	P	4.45	Flow	0.21	6.29	NA			7.18	NA		
692190	PDM	133	15	P	9.00	Flow	0.30	28.43	NA			56.86	NA		
692220	PDM	NA	15	P	8.65	Flow	0.46	11.02	NA			13.18	NA		
692330	PDM	NA	15	P	7.07	Flow	0.50	3.94	NA			5.20	NA		
692418	PDM	33	15	P	9.02	Flow	0.74	9.17	NA			18.35	NA		
692422	PDM	104	15	P	9.00	Flow	0.47	47.74	NA			55.20	NA		
692423	PDM	116	15	P	9.00	Flow	0.33	50.78	NA			61.01	NA		
692524	PDM	437	15	P	9.00	Flow	0.64	156.87	NA			199.31	NA		
692625	PDM	NA	15	P	2.26	Flow	0.55	6.73	NA			8.84	NA		
692727	PDM	NA	15	P	3.57	Flow	0.58	96.08	NA			121.95	NA		
692800	PDM	14	15	P	9.00	Flow	0.21	9.78	NA			11.40	NA		
692830	PDM	0	15	P	8.18	Flow	0.25	0.86	NA			1.01	NA		
693031	PDM	NA	15	P	8.99	Flow	0.72	29.50	NA			33.30	NA		
693115	PDM	NA	15	P	4.20	Flow	0.28	0.76	NA			0.83	NA		
693321	PDM	NA	15	P	8.99	Flow	0.41	1.97	NA			2.90	NA		
693421	PDM	NA	15	P	3.66	Flow	0.60	2.89	NA			3.52	NA		
693515	PDM	180	15	P	9.09	Flow	0.59	23.34	NA			27.84	NA		
700295	PDM	NA	15	P	8.97	Flow	0.61	15.89	NA			19.60	NA		
700325	PDM	49	15	P	8.97	Flow	0.65	17.25	NA			18.90	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
710151	PDM	102	15	P	9.00	Flow	0.33	117.13	NA			121.74	NA		
711610	PDM	248	15	P	8.93	Flow	0.81	119.51	NA			239.02	NA		
680301	G2G	137	15	P	5.00	Flow	0.47	9.97	NA			11.04	NA		
680403	G2G	69	15	P	5.00	Flow	0.50	6.69	NA			10.02	NA		
680504	G2G	411	15	P	5.00	Flow	0.52	20.88	NA			41.76	NA		
681003	G2G	65	15	P	5.00	Flow	0.54	29.50	NA			37.78	NA		
681006	G2G	126	15	P	5.00	Flow	0.60	33.96	NA			42.10	NA		
681210	G2G	307	15	P	5.00	Flow	0.42	54.86	NA			69.04	NA		
681213	G2G	103	15	P	5.00	Flow	0.58	26.56	NA			30.20	NA		
684027	G2G	108	15	P	5.00	Flow	0.50	6.00	NA			11.99	NA		
690140	G2G	80	15	P	5.00	Flow	0.24	81.51	NA			112.99	NA		
690160	G2G	124	15	P	5.00	Flow	0.56	91.69	NA			107.34	NA		
690203	G2G	82	15	P	5.00	Flow	0.62	27.87	NA			31.10	NA		
690205	G2G	133	15	P	5.00	Flow	0.41	82.40	NA			96.86	NA		
690206	G2G	13	15	P	5.00	Flow	0.30	7.57	NA			9.78	NA		
690207	G2G	48	15	P	5.00	Flow	0.68	8.54	NA			17.08	NA		
690408	G2G	94	15	P	5.00	Flow	0.53	48.82	NA			57.95	NA		
690510	G2G	397	15	P	5.00	Flow	0.64	210.12	NA			254.55	NA		
690611	G2G	41	15	P	5.00	Flow	0.78	27.63	NA			37.75	NA		
690713	G2G	31	15	P	5.00	Flow	0.44	10.01	NA			12.05	NA		
692190	G2G	133	15	P	5.00	Flow	0.41	34.13	NA			50.48	NA		
692348	G2G	98	15	P	5.00	Flow	0.72	16.70	NA			23.75	NA		
692370	G2G	158	15	P	5.00	Flow	0.64	37.98	NA			54.27	NA		
692418	G2G	33	15	P	5.00	Flow	0.59	11.91	NA			13.35	NA		
692421	G2G	95	15	P	5.00	Flow	0.61	43.85	NA			53.85	NA		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
692423	G2G	116	15	P	5.00	Flow	0.63	41.32	NA			46.10	NA		
692524	G2G	437	15	P	5.00	Flow	0.62	128.89	NA			208.96	NA		
692726	G2G	516	15	P	5.00	Flow	0.52	147.25	NA			348.16	NA		
692800	G2G	14	15	P	5.00	Flow	0.54	9.83	NA			10.39	NA		
692825	G2G	7	15	P	5.00	Flow	0.35	9.39	NA			11.26	NA		
693132	G2G	28	15	P	5.00	Flow	0.57	4.69	NA			6.50	NA		
693333	G2G	42	15	P	5.00	Flow	0.47	9.51	NA			11.56	NA		
693435	G2G	47	15	P	5.00	Flow	0.51	13.21	NA			19.62	NA		
693515	G2G	180	15	P	5.00	Flow	0.64	17.33	NA			34.65	NA		
694039	G2G	94	15	P	5.00	Flow	0.57	14.50	NA			29.01	NA		
694744	G2G	49	15	P	5.00	Flow	0.54	10.73	NA			21.45	NA		
700408	G2G	56	15	P	5.00	Flow	0.42	22.45	NA			44.90	NA		
700509	G2G	40	15	P	5.00	Flow	0.48	23.90	NA			29.88	NA		
710151	G2G	102	15	P	5.00	Flow	0.38	109.60	NA			121.56	NA		
710301	G2G	363	15	P	5.00	Flow	0.38	248.33	NA			301.46	NA		
710305	G2G	391	15	P	5.00	Flow	0.54	241.83	NA			288.73	NA		
711610	G2G	248	15	P	5.00	Flow	0.77	187.09	NA			211.19	NA		
712052	G2G	17	15	P	5.00	Flow	0.05	20.55	NA			25.83	NA		
712113	G2G	88	15	P	5.00	Flow	0.34	76.18	NA			101.94	NA		
712615	G2G	260	15	P	5.00	Flow	0.42	157.57	NA			193.54	NA		
713019	G2G	999	15	P	5.00	Flow	0.66	476.30	NA			623.83	NA		
713056	G2G	920	15	P	5.00	Flow	0.61	550.12	NA			646.45	NA		
713120	G2G	29	15	P	5.00	Flow	0.39	26.32	NA			29.34	NA		
713122	G2G	96	15	P	5.00	Flow	0.40	68.99	NA			83.26	NA		
720101	G2G	45	15	P	5.00	Flow	0.31	51.13	NA			66.23	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^{3}s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^{3}s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
720102	G2G	86	15	P	5.00	Flow	0.57	60.94	NA			73.85	NA		
720105	G2G	110	15	P	5.00	Flow	0.30	101.75	NA			136.65	NA		
720107	G2G	111	15	P	5.00	Flow	0.39	110.71	NA			116.74	NA		
720120	G2G	NA	15	P	5.00	Flow	0.27	80.75	NA			101.50	NA		
720215	G2G	27	15	P	5.00	Flow	0.47	25.23	NA			29.26	NA		
720517	G2G	253	15	P	5.00	Flow	0.68	115.75	NA			133.77	NA		
722242	G2G	122	15	P	5.00	Flow	0.03	217.45	NA			268.29	NA		
723423	G2G	185	15	P	5.00	Flow	0.37	142.30	NA			284.61	NA		
724326	G2G	117	15	P	5.00	Flow	0.34	109.02	NA			126.22	NA		
724427	G2G	80	15	P	5.00	Flow	0.01	143.33	NA			217.35	NA		
724528	G2G	204	15	P	5.00	Flow	0.04	218.21	NA			253.61	NA		
724629	G2G	886	15	P	5.00	Flow	0.36	567.55	NA			663.73	NA		
724647	G2G	901	15	P	5.00	Flow	0.30	590.56	NA			716.90	NA		
724836	G2G	22	15	P	5.00	Flow	0.50	14.79	NA			18.22	NA		
730120	G2G	68	15	P	5.00	Flow	0.69	61.54	NA			70.17	NA		
730203	G2G	33	15	P	5.00	Flow	0.31	39.66	NA			49.05	NA		
730404	G2G	58	15	P	5.00	Flow	0.47	58.86	NA			72.99	NA		
730507	G2G	168	15	P	5.00	Flow	0.64	105.68	NA			127.23	NA		
730511	G2G	180	15	P	5.00	Flow	0.58	157.03	NA			177.32	NA		
733020	G2G	25	15	P	5.00	Flow	0.39	18.88	NA			22.94	NA		
740101	G2G	46	15	P	5.00	Flow	0.71	55.20	NA			61.72	NA		
740102	G2G	77	15	P	5.00	Flow	0.56	96.32	NA			120.99	NA		
742006	G2G	63	15	P	5.00	Flow	0.65	90.89	NA			106.56	NA		
743509	G2G	41	15	P	5.00	Flow	0.77	42.76	NA			49.81	NA		
744312	G2G	108	15	P	5.00	Flow	0.64	59.04	NA			65.35	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
750504	G2G	58	15	P	3.08	Flow	0.52	46.35	NA			49.24	NA		
750806	G2G	132	15	P	5.00	Flow	0.71	53.95	NA			107.90	NA		
750832	G2G	134	15	P	5.00	Flow	0.49	95.45	NA			123.66	NA		
751110	G2G	332	15	P	5.00	Flow	0.22	78.64	NA			106.92	NA		
751613	G2G	107	15	P	5.00	Flow	0.68	40.51	NA			59.37	NA		
751690	G2G	116	15	P	5.00	Flow	0.58	43.24	NA			55.52	NA		
754016	G2G	75	15	P	5.00	Flow	0.49	37.41	NA			41.78	NA		
760101	G2G	56	15	P	5.00	Flow	0.35	71.64	NA			89.19	NA		
760112	G2G	193	15	P	5.00	Flow	0.44	141.00	NA			152.97	NA		
760502	G2G	474	15	P	5.00	Flow	0.39	263.57	NA			328.24	NA		
761104	G2G	132	15	P	5.00	Flow	0.59	104.52	NA			132.47	NA		
761260	G2G	59	15	P	5.00	Flow	0.62	30.60	NA			61.20	NA		
761605	G2G	133	15	P	5.00	Flow	0.10	38.21	NA			52.76	NA		
761706	G2G	29	15	P	5.00	Flow	0.69	17.20	NA			34.40	NA		
762006	G2G	334	15	P	5.00	Flow	0.55	182.14	NA			217.06	NA		
762505	G2G	1052	15	P	5.00	Flow	0.44	422.98	NA			512.77	NA		
763201	G2G	29	15	P	5.00	Flow	0.04	26.45	NA			33.10	NA		
763308	G2G	283	15	P	5.00	Flow	0.27	149.19	NA			225.67	NA		
764009	G2G	84	15	P	5.00	Flow	0.55	29.96	NA			41.58	NA		
765013	G2G	183	15	P	5.00	Flow	0.57	111.62	NA			139.15	NA		
765512	G2G	1713	15	P	5.00	Flow	0.41	587.97	NA			650.53	NA		
765850	G2G	49	15	P	5.00	Flow	0.34	27.05	NA			35.60	NA		
770302	G2G	174	15	P	5.00	Flow	0.02	156.56	NA			161.35	NA		
680504	PDM	411	15	P	12.57	Level	0.51	20.88	1.437			41.76	2.406		
681210	PDM	307	15	P	12.57	Level	0.39	39.39	2.9235			78.78	3.2355		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
690140	PRTF	80	15	P	12.56	Level	0.16	70.56	1.471			141.13	1.939		
690207	PRTF	48	15	P	12.58	Level	0.48	8.54	1.131			17.08	1.659		
692190	ISIS 1	133	15	P	12.58	Level	0.42	28.43	0.842			56.86	1.33		
692370	ISIS 1	158	15	P	12.57	Level	0.44	37.08	1.3585			74.16	1.56		
692422	ISIS 1	104	15	P	12.58	Level	0.24	28.33	0.912			56.66	1.305		
692524	ISIS 1	437	15	P	12.58	Level	0.44	136.08	2.335			272.16	3.55		
693426	ISIS	NA	15	P	4.36	Level	0.53	NA	1.1955			NA	1.5395		
694039	PDM	94	15	P	12.49	Level	0.80	14.50	1.485			29.01	2.517		
694042	ISIS 1	NA	15	P	6.46	Level	0.52	15.12	1.749823			30.25	2.675566		
700309	PDM	NA	15	P	7.07	Level	0.46	23.07	1.547			46.13	1.721		
700311	PDM	NA	15	P	6.96	Level	0.42	24.78	2.2015			49.56	2.5045		
700325	ISIS	49	15	P	12.49	Level	0.56	11.42	0.847			22.84	1.398		
700408	PDM	56	15	P	12.57	Level	0.47	22.45	1.4395			44.90	1.738		
710315	PDM	NA	15	P	2.02	Level	0.65	NA	0.501			NA	0.571		
710320	PDM	NA	15	P	5.74	Level	0.57	NA	0.769			NA	0.9425		
712052	PDM	17	15	P	12.55	Level	0.49	14.43	1.0915			28.85	1.2255		
712170	PDM	NA	15	P	2.54	Level	0.66	10.58	0.841672			21.16	1.216604		
712175	PDM	NA	15	P	2.59	Level	0.68	4.03	0.696			8.07	0.85		
712221	PDM	NA	15	P	4.70	Level	0.41	6.61	0.8855			13.22	1.0025		
712415	PDM	NA	15	P	2.41	Level	0.52	10.68	0.635455			21.37	0.811297		
713019	PDM	999	15	P	12.57	Level	0.61	350.70	3.75			701.41	5.312		
713119	PDM	NA	15	P	6.74	Level	0.58	NA	1.333			NA	1.524		
713122	ISIS	96	15	P	12.40	Level	0.53	49.60	1.576			99.20	2.278		
713205	PDM	NA	15	P	7.54	Level	0.62	1.50	0.258133			2.99	0.385502		
720101	PDM	45	15	P	12.57	Level	0.47	36.85	0.557			73.71	0.862		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
720102	ISIS 1	86	15	P	12.57	Level	0.30	74.50	1.0565			149.00	1.082		
720107	ISIS 1	111	15	P	12.57	Level	0.43	60.75	2.148			121.49	3.245		
720120	PDM	NA	15	P	7.47	Level	0.42	74.50	1.723			149.00	1.7995		
720215	PDM	27	15	P	12.57	Level	0.39	18.44	1.175			36.88	1.253		
720248	ISIS	33	15	P	12.57	Level	0.66	19.15	2.296			38.29	3.524		
720517	ISIS 1	253	15	P	12.57	Level	0.41	69.92	4.469			139.83	4.646		
720535	ISIS	NA	15	P	7.58	Level	0.55	NA	9.145			NA	9.52		
720780	ISIS	NA	15	P	8.62	Level	0.24	NA	1.3635			NA	1.6435		
722421	ISIS 1	199	15	P	12.56	Level	0.77	169.66	1.755			339.32	2.342		
724320	PDM	NA	15	P	6.93	Level	0.69	40.08	1.548568			80.17	2.076211		
724528	PDM	204	15	P	12.55	Level	0.58	133.66	1.311			267.32	1.779		
724647	ISIS	901	15	P	8.99	Level	0.36	413.40	1.677			826.81	1.8965		
730120	PDM	68	15	P	12.57	Level	0.61	41.93	1.167			83.86	1.797		
730404	PDM	58	15	P	12.57	Level	0.76	38.62	1.422			77.24	1.91		
730507	PDM	168	15	P	12.48	Level	0.63	77.03	2.265			154.07	2.86		
730511	ISIS	180	15	P	12.48	Level	0.79	115.03	1.635			230.07	2.272		
744312	ISIS	108	15	P	12.56	Level	0.49	36.53	1.875			73.06	1.974		
750106	ISIS 1	NA	15	P	12.57	Level	0.41	NA	2.5285			NA	2.839		
750504	PDM	58	15	P	12.57	Level	0.86	27.89	1.587			55.78	2.393		
750806	ISIS1	132	15	P	12.57	Level	0.70	53.95	1.462			107.90	1.87		
750832	ISIS	134	15	P	11.85	Level	0.57	62.67	3.666			125.35	3.78		
751007	ISIS	217	15	P	12.57	Level	0.61	60.97	2.477			121.94	2.6755		
751110	ISIS	332	15	P	12.57	Level	0.66	77.25	2.05			154.49	2.653		
751612	ISIS	60	15	P	12.57	Level	0.43	36.54	1.566			73.07	2.132		
751613	ISIS	107	15	P	12.57	Level	0.41	46.41	1.516			92.82	2.086		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
751690	ISIS	116	15	P	11.83	Level	0.31	47.13	2.1315			94.26	2.51		
752020	ISIS	NA	15	P	1.69	Level	0.12	NA	1.4535			NA	1.849		
753050	ISIS	NA	15	P	1.44	Level	0.06	NA	1.1095			NA	1.22		
760101	PDM	56	15	P	11.74	Level	0.47	46.51	1.453			93.02	2.144		
760112	ISIS	193	15	P	11.94	Level	0.48	100.00	2.3705			200.00	2.594		
760115	ISIS	287	15	P	12.57	Level	0.65	113.21	1.819			226.41	2.953		
760502	ISIS	474	15	P	12.57	Level	0.52	177.60	3.3955			355.19	3.523		
761104	PDM	132	15	P	12.57	Level	0.51	83.78	2.1615			167.56	2.354		
761605	ISIS	133	15	P	12.49	Level	0.56	33.06	1.2695			66.13	1.3525		
761659	ISIS	NA	15	P	12.49	Level	0.42	NA	1.758			NA	1.8655		
761706	PDM	29	15	P	12.57	Level	0.61	17.20	0.968			34.40	1.345		
762006	ISIS	334	15	P	12.49	Level	0.52	121.48	1.559			242.96	2.224		
762505	ISIS	1052	15	P	12.57	Level	0.71	281.95	2.49			563.90	4.063		
762540	ISIS	NA	15	P	12.57	Level	0.46	NA	3.619			NA	3.7165		
763308	PDM	283	15	P	12.57	Level	0.49	119.07	2.283			238.13	3.308		
764010	ISIS	NA	15	P	2.72	Level	0.52	18.72	1.120545			37.44	1.482742		
764050	PDM	74	15	P	7.30	Level	0.41	18.14	1.486375			36.28	1.906735		
764070	ISIS	NA	15	P	10.77	Level	0.36	NA	1.8425			NA	2.013		
765013	ISIS	183	15	P	12.57	Level	0.41	81.48	1.866			162.95	2.832		
765045	ISIS	NA	15	P	11.85	Level	0.31	NA	2.4335			NA	2.705		
765512	ISIS	1713	15	P	12.57	Level	0.49	390.19	4.319			780.38	4.536		
765850	PDM	49	15	P	12.57	Level	0.36	20.50	1.056			41.00	1.529		
690140	PDM	80	15	P	12.57	Level	0.44	70.56	1.471			141.13	1.939		
690510	PDM	397	15	P	12.57	Level	0.62	147.85	2.578			295.71	3.64		
693132	PDM	28	15	P	12.57	Level	0.31	3.58	0.862			7.15	0.9495		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
694039	ISIS	94	15	P	12.55	Level	0.82	14.50	1.485			29.01	2.517		
700325	PDM	49	15	P	12.48	Level	0.57	11.42	1.103			22.84	1.2765		
712153	PDM	83	15	P	12.57	Level	0.53	27.43	1.002			54.87	1.528		
713120	ISIS	29	15	P	12.47	Level	0.63	17.87	1.126			35.73	1.464		
713122	PDM	96	15	P	12.38	Level	0.67	49.60	2.0185			99.20	2.113		
720102	ISIS 2	86	15	P	12.57	Level	0.33	74.50	1.0565			149.00	1.082		
720105	ISIS	110	15	P	11.66	Level	0.06	131.79	2.5635			263.58	3.3235		
720107	ISIS 2	111	15	P	12.57	Level	0.45	60.75	2.148			121.49	3.245		
720120	ISIS 1	NA	15	P	7.46	Level	0.25	74.50	1.631			149.00	1.7635		
720517	ISIS 2	253	15	P	12.57	Level	0.42	69.92	4.469			139.83	4.646		
722421	ISIS 2	199	15	P	12.56	Level	0.77	169.66	1.755			339.32	2.342		
724528	ISIS1	204	15	P	12.56	Level	0.50	133.66	1.311			267.32	1.779		
724629	ISIS	886	15	P	12.56	Level	0.67	354.11	3.282			708.21	5.107		
730203	PDM	33	15	P	12.57	Level	0.70	28.58	1.027			57.15	1.443		
730511	PDM	180	15	P	12.48	Level	0.63	115.03	1.635			230.07	2.272		
744130	PDM	98	15	P	7.69	Level	0.60	55.52	2.0015			111.03	2.264		
750106	ISIS 2	NA	15	P	12.57	Level	0.73	NA	2.5285			NA	2.839		
750806	PRTF	132	15	P	12.56	Level	0.58	53.95	1.462			107.90	1.87		
751110	ISIS2	332	15	P	12.57	Level	0.47	77.25	2.05			154.49	2.653		
751613	ISIS2	107	15	P	12.57	Level	0.38	46.41	1.516			92.82	2.086		
751690	ISIS2	116	15	P	11.83	Level	0.44	47.13	2.1315			94.26	2.51		
760112	ISIS2	193	15	P	11.94	Level	0.47	100.00	2.3705			200.00	2.594		
760115	ISIS2	287	15	P	12.57	Level	0.66	113.21	1.819			226.41	2.953		
760502	ISIS2	474	15	P	12.57	Level	0.50	177.60	3.3955			355.19	3.523		
761605	ISIS2	133	15	P	12.49	Level	0.63	33.06	1.2695			66.13	1.3525		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
762006	PDM	334	15	P	12.49	Level	0.44	121.48	1.559			242.96	2.224		
762505	ISIS2	1052	15	P	12.57	Level	0.73	281.95	2.49			563.90	4.063		
764010	PDM	NA	15	P	2.72	Level	0.55	18.72	1.120545			37.44	1.482742		
765013	PDM	183	15	P	12.57	Level	0.40	81.48	2.4625			162.95	2.608		
765512	PDM	1713	15	P	12.57	Level	0.49	390.19	4.319			780.38	4.536		
713122	ISIS2	96	15	P	12.40	Level	0.55	49.60	1.576			99.20	2.278		
720102	PRTF	86	15	P	12.55	Level	0.58	74.50	1.0595			149.00	1.0945		
720120	ISIS 2	NA	15	P	7.46	Level	0.21	74.50	1.712			149.00	1.778		
724528	ISIS2	204	15	P	12.56	Level	0.53	133.66	1.311			267.32	1.779		
730507	ISIS	168	15	P	12.48	Level	0.70	77.03	2.265			154.07	2.86		
750806	ISIS2	132	15	P	12.57	Level	0.64	53.95	1.462			107.90	1.87		
760112	PDM	193	15	P	11.86	Level	0.52	100.00	2.349			200.00	2.499		
760502	PDM	474	15	P	12.57	Level	0.38	177.60	3.3955			355.19	3.523		
762006	ISIS2	334	15	P	12.49	Level	0.56	121.48	1.559			242.96	2.224		

SOUTH WEST

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
43108	PRTF	48	60	P	14.34	Level	0.35	6.89	2.036			13.79	2.2485		
43114	PRTF	37	60	P	12.29	Level	0.61	2.24	0.488			4.49	0.758		
43209	PRTF	390	60	P	14.11	Level	0.67	50.53	2.218			101.06	2.748		
44109	PRTF	11	15	P	13.10	Level	0.48	2.82	0.43			5.64	0.5205		
44110	PRTF	33	15	P	13.10	Level	0.71	7.03	0.523			14.05	0.781		
44115	PRTF	NA	15	P	14.37	Level	0.36	NA	2.448			NA	2.992		
44122	PRTF	33	15	P	14.14	Level	0.47	7.05	0.9745			14.09	1.1915		
44149	PRTF	NA	15	P	2.02	Level	0.36	NA	1.6225			NA	1.7655		
44204	PRTF	49	15	P	14.28	Level	0.59	3.47	0.325			6.94	0.513		
45117	PRTF	216	15	P	15.15	Level	0.73	34.62	2.9875			69.23	3.373		
45118	PRTF	487	60	P	14.11	Level	0.61	89.67	1.399			179.34	2.215		
45119	PRTF	157	60	P	14.14	Level	0.43	38.50	1.956			77.00	2.537		
45120	PRTF	341	60	P	14.15	Level	0.49	62.35	2.396			124.69	3.14		
45132	PRTF	30	60	P	14.09	Level	0.76	7.34	1.201			14.68	1.586		
45159	PRTF	52	15	P	5.06	Level	0.32	18.04	1.5955			36.08	1.759		
45209	PRTF	16	15	P	15.20	Level	0.19	5.56	1.6335			11.12	1.935		
45210	PRTF	70	15	P	14.33	Level	0.42	31.90	1.442			63.80	1.995		
45217	PRTF	NA	15	P	15.43	Level	0.47	8.78	0.353			17.56	0.707		
45223	PRTF	63	60	P	14.26	Level	0.59	18.41	1.225			36.82	2.108		
46122	PRTF	192	60	P	14.24	Level	0.71	113.09	1.927			226.18	2.82		
46123	PRTF	19	60	P	14.23	Level	0.41	17.85	1.457			35.71	1.886		
46128	PRTF	25	15	P	14.11	Level	0.47	7.01	1.429			14.02	1.6885		
46129	PRTF	13	60	P	14.22	Level	0.56	2.83	0.664			5.66	0.946		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	Tₗ Flow (m³s⁻¹)	Tₗ Level (m)	Tₗ 2h	Tₗ 12h	Tᵤ Flow (m³s⁻¹)	Tᵤ Level (m)	Tᵤ 2h	Tᵤ 12h
46133	PRTF	69	15	P	8.28	Level	0.65	11.74	1.441			23.48	1.7085		
46135	PRTF	190	15	P	10.18	Level	0.28	36.06	2.8375			72.12	3.0075		
47118	PRTF	30	15	P	13.92	Level	0.71	16.47	1.095			32.93	1.204		
47119	PRTF	NA	15	P	7.17	Level	0.05	NA	1.316			NA	1.316		
47133	PRTF	67	15	P	14.24	Level	0.33	9.69	1.9515			19.39	2.021		
47136	PRTF	100	15	P	14.00	Level	0.56	23.54	1.317			47.08	1.875		
49110	PRTF	125	60	P	14.17	Level	0.76	24.18	1.328			48.37	1.7155		
49113	PRTF	11	15	P	15.12	Level	0.37	1.75	1.258			3.49	1.402		
49115	PRTF	16	15	P	14.21	Level	0.50	2.37	0.6695			4.74	0.7315		
49120	PRTF	26	15	P	14.17	Level	0.42	6.22	1.4095			12.43	1.575		
49134	PRTF	36	15	P	14.28	Level	0.55	10.21	1.072			20.42	1.495		
50114	PRTF	60	60	P	14.16	Level	0.54	7.97	0.817			15.93	1.117		
50117	PRTF	457	60	P	14.11	Level	0.57	113.83	3.4795			227.67	3.6215		
50150	PRTF	NA	15	P	13.98	Level	0.42	NA	2.91			NA	2.91		
50153	PRTF	NA	15	P	14.02	Level	0.72	NA	0.725			NA	1.1655		
51107	PRTF	25	15	P	13.11	Level	0.69	2.63	0.759			5.26	0.8355		
52108	PRTF	53	15	P	14.09	Level	0.51	7.56	0.945			15.12	1.5		
52109	PRTF	156	60	P	14.10	Level	0.65	20.86	1.017			41.72	1.895		
52111	PRTF	244	60	P	3.04	Level	0.29	42.95	1.58			85.90	1.58		
52113	PRTF	NA	15	P	15.20	Level	0.39	NA	1.224			NA	1.41		
52114	PRTF	68	15	P	14.10	Level	0.40	17.50	1.977			35.01	2.0785		
52116	PRTF	58	60	P	14.14	Level	0.52	13.46	1.778			26.92	2.254		
52117	PRTF	147	60	P	14.10	Level	0.70	22.71	2.357			45.42	3.835		
52130	PRTF	9	60	P	14.23	Level	0.33	3.63	1.667			7.26	1.8565		
52204	PRTF	34	60	P	13.28	Level	0.57	4.49	0.663			8.99	1.12		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
52207	PRTF	90	60	P	14.11	Level	0.62	25.66	1.936			51.33	3.004		
531112	PRTF	18	60	P	14.15	Level	0.37	3.38	0.8035			6.77	1.0045		
531116	PRTF	67	60	P	14.11	Level	0.44	16.55	2.236			33.09	2.508		
53119	PRTF	65	60	P	12.08	Level	0.79	10.81	0.898			21.63	1.383		
53120	PRTF	164	60	P	12.08	Level	0.59	28.91	2.483			57.81	3.265		
53122	PRTF	45	60	P	12.62	Level	0.83	4.96	1.143			9.92	1.3985		
53124	PRTF	91	60	P	12.08	Level	0.49	9.56	3.397			19.12	3.397		
53125	PRTF	74	60	P	13.25	Level	0.61	13.31	3.026			26.63	3.227		
53131	PRTF	31	60	P	13.92	Level	0.60	7.46	1.026			14.92	1.0935		
53134	PRTF	97	60	P	13.92	Level	0.63	13.84	1.799			27.67	2.367		
53135	PRTF	29	60	P	13.94	Level	0.41	3.40	0.548			6.80	0.754		
53136	PRTF	13	60	P	14.27	Level	0.27	5.54	0.753			11.08	1.169		
53139	PRTF	9	15	P	7.28	Level	0.57	4.61	1.1995			9.21	1.7055		
53143	PRTF	132	60	P	14.23	Level	0.44	22.92	1.091			45.84	1.534		
53183	PRTF	10	15	P	10.23	Level	0.34	1.88	0.7435			3.77	0.8025		
53192	PRTF	8	60	P	5.34	Level	0.63	0.91	2.126			1.81	2.126		
43108	G2G	48	15	P	5.00	Flow	0.23	8.12	NA			11.87	NA		
43109	G2G	74	15	P	5.00	Flow	0.19	11.18	NA			13.41	NA		
43111	G2G	90	15	P	5.00	Flow	0.45	8.35	NA			9.59	NA		
43112	G2G	29	15	P	5.00	Flow	0.64	2.16	NA			4.32	NA		
43113	G2G	94	15	P	5.00	Flow	0.27	7.25	NA			8.78	NA		
43114	G2G	37	15	P	5.00	Flow	0.51	2.61	NA			4.37	NA		
43119	G2G	41	15	P	5.00	Flow	0.26	0.99	NA			1.98	NA		
43126	G2G	14	15	P	5.00	Flow	0.58	2.96	NA			5.91	NA		
43207	G2G	14	15	P	5.00	Flow	0.03	8.41	NA			11.60	NA		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
43212	G2G	577	15	P	5.00	Flow	0.30	82.88	NA			102.97	NA		
43213	G2G	552	15	P	5.00	Flow	0.20	78.05	NA			92.08	NA		
43214	G2G	85	15	P	5.00	Flow	0.38	9.74	NA			13.00	NA		
43216	G2G	48	15	P	5.00	Flow	0.39	3.17	NA			6.35	NA		
44122	G2G	33	15	P	5.00	Flow	0.51	7.05	NA			14.09	NA		
44206	G2G	44	15	P	5.00	Flow	0.37	3.44	NA			3.92	NA		
44207	G2G	161	15	P	5.00	Flow	0.35	13.75	NA			15.25	NA		
44216	G2G	2	15	P	5.00	Flow	0.63	0.57	NA			0.71	NA		
44220	G2G	6	15	P	5.00	Flow	0.25	0.40	NA			0.51	NA		
44221	G2G	3	15	P	5.00	Flow	0.49	0.64	NA			0.86	NA		
45117	G2G	216	15	P	5.00	Flow	0.41	45.07	NA			62.18	NA		
45118	G2G	487	15	P	5.00	Flow	0.48	89.67	NA			179.34	NA		
45119	G2G	157	15	P	5.00	Flow	0.41	38.50	NA			77.00	NA		
45120	G2G	341	15	P	5.00	Flow	0.48	62.35	NA			124.69	NA		
45121	G2G	98	15	P	5.00	Flow	0.04	75.43	NA			85.79	NA		
45122	G2G	115	15	P	5.00	Flow	0.28	34.87	NA			39.04	NA		
45125	G2G	216	15	P	5.00	Flow	0.41	88.07	NA			108.24	NA		
45132	G2G	30	15	P	5.00	Flow	0.45	7.34	NA			14.68	NA		
45134	G2G	192	15	P	5.00	Flow	0.52	35.19	NA			47.22	NA		
45135	G2G	419	15	P	5.00	Flow	0.41	82.21	NA			101.10	NA		
45139	G2G	41	15	P	3.84	Flow	0.37	11.62	NA			23.24	NA		
45142	G2G	932	15	P	5.00	Flow	0.48	184.90	NA			251.92	NA		
45159	G2G	52	15	P	3.79	Flow	0.49	19.50	NA			26.20	NA		
45210	G2G	70	15	P	5.00	Flow	0.60	39.64	NA			58.74	NA		
45211	G2G	203	15	P	5.00	Flow	0.34	60.50	NA			121.00	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
45212	G2G	139	15	P	5.00	Flow	0.48	48.23	NA			63.45	NA		
45223	G2G	63	15	P	5.00	Flow	0.44	18.41	NA			36.82	NA		
46111	G2G	24	15	P	5.00	Flow	0.03	9.35	NA			10.55	NA		
46118	G2G	27	15	P	5.00	Flow	0.04	38.59	NA			48.70	NA		
46119	G2G	78	15	P	5.00	Flow	0.28	58.52	NA			64.32	NA		
46122	G2G	192	15	P	5.00	Flow	0.34	157.51	NA			194.24	NA		
46123	G2G	19	15	P	5.00	Flow	0.31	28.00	NA			34.19	NA		
46126	G2G	40	15	P	5.00	Flow	0.03	63.85	NA			67.98	NA		
46128	G2G	25	15	P	5.00	Flow	0.48	9.92	NA			11.80	NA		
46129	G2G	13	15	P	5.00	Flow	0.48	2.83	NA			5.66	NA		
46133	G2G	69	15	P	5.00	Flow	0.37	20.41	NA			22.33	NA		
46135	G2G	190	15	P	4.00	Flow	0.37	51.97	NA			58.91	NA		
47115	G2G	419	15	P	5.00	Flow	0.41	124.50	NA			144.01	NA		
47116	G2G	193	15	P	5.00	Flow	0.56	62.03	NA			75.15	NA		
47117	G2G	794	15	P	5.00	Flow	0.42	202.87	NA			225.61	NA		
47118	G2G	30	15	P	5.00	Flow	0.30	27.44	NA			30.96	NA		
47121	G2G	58	15	P	5.00	Flow	0.23	39.63	NA			47.59	NA		
47124	G2G	51	15	P	5.00	Flow	0.52	28.44	NA			30.98	NA		
47125	G2G	37	15	P	5.00	Flow	0.47	25.15	NA			28.65	NA		
47129	G2G	102	15	P	5.00	Flow	0.26	42.98	NA			49.90	NA		
47133	G2G	67	15	P	5.00	Flow	0.32	16.17	NA			18.35	NA		
47136	G2G	100	15	P	5.00	Flow	0.31	36.51	NA			41.64	NA		
47139	G2G	84	15	P	5.00	Flow	0.13	25.15	NA			30.89	NA		
47141	G2G	34	15	P	5.00	Flow	0.40	4.65	NA			5.35	NA		
47165	G2G	5	15	P	5.00	Flow	0.34	2.35	NA			2.97	NA		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
48108	G2G	57	15	P	5.00	Flow	0.51	5.10	NA			10.20	NA		
48115	G2G	18	15	P	5.00	Flow	0.64	3.05	NA			3.66	NA		
48119	G2G	16	15	P	4.06	Flow	0.67	1.07	NA			2.15	NA		
48125	G2G	26	15	P	5.00	Flow	0.19	2.02	NA			4.04	NA		
48126	G2G	15	15	P	5.00	Flow	0.35	1.97	NA			2.34	NA		
48128	G2G	17	15	P	5.00	Flow	0.31	2.89	NA			3.44	NA		
48137	G2G	16	15	P	5.00	Flow	0.53	3.46	NA			3.74	NA		
48138	G2G	20	15	P	4.88	Flow	0.42	2.63	NA			2.88	NA		
49109	G2G	156	15	P	5.00	Flow	0.33	48.99	NA			73.99	NA		
49110	G2G	125	15	P	5.00	Flow	0.43	30.19	NA			36.92	NA		
49111	G2G	75	15	P	5.00	Flow	0.26	22.44	NA			27.14	NA		
49113	G2G	11	15	P	5.00	Flow	0.46	1.75	NA			3.49	NA		
49121	G2G	20	15	P	5.00	Flow	0.53	9.27	NA			10.66	NA		
49130	G2G	28	15	P	5.00	Flow	0.37	7.67	NA			11.42	NA		
49132	G2G	34	15	P	5.00	Flow	0.32	5.32	NA			5.85	NA		
50115	G2G	264	15	P	5.00	Flow	0.50	89.70	NA			110.19	NA		
50116	G2G	561	15	P	5.00	Flow	0.34	194.25	NA			224.80	NA		
50118	G2G	212	15	P	5.00	Flow	0.39	85.20	NA			93.75	NA		
50119	G2G	53	15	P	5.00	Flow	0.28	27.02	NA			33.91	NA		
50120	G2G	66	15	P	5.00	Flow	0.32	21.95	NA			43.90	NA		
50121	G2G	65	15	P	5.00	Flow	0.34	24.58	NA			49.15	NA		
50130	G2G	15	15	P	5.00	Flow	0.33	9.95	NA			11.75	NA		
50132	G2G	370	15	P	5.00	Flow	0.41	90.92	NA			116.18	NA		
50134	G2G	18	15	P	5.00	Flow	0.23	9.06	NA			18.13	NA		
50140	G2G	675	15	P	5.00	Flow	0.43	157.34	NA			211.11	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
50152	G2G	17	15	P	5.00	Flow	0.21	3.92	NA			4.94	NA		
51105	G2G	18	15	P	5.00	Flow	0.26	4.18	NA			8.35	NA		
51106	G2G	54	15	P	5.00	Flow	0.45	9.27	NA			10.85	NA		
51107	G2G	25	15	P	5.00	Flow	0.26	2.63	NA			5.26	NA		
52107	G2G	21	15	P	5.00	Flow	0.40	6.06	NA			10.14	NA		
52108	G2G	53	15	P	5.00	Flow	0.57	7.56	NA			15.12	NA		
52109	G2G	156	15	P	5.00	Flow	0.52	20.86	NA			41.72	NA		
52111	G2G	244	15	P	5.00	Flow	0.56	43.60	NA			66.98	NA		
52114	G2G	68	15	P	5.00	Flow	0.31	22.22	NA			31.94	NA		
52115	G2G	38	15	P	5.00	Flow	0.22	12.84	NA			16.52	NA		
52116	G2G	58	15	P	5.00	Flow	0.28	22.40	NA			25.82	NA		
52117	G2G	147	15	P	5.00	Flow	0.48	22.71	NA			45.42	NA		
52130	G2G	9	15	P	5.00	Flow	0.31	5.86	NA			6.81	NA		
52206	G2G	138	15	P	5.00	Flow	0.56	14.60	NA			29.19	NA		
52207	G2G	90	15	P	5.00	Flow	0.30	25.66	NA			51.33	NA		
531107	G2G	4	15	P	4.97	Flow	0.24	1.09	NA			1.80	NA		
531116	G2G	67	15	P	5.00	Flow	0.43	22.73	NA			30.90	NA		
531118	G2G	23	15	P	3.19	Flow	0.31	3.44	NA			4.07	NA		
53119	G2G	65	15	P	5.00	Flow	0.46	10.81	NA			21.63	NA		
53120	G2G	164	15	P	5.00	Flow	0.48	28.91	NA			57.81	NA		
53121	G2G	42	15	P	5.00	Flow	0.43	10.51	NA			13.52	NA		
53122	G2G	45	15	P	5.00	Flow	0.71	4.96	NA			9.92	NA		
53123	G2G	86	15	P	5.00	Flow	0.50	9.13	NA			18.25	NA		
53128	G2G	916	15	P	4.00	Flow	0.47	117.00	NA			156.50	NA		
53129	G2G	884	15	P	5.00	Flow	0.44	83.82	NA			167.65	NA		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	Tₗ Flow (m³s⁻¹)	Tₗ Level (m)	Tₗ 2h	Tₗ 12h	Tᵤ Flow (m³s⁻¹)	Tᵤ Level (m)	Tᵤ 2h	Tᵤ 12h
53130	G2G	58	15	P	5.00	Flow	0.18	5.71	NA			7.43	NA		
53131	G2G	31	15	P	5.00	Flow	0.26	9.64	NA			14.39	NA		
53132	G2G	61	15	P	5.00	Flow	0.63	5.81	NA			11.62	NA		
53134	G2G	97	15	P	5.00	Flow	0.60	20.75	NA			25.97	NA		
53135	G2G	29	15	P	5.00	Flow	0.41	3.40	NA			6.80	NA		
53136	G2G	13	15	P	5.00	Flow	0.26	7.67	NA			10.08	NA		
53137	G2G	3	15	P	5.00	Flow	0.27	0.63	NA			1.26	NA		
53139	G2G	9	15	P	5.00	Flow	0.26	4.15	NA			6.08	NA		
53141	G2G	57	15	P	5.00	Flow	0.40	5.83	NA			11.66	NA		
53143	G2G	132	15	P	5.00	Flow	0.42	24.68	NA			36.18	NA		
53153	G2G	12	15	P	5.00	Flow	0.03	4.29	NA			7.09	NA		
53154	G2G	28	15	P	5.00	Flow	0.03	20.09	NA			28.57	NA		
53155	G2G	547	15	P	5.00	Flow	0.47	44.03	NA			88.07	NA		
44122	PDM	33	15	P	11.00	Level	0.57	7.05	1.0435			14.09	1.1485		
44139	PDM	NA	15	P	4.84	Level	0.35	NA	2.0595			NA	2.171		

SOUTHERN

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
Adu.CheBri	G2G	18	15	P	3.48	Flow	0.43	10.33	NA			12.60	NA		
Adu.Hoesbr	G2G	21	15	P	5.00	Flow	0.37	4.20	NA			8.41	NA		
Adu.Sakeha	G2G	79	15	P	5.00	Flow	0.44	29.07	NA			33.44	NA		
Aru.Alfold	G2G	130	15	P	5.00	Flow	0.28	37.30	NA			41.11	NA		
Aru.HalBri	G2G	40	15	P	5.00	Flow	0.36	13.04	NA			16.34	NA		
Aru.IpiMil	G2G	92	15	P	5.00	Flow	0.38	24.39	NA			32.86	NA		
Aru.Lodsbr	G2G	136	15	P	5.00	Flow	0.30	55.17	NA			59.99	NA		
Aru.NewBri	G2G	249	15	P	5.00	Flow	0.49	42.20	NA			51.00	NA		
Aru.Pallin	G2G	321	15	P	5.00	Flow	0.41	75.58	NA			92.88	NA		
Aru.PriMar	G2G	23	15	P	5.00	Flow	0.04	13.72	NA			18.98	NA		
Cuc.CowWei	G2G	18	15	P	5.00	Flow	0.04	5.53	NA			7.09	NA		
Cuc.Leabri	G2G	31	15	P	5.00	Flow	0.04	10.54	NA			12.52	NA		
Dar.Crayfo	G2G	30	15	P	5.00	Flow	0.35	4.03	NA			5.56	NA		
Dar.Hawley	G2G	63	15	P	5.00	Flow	0.03	1.98	NA			2.48	NA		
Dar.Otford	G2G	43	15	P	5.00	Flow	0.26	6.72	NA			13.45	NA		
Dar.PaFarm	G2G	14	15	P	5.00	Flow	0.57	1.90	NA			2.26	NA		
EHS.NFareh	G2G	38	15	P	5.00	Flow	0.47	11.34	NA			16.11	NA		
Itc.Boroug	G2G	14	15	P	5.00	Flow	0.24	0.49	NA			0.98	NA		
Itc.Easton	G2G	37	15	P	5.00	Flow	0.11	2.94	NA			5.89	NA		
Itc.Seward	G2G	10	15	P	5.00	Flow	0.19	0.69	NA			1.37	NA		
IWS.Budbri	G2G	26	15	P	5.00	Flow	0.36	4.28	NA			5.06	NA		
IWS.BurntH	G2G	37	15	P	5.00	Flow	0.35	11.15	NA			11.55	NA		
IWS.CarrisM	G2G	3	15	P	5.00	Flow	0.20	0.38	NA			0.77	NA		
IWS.Freshw	G2G	3	15	P	5.00	Flow	0.47	0.39	NA			0.49	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
IWS.Shide	G2G	18	15	P	5.00	Flow	0.30	5.12	NA			6.56	NA		
Lym.Broc	G2G	83	15	P	5.00	Flow	0.50	18.40	NA			25.68	NA		
Lym.Meer	G2G	7	15	P	5.00	Flow	0.03	3.64	NA			4.21	NA		
Med.Collie	G2G	212	15	P	5.00	Flow	0.32	42.42	NA			58.86	NA		
Med.Hadlow	G2G	28	15	P	5.00	Flow	0.27	2.26	NA			4.51	NA		
Med.Hendal	G2G	43	15	P	5.00	Flow	0.05	22.33	NA			23.99	NA		
Med.Lamber	G2G	55	15	P	5.00	Flow	0.22	6.76	NA			8.86	NA		
Med.Pens	G2G	177	15	P	5.00	Flow	0.11	8.06	NA			8.07	NA		
Med.Smard	G2G	56	15	P	5.00	Flow	0.50	19.94	NA			27.23	NA		
Med.Summer	G2G	114	15	P	5.00	Flow	0.28	46.51	NA			48.79	NA		
Ous.ArdWei	G2G	36	15	P	5.00	Flow	0.30	9.51	NA			14.09	NA		
Ous.Goldbr	G2G	161	15	P	5.00	Flow	0.38	29.64	NA			38.16	NA		
Ous.IsfWei	G2G	75	15	P	5.00	Flow	0.03	33.17	NA			38.42	NA		
Rth.BredWW	G2G	39	15	P	4.00	Flow	0.32	9.92	NA			12.65	NA		
Rth.Burwas	G2G	26	15	P	5.00	Flow	0.03	14.57	NA			29.14	NA		
Rth.CrowhW	G2G	89	15	P	5.00	Flow	0.04	33.25	NA			38.75	NA		
Sto.BroMil	G2G	27	15	P	5.00	Flow	0.40	3.18	NA			3.61	NA		
Sto.ChaLea	G2G	41	15	P	5.00	Flow	0.40	2.38	NA			4.77	NA		
Sto.ES2.Ung	G2G	44	15	P	5.00	Flow	0.64	8.22	NA			11.10	NA		
Sto.Horton.Wei	G2G	173	15	P	5.00	Flow	0.21	14.22	NA			19.18	NA		
Sto.Wye	G2G	146	15	P	5.00	Flow	0.37	17.35	NA			21.19	NA		
Tst.Bosgtn	G2G	12	15	P	5.00	Flow	0.20	0.38	NA			0.76	NA		
Tst.Dunbge	G2G	34	15	P	5.00	Flow	0.47	3.13	NA			6.27	NA		
Tst.Millbr	G2G	11	15	P	5.00	Flow	0.38	3.14	NA			3.59	NA		
Tst.Ower	G2G	65	15	P	5.00	Flow	0.00	40.81	NA			41.12	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
Tst.RomsBR	G2G	14	15	P	5.00	Flow	0.45	1.28	NA			2.56	NA		
WSS.Westbo	G2G	13	15	P	5.00	Flow	0.46	2.46	NA			3.19	NA		
3240TH	ARMA TCM	116	15	F	8.99	Mixed	0.43	23.67	2.735			47.35	2.964		
Aru.Alfold	PDM	130	15	P	12.14	Level	0.57	21.65	1.358			43.30	2.325		
Aru.Fittle	ISIS	223	15	P	12.14	Level	0.22	47.57	5.469			95.15	5.5245		
Aru.HalBri	PDM	40	15	P	12.11	Level	0.43	10.88	0.843			21.76	1.328		
Aru.IpiMil	PDM	92	15	P	12.14	Level	0.50	17.62	1.005			35.24	1.49		
Aru.Lodsbr	PDM	136	15	P	11.32	Level	0.19	30.64	13.4175			61.28	13.4945		
Aru.Pallin	ISIS	321	15	P	12.14	Level	0.59	54.91	2.496			109.81	2.979		
Aru.PriMar	PDM	23	15	P	12.12	Level	0.56	10.00	0.938			20.01	1.433		
Aru.Tanbri	PDM	34	15	P	11.33	Level	0.41	1.72	0.743			3.44	1.113		
Dar.Crayfo	PDM	30	15	P	9.03	Level	0.44	3.51	0.401			7.03	0.568		
EHS.NFareh	PDM	38	15	P	9.07	Level	0.35	10.97	1.171			21.94	1.352		
IWS.Budbri	PDM	26	15	P	9.09	Level	0.38	3.14	0.685			6.28	1.004		
IWS.BurntH	PDM	37	15	P	9.09	Level	0.48	5.87	0.85			11.74	1.239		
Med.Collie	PDM	212	15	P	9.09	Level	0.32	32.66	3.8165			65.31	3.9345		
Med.Edenbr	PDM	108	15	P	9.03	Level	0.29	15.46	39.132			30.92	39.729		
Med.EstFar.Dns	ISIS	934	15	P	9.09	Level	0.27	130.60	6.77			261.19	7.016		
Med.Hadlow	PDM	28	15	P	9.09	Level	0.28	2.26	0.809			4.51	1.123		
Med.Hendal	PDM	43	15	P	9.03	Level	0.04	13.12	1.854			26.23	1.91		
Med.LiMill	ISIS	NA	15	P	6.63	Level	0.34	NA	13.703			NA	14.272		
Med.Smard	PDM	56	15	P	9.03	Level	0.23	18.43	21.385			36.87	21.515		
Med.StileB	PDM	187	15	P	8.99	Level	0.31	35.81	1.793			71.62	2.672		
Med.StoneB	PDM	110	15	P	9.03	Level	0.40	15.17	1.688			30.34	1.8935		
Med.Summer	PDM	114	15	P	9.03	Level	0.51	26.63	41.75			53.26	42.253		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
Med.Yaldin.Dns	ISIS	NA	15	P	9.09	Level	0.28	NA	9.704			NA	9.9845		

THAMES

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
0260TH	G2G	39	15	P	5.00	Flow	0.23	1.34	NA			2.68	NA		
0290TH	G2G	58	15	P	5.00	Flow	0.32	1.57	NA			3.14	NA		
0390TH	G2G	48	15	P	5.00	Flow	0.37	8.03	NA			16.07	NA		
0470TH	G2G	12	15	P	5.00	Flow	0.13	1.19	NA			2.38	NA		
0490TH	G2G	26	15	P	5.00	Flow	0.28	1.66	NA			3.32	NA		
0530TH	G2G	9	15	P	5.00	Flow	0.16	3.77	NA			7.54	NA		
0630TH	G2G	35	15	P	5.00	Flow	0.16	0.86	NA			1.72	NA		
0660TH	G2G	42	15	P	5.00	Flow	0.19	1.80	NA			3.60	NA		
0680TH	G2G	53	15	P	5.00	Flow	0.26	2.73	NA			5.46	NA		
0710TH	G2G	2	15	P	5.00	Flow	0.04	3.09	NA			3.36	NA		
0712TH	G2G	11	15	P	5.00	Flow	0.41	2.96	NA			3.83	NA		
0790TH	G2G	83	15	P	5.00	Flow	0.43	7.57	NA			15.14	NA		
1020TH	G2G	31	15	P	5.00	Flow	0.25	1.24	NA			1.39	NA		
1029TH	G2G	22	15	P	5.00	Flow	0.55	3.68	NA			4.46	NA		
1080TH	G2G	131	15	P	5.00	Flow	0.42	5.81	NA			11.62	NA		
1100TH	G2G	814	15	P	4.98	Flow	0.17	47.29	NA			63.72	NA		
1289TH	G2G	62	15	P	5.00	Flow	0.26	2.02	NA			4.04	NA		
1420TH	G2G	130	15	P	5.00	Flow	0.17	11.51	NA			24.47	NA		
1437TH	G2G	54	15	P	5.00	Flow	0.26	3.29	NA			3.99	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
1460_w1TH	G2G	348	15	P	5.00	Flow	0.39	9.68	NA			19.36	NA		
1471TH	G2G	14	15	P	5.00	Flow	0.44	2.35	NA			4.69	NA		
1483TH	G2G	86	15	P	5.00	Flow	0.25	7.33	NA			10.76	NA		
1489TH	G2G	206	15	P	5.00	Flow	0.28	7.55	NA			15.10	NA		
1490TH	G2G	598	15	P	5.00	Flow	0.18	22.50	NA			28.72	NA		
1790TH	G2G	164	15	P	5.00	Flow	0.27	6.85	NA			10.74	NA		
1800TH	G2G	1954	15	P	5.00	Flow	0.35	102.27	NA			128.59	NA		
1904TH	G2G	44	15	P	5.00	Flow	0.18	7.35	NA			14.70	NA		
1980TH	G2G	354	15	P	5.00	Flow	0.17	24.34	NA			31.46	NA		
1995TH	G2G	1	15	P	5.00	Flow	0.16	0.05	NA			0.10	NA		
2150TH	G2G	24	15	P	5.00	Flow	0.16	1.21	NA			1.44	NA		
2190TH	G2G	49	15	P	5.00	Flow	0.13	0.94	NA			1.88	NA		
2200TH	G2G	2572	15	P	5.00	Flow	0.33	115.96	NA			231.93	NA		
2210TH	G2G	30	15	P	5.00	Flow	0.30	1.69	NA			3.38	NA		
2219TH	G2G	9	15	P	5.00	Flow	0.15	0.43	NA			0.86	NA		
2230TH	G2G	55	15	P	5.00	Flow	0.21	3.72	NA			7.45	NA		
2239TH	G2G	21	15	P	5.00	Flow	0.25	1.45	NA			2.31	NA		
2241TH	G2G	8	15	P	5.00	Flow	0.54	0.56	NA			1.12	NA		
2250TH	G2G	133	15	P	5.00	Flow	0.24	5.75	NA			11.50	NA		
2264TH	G2G	7	15	P	5.00	Flow	0.26	0.24	NA			0.49	NA		
2269TH	G2G	39	15	P	5.00	Flow	0.38	1.91	NA			3.82	NA		
2279TH	G2G	94	15	P	5.00	Flow	0.46	15.69	NA			25.46	NA		
2290TH	G2G	319	15	P	5.00	Flow	0.33	18.64	NA			37.28	NA		
2293TH	G2G	31	15	P	5.00	Flow	0.31	6.10	NA			8.70	NA		
2419TH	G2G	3	15	P	5.00	Flow	0.43	0.90	NA			1.19	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
2458TH	G2G	46	15	P	5.00	Flow	0.40	3.84	NA			7.67	NA		
2481TH	G2G	242	15	P	5.00	Flow	0.13	20.43	NA			25.23	NA		
2486TH	G2G	14	15	P	5.00	Flow	0.50	1.46	NA			2.28	NA		
2569TH	G2G	3	15	P	4.90	Flow	0.06	0.20	NA			0.23	NA		
2590TH	G2G	21	15	P	5.00	Flow	0.23	2.25	NA			2.35	NA		
2620TH	G2G	29	15	P	5.00	Flow	0.41	4.77	NA			5.45	NA		
2700TH	G2G	3459	15	P	5.00	Flow	0.23	185.30	NA			217.70	NA		
2819TH	G2G	30	15	P	5.00	Flow	0.08	1.08	NA			1.16	NA		
2830TH	G2G	128	15	P	5.00	Flow	0.04	2.55	NA			3.49	NA		
2844TH	G2G	9	15	P	5.00	Flow	0.26	1.48	NA			2.21	NA		
2846TH	G2G	11	15	P	5.00	Flow	0.37	0.52	NA			1.05	NA		
2849TH	G2G	39	15	P	5.00	Flow	0.29	1.21	NA			2.43	NA		
2859TH	G2G	21	15	P	5.00	Flow	0.18	0.44	NA			0.89	NA		
2870TH	G2G	233	15	P	5.00	Flow	0.18	5.20	NA			10.41	NA		
2873TH	G2G	6	15	P	5.00	Flow	0.08	0.31	NA			0.34	NA		
2889TH	G2G	28	15	P	5.00	Flow	0.31	4.04	NA			4.33	NA		
2900TH	G2G	3873	15	P	5.00	Flow	0.24	186.10	NA			208.35	NA		
2928TH	G2G	36	15	P	5.00	Flow	0.50	2.35	NA			4.69	NA		
2936TH	G2G	46	15	P	5.00	Flow	0.07	1.32	NA			1.56	NA		
2937TH	G2G	52	15	P	5.00	Flow	0.07	1.28	NA			1.46	NA		
2938TH	G2G	52	15	P	3.27	Flow	0.07	1.50	NA			1.77	NA		
2976TH	G2G	10	15	P	5.00	Flow	0.33	1.22	NA			1.52	NA		
2989TH	G2G	53	15	P	5.00	Flow	0.34	2.54	NA			5.08	NA		
3015TH	G2G	21	15	P	5.00	Flow	0.29	1.38	NA			1.73	NA		
3020TH	G2G	55	15	P	5.00	Flow	0.38	4.98	NA			7.64	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
3040TH	G2G	179	15	P	5.00	Flow	0.46	24.90	NA			30.00	NA		
3055TH	G2G	6	15	P	5.00	Flow	0.24	0.75	NA			0.95	NA		
3061TH	G2G	35	15	P	4.95	Flow	0.31	9.14	NA			11.31	NA		
3069TH	G2G	83	15	P	5.00	Flow	0.33	15.28	NA			19.36	NA		
3079TH	G2G	32	15	P	5.00	Flow	0.25	1.72	NA			1.87	NA		
3080TH	G2G	366	15	P	5.00	Flow	0.34	35.25	NA			40.24	NA		
3100TH	G2G	4479	15	P	5.00	Flow	0.24	223.55	NA			238.00	NA		
3229TH	G2G	27	15	P	5.00	Flow	0.29	8.02	NA			9.82	NA		
3230TH	G2G	75	15	P	5.00	Flow	0.32	26.27	NA			31.31	NA		
3240TH	G2G	116	15	P	5.00	Flow	0.44	23.67	NA			47.35	NA		
3270TH	G2G	246	15	P	5.00	Flow	0.42	45.40	NA			49.10	NA		
3369TH	G2G	20	15	P	5.00	Flow	0.40	5.20	NA			6.66	NA		
3625TH	G2G	11	15	P	5.00	Flow	0.50	3.88	NA			4.29	NA		
3629TH	G2G	8	15	P	5.00	Flow	0.26	2.42	NA			2.80	NA		
3650TH	G2G	24	15	P	5.00	Flow	0.41	5.03	NA			10.07	NA		
3660TH	G2G	35	15	P	5.00	Flow	0.39	9.16	NA			10.49	NA		
3809TH	G2G	17	15	P	5.00	Flow	0.40	3.25	NA			4.06	NA		
3820TH	G2G	26	15	P	5.00	Flow	0.29	11.74	NA			17.06	NA		
3826TH	G2G	15	15	P	5.00	Flow	0.36	3.59	NA			5.41	NA		
3829TH	G2G	19	15	P	5.00	Flow	0.56	9.04	NA			11.32	NA		
3839TH	G2G	10	15	P	5.00	Flow	0.36	5.09	NA			10.19	NA		
4080TH	G2G	23	15	P	5.00	Flow	0.51	3.70	NA			7.41	NA		
4150TH	G2G	16	15	P	5.00	Flow	0.26	3.16	NA			3.90	NA		
4182TH	G2G	2	15	P	5.00	Flow	0.27	1.35	NA			1.61	NA		
4186TH	G2G	8	15	P	5.00	Flow	0.30	4.22	NA			5.05	NA		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
4189TH	G2G	10	15	P	5.00	Flow	0.39	5.05	NA			10.10	NA		
4314TH	G2G	1	15	P	5.00	Flow	0.22	0.58	NA			1.16	NA		
4319TH	G2G	2	15	P	5.00	Flow	0.40	2.59	NA			2.85	NA		
4326TH	G2G	18	15	P	5.00	Flow	0.37	4.99	NA			5.89	NA		
4327TH	G2G	1	15	P	4.04	Flow	0.29	0.78	NA			1.30	NA		
4345TH	G2G	5	15	P	5.00	Flow	0.21	1.09	NA			1.39	NA		
4369TH	G2G	18	15	P	5.00	Flow	0.35	7.41	NA			8.57	NA		
4386TH	G2G	12	15	P	5.00	Flow	0.34	0.87	NA			0.93	NA		
4389TH	G2G	16	15	P	5.00	Flow	0.65	1.76	NA			3.53	NA		
4640TH	G2G	20	15	P	5.00	Flow	0.43	3.34	NA			3.91	NA		
4770TH	G2G	17	15	P	5.00	Flow	0.08	0.38	NA			0.40	NA		
4790TH	G2G	27	15	P	5.00	Flow	0.34	1.00	NA			2.01	NA		
4827TH	G2G	10	15	P	5.00	Flow	0.47	1.33	NA			2.65	NA		
4890TH	G2G	88	15	P	5.00	Flow	0.26	3.99	NA			4.83	NA		
4939TH	G2G	45	15	P	5.00	Flow	0.40	3.71	NA			4.43	NA		
4980TH	G2G	116	15	P	5.00	Flow	0.38	7.65	NA			8.79	NA		
5080TH	G2G	61	15	P	5.00	Flow	0.47	4.52	NA			5.59	NA		
5129TH	G2G	16	15	P	5.00	Flow	0.62	1.04	NA			1.66	NA		
5169TH	G2G	45	15	P	5.00	Flow	0.27	6.77	NA			12.06	NA		
5189TH	G2G	15	15	P	5.00	Flow	0.28	3.26	NA			6.52	NA		
5290TH	G2G	629	15	P	4.75	Flow	0.53	32.16	NA			42.22	NA		
5329TH	G2G	28	15	P	5.00	Flow	0.23	7.40	NA			8.82	NA		
5339TH	G2G	27	15	P	5.00	Flow	0.43	3.51	NA			4.65	NA		
5349TH	G2G	36	15	P	5.00	Flow	0.36	4.75	NA			7.21	NA		
5357TH	G2G	18	15	P	5.00	Flow	0.44	4.48	NA			4.94	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^{3}s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^{3}s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
5364TH	G2G	14	15	P	5.00	Flow	0.39	2.88	NA			3.09	NA		
5369TH	G2G	25	15	P	5.00	Flow	0.37	13.10	NA			14.05	NA		
5380TH	G2G	786	15	P	4.80	Flow	0.38	37.95	NA			44.30	NA		
5420TH	G2G	79	15	P	5.00	Flow	0.35	8.83	NA			10.09	NA		
5427TH	G2G	49	15	P	5.00	Flow	0.27	9.90	NA			12.00	NA		
5480TH	G2G	231	15	P	5.00	Flow	0.24	14.64	NA			17.70	NA		
5541TH	G2G	31	15	P	5.00	Flow	0.65	4.14	NA			8.28	NA		
5550TH	G2G	37	15	P	5.00	Flow	0.36	5.10	NA			7.15	NA		
1100TH	TCM	814	15	F	8.99	Level	0.20	40.01	1.333			80.02	1.4695		
1102TH_T	ISIS	NA	15	F	8.99	Level	0.26	36.09	2.289230485			72.19	2.86716		
1201TH_T	ISIS	NA	15	F	8.99	Level	0.34	NA	3.081			NA	3.382		
1290TH	TCM	NA	15	F	8.99	Flow	0.10	16.30	NA			17.51	NA		
1301TH_T	ISIS	NA	15	F	8.99	Level	0.27	NA	2.554			NA	2.568		
1302TH_T	ISIS	NA	15	F	8.66	Level	0.33	NA	2.799			NA	2.9185		
1303TH_T	ISIS	NA	15	F	8.99	Level	0.39	NA	3.3605			NA	3.4655		
1483TH	TCM	86	15	F	8.99	Level	0.35	6.32	2.335			12.63	2.748		
1489TH	ISIS	206	15	F	8.99	Level	0.37	7.55	8.565			15.10	8.778		
1635TH	ISIS	NA	15	F	7.54	Level	0.34	NA	2.1505			NA	2.287		
1645TH	ISIS	NA	15	F	8.75	Level	0.32	NA	2.365			NA	2.5035		
1675TH	ISIS	NA	15	F	8.75	Level	0.31	NA	1.4395			NA	1.72		
1790TH	TCM	164	15	F	8.99	Flow	0.22	7.09	NA			14.17	NA		
1799TH_T	ISIS	NA	15	F	8.84	Level	0.32	NA	3.5305			NA	3.604		
1800TH	ISIS	1954	15	F	8.99	Level	0.35	69.04	2.49			138.09	3.66		
3040TH	TCM	179	15	F	8.99	Level	0.34	17.34	1.604			34.69	1.658		
3804TH	PDM	NA	15	P	5.57	Level	0.38	NA	0.7705			NA	0.8505		

ID	Model	Area (km²)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
3806TH	ISIS	NA	15	P	10.99	Level	0.42	NA	1.147			NA	1.337		
3809TH	ISIS	17	15	P	12.65	Level	0.36	2.57	0.582			5.15	0.6465		
3815TH	PDM	NA	15	P	8.90	Level	0.42	NA	1.367			NA	1.469		
3820TH	ISIS	26	15	P	12.65	Level	0.49	8.94	0.746			17.88	1.017		
3822TH	PDM	3	15	P	12.45	Level	0.45	0.35	1.017			0.69	1.203		
3823TH	PDM	NA	15	P	12.45	Level	0.37	0.36	0.108			0.72	0.193		
3826TH	ISIS	15	15	P	11.90	Level	0.42	2.86	1.376			5.73	1.644		
3829TH	ISIS	19	15	P	12.65	Level	0.49	5.90	0.833			11.79	1.331		
3839TH	ISIS	10	15	P	12.65	Level	0.56	5.09	0.7			10.19	0.988		
3850TH	ISIS	63	15	P	12.65	Level	0.53	15.30	1.043			30.61	1.6		
3870TH	ISIS	72	15	P	12.65	Level	0.58	12.75	0.79			25.51	1.134		
3880TH	ISIS	NA	15	P	11.90	Level	0.29	NA	2.1475			NA	2.271		
5329TH	TCM	28	15	F	8.99	Level	0.29	4.64	0.76			9.27	1.021		

WALES

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
056006_TG_413	PDM	NA	15	P	8.69	Flow	0.69	159.83	NA			168.53	NA		
056012_TG_406	PDM	66	15	P	8.69	Flow	0.62	7.09	NA			14.18	NA		
056013_TG_408	PDM	52	15	P	8.69	Flow	0.75	7.51	NA			15.01	NA		
058005_TG_201	PDM	73	15	P	10.45	Flow	0.53	54.44	NA			60.06	NA		
058007_TG_203	PDM	46	15	P	10.04	Flow	0.60	44.40	NA			46.27	NA		
058S0655W_TG_217	PDM	17	15	P	10.45	Flow	0.45	9.86	NA			11.35	NA		
055002_TG_301	G2G	1577	15	P	5.00	Flow	0.60	208.49	NA			416.99	NA		
055007_TG_311	G2G	1113	15	P	5.00	Flow	0.58	384.00	NA			444.10	NA		
055012_TG_308	G2G	223	15	P	5.00	Flow	0.32	137.50	NA			159.00	NA		
055013_TG_326	G2G	91	15	P	5.00	Flow	0.55	16.55	NA			19.10	NA		
055014_TG_306	G2G	157	15	P	5.00	Flow	0.45	19.15	NA			23.75	NA		
055016_TG_310	G2G	316	15	P	5.00	Flow	0.47	102.00	NA			121.65	NA		
055018_TG_327	G2G	105	15	P	5.00	Flow	0.35	12.85	NA			22.40	NA		
055021_TG_305	G2G	269	15	P	5.00	Flow	0.26	37.10	NA			50.13	NA		
055023_TG_322	G2G	3135	15	P	5.00	Flow	0.47	246.25	NA			492.50	NA		
055025_TG_325	G2G	119	15	P	5.00	Flow	0.46	27.05	NA			35.90	NA		
055026_TG_309	G2G	151	15	P	5.00	Flow	0.35	95.10	NA			131.00	NA		
055028_TG_9302	G2G	64	15	P	5.00	Flow	0.29	10.86	NA			16.05	NA		
055029_TG_313	G2G	302	15	P	3.80	Flow	0.31	91.20	NA			127.00	NA		
055031_TG_329	G2G	24	15	P	5.00	Flow	0.06	1.05	NA			1.38	NA		
056001_TG_402	G2G	748	15	P	5.00	Flow	0.34	304.15	NA			362.82	NA		
056002_TG_411	G2G	157	15	P	5.00	Flow	0.62	39.66	NA			79.32	NA		
056004_TG_404	G2G	453	15	P	5.00	Flow	0.45	231.00	NA			293.00	NA		
056019_TG_400	G2G	54	15	P	5.00	Flow	0.72	23.80	NA			29.30	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
057004_TG_9500	G2G	85	15	P	5.00	Flow	0.35	56.98	NA			66.16	NA		
057005_TG_513	G2G	377	15	P	5.00	Flow	0.73	246.12	NA			294.16	NA		
057006_TG_515	G2G	163	15	P	5.00	Flow	0.56	97.91	NA			104.46	NA		
057007_TG_504	G2G	151	15	P	5.00	Flow	0.67	87.60	NA			124.63	NA		
057008_TG_9509	G2G	158	15	P	5.00	Flow	0.55	76.40	NA			83.70	NA		
057009_TG_514	G2G	124	15	P	5.00	Flow	0.67	28.00	NA			56.00	NA		
057010_TG_508	G2G	36	15	P	5.00	Flow	0.57	15.55	NA			31.10	NA		
057805_TG_501	G2G	51	15	P	5.00	Flow	0.47	50.87	NA			55.75	NA		
57809	G2G	17	15	P	5.00	Flow	0.49	19.04	NA			21.79	NA		
058001_TG_200	G2G	147	15	P	5.00	Flow	0.20	75.08	NA			76.68	NA		
058002_TG_209	G2G	165	15	P	5.00	Flow	0.60	92.35	NA			184.70	NA		
058005_TG_201	G2G	73	15	P	5.00	Flow	0.43	32.40	NA			64.81	NA		
058006_TG_208	G2G	53	15	P	5.00	Flow	0.52	55.05	NA			66.51	NA		
058007_TG_203	G2G	46	15	P	5.00	Flow	0.04	54.31	NA			57.42	NA		
058008_TG_202	G2G	36	15	P	5.00	Flow	0.46	40.94	NA			48.20	NA		
058009_TG_205	G2G	48	15	P	5.00	Flow	0.69	13.95	NA			27.90	NA		
058011_TG_506	G2G	30	15	P	5.00	Flow	0.23	13.40	NA			16.75	NA		
058012_TG_206	G2G	86	15	P	4.93	Flow	0.24	75.41	NA			89.24	NA		
058S0014W_TG_9204	G2G	79	15	P	5.00	Flow	0.36	82.95	NA			92.03	NA		
058S0655W_TG_217	G2G	17	15	P	5.00	Flow	0.70	9.33	NA			18.66	NA		
059001_TG_210	G2G	194	15	P	5.00	Flow	0.03	231.40	NA			251.04	NA		
059002_TG_9211	G2G	39	15	P	5.00	Flow	0.52	24.08	NA			48.15	NA		
059S0405W_TG_215	G2G	43	15	P	5.00	Flow	0.40	49.75	NA			56.03	NA		
059S0525W_TG_9216	G2G	30	15	P	5.00	Flow	0.41	35.08	NA			41.43	NA		
059S0670W_TG_223	G2G	75	15	P	5.00	Flow	0.05	110.90	NA			117.91	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
060001_TG_9128	G2G	961	15	P	5.00	Flow	0.53	271.59	NA			320.98	NA		
060002_TG_106	G2G	264	15	P	5.00	Flow	0.29	132.74	NA			163.15	NA		
060003_TG_110	G2G	174	15	P	5.00	Flow	0.57	42.22	NA			84.45	NA		
060004_TG_9111	G2G	34	15	P	5.00	Flow	0.31	11.20	NA			22.40	NA		
60005	G2G	63	15	P	5.00	Flow	0.31	26.47	NA			33.38	NA		
060006_TG_9105	G2G	113	15	P	5.00	Flow	0.02	73.86	NA			87.74	NA		
060009_TG_9107	G2G	78	15	P	5.00	Flow	0.02	69.25	NA			76.10	NA		
060010_TG_9101	G2G	962	15	P	5.00	Flow	0.46	254.00	NA			279.00	NA		
060012_TG_109	G2G	17	15	P	5.00	Flow	0.36	5.85	NA			11.70	NA		
060099_TG_9102	G2G	527	15	P	5.00	Flow	0.41	196.01	NA			212.77	NA		
060S0579W_TG_2080	G2G	54	15	P	5.00	Flow	0.28	31.34	NA			62.69	NA		
060S0660W_TG_9131	G2G	24	15	P	5.00	Flow	0.45	4.16	NA			8.31	NA		
060S0661W_TG_9132	G2G	23	15	P	5.00	Flow	0.29	10.19	NA			12.32	NA		
060S0685W_TG_9139	G2G	46	15	P	5.00	Flow	0.61	11.41	NA			22.83	NA		
060S0690W_TG_9140	G2G	45	15	P	4.79	Flow	0.02	33.38	NA			42.69	NA		
061001_TG_9112	G2G	142	15	P	5.00	Flow	0.35	51.60	NA			65.68	NA		
061002_TG_113	G2G	141	15	P	5.00	Flow	0.43	37.80	NA			75.60	NA		
061S0397W_DL_2880	G2G	29	15	P	5.00	Flow	0.32	14.50	NA			18.94	NA		
061S0578W_DL_2100	G2G	22	15	P	5.00	Flow	0.32	5.21	NA			10.42	NA		
061S0677W_TG_9137	G2G	20	15	P	5.00	Flow	0.48	17.12	NA			19.18	NA		
062001_TG_9115	G2G	685	15	P	5.00	Flow	0.67	90.25	NA			180.51	NA		
062002_DL_2890	G2G	396	15	P	5.00	Flow	0.37	95.36	NA			114.00	NA		
062S0577W_TG_2110	G2G	151	15	P	5.00	Flow	0.34	35.06	NA			41.55	NA		
062S0657W_TG_129	G2G	35	15	P	5.00	Flow	0.38	16.77	NA			19.58	NA		
062S0666W_TG_135	G2G	38	15	P	5.00	Flow	0.03	24.33	NA			32.58	NA		

ID	Model	Area (km^2)	Interval (mins)	Scenario	Record length (years)	Variable	Overall score	T_l Flow (m^3s^{-1})	T_l Level (m)	T_l 2h	T_l 12h	T_u Flow (m^3s^{-1})	T_u Level (m)	T_u 2h	T_u 12h
063001_TG_9116	G2G	158	15	P	5.00	Flow	0.32	74.65	NA			111.41	NA		
063003_TG_125	G2G	36	15	P	5.00	Flow	0.41	10.15	NA			20.30	NA		
063004_TG_9117	G2G	29	15	P	5.00	Flow	0.44	30.20	NA			37.70	NA		
063S0443W_DL_2010	G2G	132	15	P	5.00	Flow	0.44	35.41	NA			38.04	NA		
063S0674W_TG_9134	G2G	37	15	P	5.00	Flow	0.41	7.44	NA			10.42	NA		
064001_TG_401	G2G	438	15	P	5.00	Flow	0.62	304.00	NA			316.50	NA		
064010_TG_302	G2G	61	15	P	5.00	Flow	0.32	90.35	NA			103.50	NA		
065001_TG_1201	G2G	60	15	P	5.00	Flow	0.31	83.78	NA			96.40	NA		
065005_TG_900	G2G	16	15	P	5.00	Flow	0.31	4.74	NA			9.49	NA		
065006_TG_802	G2G	67	15	P	5.00	Flow	0.48	36.62	NA			42.12	NA		
065014_TG_1202	G2G	7	15	P	5.00	Flow	0.62	12.03	NA			13.55	NA		
065015_TG_1303	G2G	35	15	P	5.00	Flow	0.32	17.26	NA			19.15	NA		
066006_TG_505	G2G	169	15	P	5.00	Flow	0.41	56.52	NA			77.43	NA		
066012_TG_216	G2G	65	15	P	5.00	Flow	0.33	107.00	NA			134.00	NA		
067005_TG_116	G2G	89	15	P	5.00	Flow	0.43	22.15	NA			25.97	NA		
067006_TG_122	G2G	154	15	P	5.00	Flow	0.41	54.35	NA			65.53	NA		
067008_TG_138	G2G	157	15	P	5.00	Flow	0.30	15.37	NA			17.58	NA		
067010_TG_124	G2G	11	15	P	5.00	Flow	0.69	15.00	NA			20.25	NA		
067015_TG_132	G2G	869	15	P	5.00	Flow	0.51	173.67	NA			207.00	NA		
067018_TG_9136	G2G	51	15	P	5.00	Flow	0.59	38.65	NA			77.31	NA		
067023_TG_117	G2G	11	15	P	5.00	Flow	0.31	0.83	NA			1.66	NA		
067025_TG_121	G2G	77	15	P	5.00	Flow	0.24	12.15	NA			12.89	NA		
Pont_Felindre_001Stage	G2G	54	15	P	5.00	Flow	0.30	11.20	NA			13.52	NA		

Appendix G: Model comparison for sites with multiple models

The following tables identify, for each region, sites where multiple models exist along with each model's Overall Performance Score (OPS) and colour-coded score grades as defined in Section 6.2.8.

The tables are followed by 'model performance comparison displays', as described in Section 6.2.9, for all sites where multiple models exist.

ANGLIAN

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS	Model 3	Model 3 OPS
E19862	PDM	0.37	G2G	0.23	0	0
E21187	PDM	0.31	G2G	0.34	0	0
E21505	KW	0.45	G2G	0.30	0	0
E21647	KW	0.60	G2G	0.58	0	0
E21657	MIKE 11	0.14	G2G	0.21	0	0
E21987	PDM	0.41	G2G	0.03	0	0
E22344	PDM	0.56	G2G	0.49	0	0
E22351	PDM	0.49	G2G	0.43	0	0
E22518	PDM	0.41	G2G	0.27	0	0
E22727	ISIS	0.01	ISIS	0.63	G2G	0.03
E22744	ISIS	0.02	ISIS	0.69	G2G	0.16
E22761	ISIS	0.01	G2G	0.33	0	0
E22843	ISIS	0.10	G2G	0.53	0	0
E22869	ISIS	0.10	G2G	0.39	0	0
E22889	ISIS	0.15	ISIS	0.79	G2G	0.38
E2862	PDM	0.36	G2G	0.47	0	0
E2901	PDM	0.44	G2G	0.53	0	0
E4222	PDM	0.51	G2G	0.41	0	0

MIDLANDS

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS	Model 3	Model 3 OPS
2001	G2G	0.29	DODO	0.74	0	0
2004	G2G	0.57	DODO	0.36	0	0
2005	G2G	0.09	DODO	0.54	0	0
2008	G2G	0.43	DODO	0.43	0	0
2010	G2G	0.40	DODO	0.54	0	0
2011	G2G	0.61	MCRM	0.37	0	0
2012	G2G	0.47	DODO	0.50	0	0
2015	G2G	0.49	MCRM	0.34	0	0
2016	G2G	0.52	MCRM	0.42	0	0
2017	G2G	0.24	MCRM	0.25	0	0
2018	G2G	0.62	MCRM	0.31	0	0

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS	Model 3	Model 3 OPS
2019	G2G	0.39	DODO	0.56	0	0
2020	G2G	0.31	MCRM	0.47	0	0
2024	G2G	0.29	MCRM	0.50	0	0
2027	G2G	0.50	MCRM	0.27	0	0
2028	G2G	0.63	DODO	0.40	0	0
2029	G2G	0.50	DODO	0.47	0	0
2032	G2G	0.36	DODO	0.57	0	0
2034	G2G	0.41	MCRM	0.46	0	0
2036	G2G	0.34	DODO	0.09	0	0
2038	G2G	0.47	MCRM	0.45	0	0
2039	G2G	0.42	MCRM	0.28	0	0
2041	G2G	0.43	MCRM	0.57	0	0
2048	G2G	0.38	MCRM	0.27	0	0
2050	G2G	0.46	DODO	0.36	0	0
2054	G2G	0.58	MCRM	0.47	0	0
2057	G2G	0.20	DODO	0.40	0	0
2067	G2G	0.57	DODO	0.33	DODO	0.41
2077	G2G	0.12	DODO	0.67	0	0
2083	DODO	0.16	DODO	0.26	0	0
2084	G2G	0.58	DODO	0.27	DODO	0.34
2085	G2G	0.28	DODO	0.70	0	0
2088	G2G	0.42	DODO	0.41	0	0
2090	G2G	0.50	DODO	0.29	0	0
2091	G2G	0.43	DODO	0.60	0	0
2092	G2G	0.35	MCRM	0.39	0	0
2093	G2G	0.39	DODO	0.49	0	0
2094	G2G	0.56	MCRM	0.31	0	0
2095	G2G	0.32	DODO	0.37	0	0
2104	G2G	0.27	DODO	0.46	0	0
2107	G2G	0.28	DODO	0.27	0	0
2132	G2G	0.44	DODO	0.26	0	0
2134	G2G	0.14	DODO	0.80	0	0
2167	G2G	0.47	DODO	0.32	DODO	0.36
2175	G2G	0.30	DODO	0.42	0	0
2180	G2G	0.16	DODO	0.74	0	0
2609	G2G	0.55	MCRM	0.45	0	0
2613	G2G	0.34	MCRM	0.27	0	0
2621	G2G	0.04	MCRM	0.36	0	0
2625	G2G	0.49	DODO	0.41	0	0
2639	G2G	0.45	MCRM	0.16	0	0
2649	G2G	0.22	MCRM	0.41	0	0
4003	G2G	0.65	DODO	0.46	ISIS	0.51
4006	G2G	0.42	DODO	0.37	0	0
4007	G2G	0.41	DODO	0.40	ISIS	0.21
4008	G2G	0.55	DODO	0.54	0	0

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS	Model 3	Model 3 OPS
4009	G2G	0.45	DODO	0.51	ISIS	0.40
4011	G2G	0.59	DODO	0.43	0	0
4012	G2G	0.22	DODO	0.49	0	0
4014	G2G	0.16	DODO	0.61	0	0
4018	G2G	0.56	DODO	0.57	0	0
4019	G2G	0.26	DODO	0.59	ISIS	0.36
4022	G2G	0.32	DODO	0.70	ISIS	0.44
4023	G2G	0.64	DODO	0.50	0	0
4024	G2G	0.42	DODO	0.26	0	0
4026	G2G	0.36	MCRM	0.44	0	0
4031	G2G	0.44	DODO	0.46	0	0
4032	G2G	0.50	MCRM	0.58	0	0
4033	G2G	0.20	MCRM	0.24	0	0
4039	G2G	0.53	MCRM	0.36	0	0
4040	G2G	0.44	MCRM	0.31	0	0
4041	G2G	0.04	MCRM	0.36	0	0
4043	G2G	0.44	DODO	0.41	0	0
4046	G2G	0.53	DODO	0.40	0	0
4048	G2G	0.35	MCRM	0.44	0	0
4049	G2G	0.37	MCRM	0.35	0	0
4052	G2G	0.56	MCRM	0.43	0	0
4053	G2G	0.36	MCRM	0.44	0	0
4055	G2G	0.49	DODO	0.49	0	0
4056	G2G	0.56	DODO	0.40	0	0
4058	G2G	0.52	MCRM	0.37	0	0
4061	G2G	0.53	DODO	0.42	0	0
4066	G2G	0.38	MCRM	0.39	0	0
4067	G2G	0.45	DODO	0.50	0	0
4069	DODO	0.40	ISIS	0.34	0	0
4074	G2G	0.37	DODO	0.36	0	0
4080	G2G	0.41	DODO	0.46	ISIS	0.44
4081	G2G	0.61	MCRM	0.30	0	0
4082	G2G	0.45	DODO	0.46	0	0
4083	G2G	0.22	DODO	0.28	0	0
4085	G2G	0.62	DODO	0.52	0	0
4086	G2G	0.31	DODO	0.08	0	0
4087	G2G	0.33	DODO	0.55	ISIS	0.50
4091	G2G	0.42	DODO	0.59	0	0
4093	G2G	0.25	DODO	0.41	0	0
4115	G2G	0.27	DODO	0.51	0	0
4116	G2G	0.33	DODO	0.45	0	0
4118	G2G	0.27	DODO	0.57	0	0
4131	DODO	0.55	ISIS	0.27	0	0
4142	G2G	0.35	DODO	0.49	0	0
4143	G2G	0.41	MCRM	0.17	0	0

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS	Model 3	Model 3 OPS
4146	G2G	0.39	MCRM	0.36	0	0
4158	G2G	0.57	MCRM	0.66	0	0
4161	G2G	0.27	MCRM	0.22	0	0
4164	G2G	0.30	DODO	0.38	0	0
4174	G2G	0.30	DODO	0.42	0	0
4186	G2G	0.33	DODO	0.43	0	0
4195	G2G	0.38	MCRM	0.40	0	0
4196	G2G	0.59	MCRM	0.47	0	0
4197	G2G	0.46	MCRM	0.33	0	0
4205	G2G	0.29	MCRM	0.21	0	0
4427	G2G	0.30	DODO	0.45	0	0
4873	G2G	0.23	MCRM	0.19	0	0
055804_TG 314	MCRM	0.44	ISIS	0.38	0	0

NORTH EAST

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS
ADDGHM1	G2G	0.60	KW	0.60
ADWICK1	G2G	0.60	ISIS	0.34
ALDWRK2	G2G	0.20	ISIS	0.67
Allen_Mill_Bridge	G2G	0.64	PDM	0.56
ALSTON1	G2G	0.38	PDM	0.45
ALWNTN1	G2G	0.30	PDM	0.53
ARMLEY1	G2G	0.63	KW	0.51
ARTHNG1	G2G	0.55	KW	0.55
BARNSL1	G2G	0.46	PDM	0.50
BEDBRN1	G2G	0.36	PDM	0.50
BRADBY5	G2G	0.31	KW	0.25
BROADW1	G2G	0.43	PDM	0.55
BROKSC5	G2G	0.45	KW	0.53
BROTON1	G2G	0.40	KW	0.47
BURNHL1	G2G	0.54	PDM	0.49
BUTTCR1	G2G	0.37	KW	0.09
BYWELL1	G2G	0.43	ISIS	0.61
CASTLF1	G2G	0.65	ISIS	0.42
CATTER1	G2G	0.55	KW	0.54
CHERRY1	G2G	0.68	PDM	0.72
CHESLS1	G2G	0.63	KW	0.55
CHESTF1	G2G	0.62	PDM	0.47
CLDENE1	G2G	0.63	KW	0.46
COLLNG1	G2G	0.49	KW	0.43
COLNEB1	G2G	0.52	KW	0.49
COPLEY1	G2G	0.41	PDM	0.49
COTTNL1	G2G	0.58	KW	0.48
CRAGHL1	G2G	0.43	ISIS	0.49

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS
CRAKEH1	G2G	0.30	ISIS	0.64
CROWNP1	G2G	0.62	KW	0.47
Dalton	G2G	0.47	PDM	0.45
DENBYD1	G2G	0.37	PDM	0.65
DEWSBY1	G2G	0.56	KW	0.55
DONCST1	G2G	0.65	ISIS	0.62
DRONFD1	G2G	0.31	PDM	0.36
EARBY01	G2G	0.32	PDM	0.38
EASBY05	G2G	0.50	PDM	0.47
EASTGT1	G2G	0.52	PDM	0.73
Ecclesfield	G2G	0.55	PDM	0.55
ELLAND1	G2G	0.48	KW	0.55
FARRER1	G2G	0.48	PDM	0.58
FEATHS1	G2G	0.37	ISIS	0.53
FLINTM1	G2G	0.51	KW	0.63
Foxton_Br4	G2G	0.55	KW	0.49
GARGRV1	G2G	0.38	PDM	0.42
Gosforth	G2G	0.50	ISIS	0.43
GREATA4	G2G	0.61	KW	0.46
HADFLD1	G2G	0.65	KW	0.44
HADYHL1	G2G	0.54	PDM	0.38
HARTBN1	G2G	0.49	PDM	0.45
HARWOD5	G2G	0.52	PDM	0.37
HAWBK01	G2G	0.42	PDM	0.33
HAYDNB1	G2G	0.43	ISIS	0.54
HEATON1	G2G	0.58	KW	0.56
HEBDBR1	G2G	0.70	KW	0.52
HEUGHM1	G2G	0.25	KW	0.40
HIGHFD1	G2G	0.43	PDM	0.43
Hollins_Bridge	G2G	0.55	ISIS	0.22
HOWEBR1	G2G	0.37	ISIS	0.40
HUNSNG1	G2G	0.62	KW	0.52
ILKLEY1	G2G	0.59	KW	0.60
JSDARL5	G2G	0.49	KW	0.33
KEIGHL1	G2G	0.59	PDM	0.55
KETTLW1	G2G	0.50	PDM	0.59
Kielder_Burn	G2G	0.26	PDM	0.62
KILDWK2	G2G	0.51	ISIS	0.51
KILGRM2	G2G	0.52	PDM	0.54
KIRKBY1	G2G	0.67	PDM	0.63
KIRKST1	G2G	0.57	KW	0.40
KNARES1	G2G	0.67	KW	0.44
Lev_Mill	G2G	0.19	PDM	0.27
Lev_Station	G2G	0.40	PDM	0.47
LOWHSS1	G2G	0.55	PDM	0.56

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS
LOWLND1	G2G	0.65	KW	0.57
LOWMOR5	G2G	0.57	ISIS	0.55
MALIN_BR	G2G	0.33	KW	0.32
MALTON1	G2G	0.44	ISIS	0.33
MASHAM1	G2G	0.49	KW	0.34
METHLY1	G2G	0.59	KW	0.54
MIDDLETON_BR	G2G	0.41	PDM	0.42
MIDDLT5	G2G	0.38	KW	0.31
MITFRD1	G2G	0.43	KW	0.48
MONKTN1	G2G	0.19	KW	0.64
MORWCK1	G2G	0.54	KW	0.52
NESS001	G2G	0.50	ISIS	0.51
NORMAN1	G2G	0.29	ISIS	0.58
NORTHP1	G2G	0.70	KW	0.58
NTCLGH1	G2G	0.69	PDM	0.56
Nunnington	G2G	0.59	PDM	0.34
NUNNYKIRK	G2G	0.40	PDM	0.25
OTLEY01	G2G	0.57	KW	0.57
OTTEUS1	G2G	0.45	PDM	0.56
PARKBG1	G2G	0.34	PDM	0.52
PATLYB1	G2G	0.20	KW	0.02
Penistone	G2G	0.51	ISIS	0.38
POOLBR1	G2G	0.54	KW	0.55
PRESTL5	G2G	0.35	KW	0.26
QUEENS1	G2G	0.61	PDM	0.49
REAVHL1	G2G	0.48	ISIS	0.59
REDEBR1	G2G	0.36	ISIS	0.42
REETH01	G2G	0.49	PDM	0.34
RICHLW1	G2G	0.63	KW	0.52
RIPON01	G2G	0.67	ISIS	0.51
ROTHBY1	G2G	0.52	KW	0.45
Rotherham_Tesco	G2G	0.47	ISIS	0.47
RPNURE1	G2G	0.51	KW	0.53
RUTHBR5	G2G	0.52	PDM	0.40
SHEEPB1	G2G	0.50	PDM	0.48
SHILMR1	G2G	0.67	PDM	0.36
SINNIN1	G2G	0.49	PDM	0.62
SKELTN1	G2G	0.52	KW	0.59
SKINNG5	G2G	0.51	PDM	0.47
SKPMOR1	G2G	0.62	PDM	0.63
SOWRBY1	G2G	0.54	KW	0.54
STANHP1	G2G	0.68	KW	0.63
STAVLY1	G2G	0.36	PDM	0.57
STHCH02	G2G	0.53	ISIS	0.58
STOCKB2	G2G	0.36	ISIS	0.22

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS
SUNDBR1	G2G	0.69	KW	0.52
TADCST1	G2G	0.42	KW	0.49
TEAMVL1	G2G	0.67	PDM	0.47
TODMDN1	G2G	0.64	PDM	0.55
VIEWLY_BR	G2G	0.46	KW	0.42
VIKING1	G2G	0.18	KW	0.61
WAKEFD1	G2G	0.56	KW	0.58
WALDEN1	G2G	0.40	PDM	0.28
WALSDN1	G2G	0.72	PDM	0.49
WEARHD1	G2G	0.61	PDM	0.70
WESTWK1	G2G	0.44	KW	0.66
Wharncliffe	G2G	0.55	ISIS	0.42
WHITTN1	G2G	0.53	KW	0.45
Wincobank	G2G	0.65	KW	0.44
WITTNP1	G2G	0.70	KW	0.68
WOODHS1	G2G	0.57	ISIS	0.51
WOOLSN1	G2G	0.48	PDM	0.37

NORTH WEST

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS	Model 3	Model 3 OPS	Model 4	Model 4 OPS
680504	G2G	0.52	PDM	0.51	0	0.00	0	0
681210	G2G	0.42	PDM	0.39	0	0.00	0	0
690140	G2G	0.24	PRTF	0.16	PDM	0.44	0	0
690160	PDM	0.74	G2G	0.56	0	0.00	0	0
690205	PDM	0.54	G2G	0.41	0	0.00	0	0
690207	PDM	0.83	G2G	0.68	PRTF	0.48	0	0
690510	G2G	0.64	PDM	0.62	0	0.00	0	0
690611	PDM	0.75	G2G	0.78	0	0.00	0	0
690713	PDM	0.82	G2G	0.44	0	0.00	0	0
692190	PDM	0.30	G2G	0.41	ISIS 1	0.42	0	0
692370	G2G	0.64	ISIS 1	0.44	0	0.00	0	0
692418	PDM	0.74	G2G	0.59	0	0.00	0	0
692422	PDM	0.47	ISIS 1	0.24	0	0.00	0	0
692423	PDM	0.33	G2G	0.63	0	0.00	0	0
692524	PDM	0.64	G2G	0.62	ISIS 1	0.44	0	0
692800	PDM	0.21	G2G	0.54	0	0.00	0	0
693132	G2G	0.57	PDM	0.31	0	0.00	0	0
693515	PDM	0.59	G2G	0.64	0	0.00	0	0
694039	G2G	0.57	PDM	0.80	ISIS	0.82	0	0
700325	PDM	0.65	ISIS	0.56	PDM	0.57	0	0
700408	G2G	0.42	PDM	0.47	0	0.00	0	0
710151	PDM	0.33	G2G	0.38	0	0.00	0	0
711610	PDM	0.81	G2G	0.77	0	0.00	0	0
712052	G2G	0.05	PDM	0.49	0	0.00	0	0

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS	Model 3	Model 3 OPS	Model 4	Model 4 OPS
713019	G2G	0.66	PDM	0.61	0	0.00	0	0
713120	G2G	0.39	ISIS	0.63	0	0.00	0	0
713122	G2G	0.40	ISIS	0.53	PDM	0.67	ISIS 2	0.55
720101	G2G	0.31	PDM	0.47	0	0.00	0	0
720102	G2G	0.57	ISIS 1	0.30	ISIS 2	0.33	PRTF	0.58
720105	G2G	0.30	ISIS	0.06	0	0.00	0	0
720107	G2G	0.39	ISIS 1	0.43	ISIS 2	0.45	0	0
720120	G2G	0.27	PDM	0.42	ISIS 1	0.25	ISIS 2	0.21
720215	G2G	0.47	PDM	0.39	0	0.00	0	0
720517	G2G	0.68	ISIS 1	0.41	ISIS 2	0.42	0	0
722421	ISIS 1	0.77	ISIS 2	0.77	0	0.00	0	0
724528	G2G	0.04	PDM	0.58	ISIS 1	0.50	ISIS 2	0.53
724629	G2G	0.36	ISIS	0.67	0	0.00	0	0
724647	G2G	0.30	ISIS	0.36	0	0.00	0	0
730120	G2G	0.69	PDM	0.61	0	0.00	0	0
730203	G2G	0.31	PDM	0.70	0	0.00	0	0
730404	G2G	0.47	PDM	0.76	0	0.00	0	0
730507	G2G	0.64	PDM	0.63	ISIS	0.70	0	0
730511	G2G	0.58	ISIS	0.79	PDM	0.63	0	0
744312	G2G	0.64	ISIS	0.49	0	0.00	0	0
750106	ISIS 1	0.41	ISIS 2	0.73	0	0.00	0	0
750504	G2G	0.52	PDM	0.86	0	0.00	0	0
750806	G2G	0.71	ISIS 1	0.70	PRTF	0.58	ISIS 2	0.64
750832	G2G	0.49	ISIS	0.57	0	0.00	0	0
751110	G2G	0.22	ISIS	0.66	ISIS2	0.47	0	0
751613	G2G	0.68	ISIS	0.41	ISIS2	0.38	0	0
751690	G2G	0.58	ISIS	0.31	ISIS2	0.44	0	0
760101	G2G	0.35	PDM	0.47	0	0.00	0	0
760112	G2G	0.44	ISIS	0.48	ISIS2	0.47	PDM	0.52
760115	ISIS	0.65	ISIS 2	0.66	0	0.00	0	0
760502	G2G	0.39	ISIS	0.52	ISIS2	0.50	PDM	0.38
761104	G2G	0.59	PDM	0.51	0	0.00	0	0
761605	G2G	0.10	ISIS	0.56	ISIS2	0.63	0	0
761706	G2G	0.69	PDM	0.61	0	0.00	0	0
762006	G2G	0.55	ISIS	0.52	PDM	0.44	ISIS2	0.56
762505	G2G	0.44	ISIS	0.71	ISIS 2	0.73	0	0
763308	G2G	0.27	PDM	0.49	0	0.00	0	0
764010	ISIS	0.52	PDM	0.55	0	0.00	0	0
765013	G2G	0.57	ISIS	0.41	PDM	0.40	0	0
765512	G2G	0.41	ISIS	0.49	PDM	0.49	0	0
765850	G2G	0.34	PDM	0.36	0	0.00	0	0

SOUTH WEST

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS	Model 3	Model 3 OPS
43108	PRTF	0.35	G2G	0.23	0	0
43114	PRTF	0.61	G2G	0.51	0	0
44122	PRTF	0.47	G2G	0.51	PDM	0.57
45117	PRTF	0.73	G2G	0.41	0	0
45118	PRTF	0.61	G2G	0.48	0	0
45119	PRTF	0.43	G2G	0.41	0	0
45120	PRTF	0.49	G2G	0.48	0	0
45132	PRTF	0.76	G2G	0.45	0	0
45159	PRTF	0.32	G2G	0.49	0	0
45210	PRTF	0.42	G2G	0.60	0	0
45223	PRTF	0.59	G2G	0.44	0	0
46122	PRTF	0.71	G2G	0.34	0	0
46123	PRTF	0.41	G2G	0.31	0	0
46128	PRTF	0.47	G2G	0.48	0	0
46129	PRTF	0.56	G2G	0.48	0	0
46133	PRTF	0.65	G2G	0.37	0	0
46135	PRTF	0.28	G2G	0.37	0	0
47118	PRTF	0.71	G2G	0.30	0	0
47133	PRTF	0.33	G2G	0.32	0	0
47136	PRTF	0.56	G2G	0.31	0	0
49110	PRTF	0.76	G2G	0.43	0	0
49113	PRTF	0.37	G2G	0.46	0	0
51107	PRTF	0.69	G2G	0.26	0	0
52108	PRTF	0.51	G2G	0.57	0	0
52109	PRTF	0.65	G2G	0.52	0	0
52111	PRTF	0.29	G2G	0.56	0	0
52114	PRTF	0.40	G2G	0.31	0	0
52116	PRTF	0.52	G2G	0.28	0	0
52117	PRTF	0.70	G2G	0.48	0	0
52130	PRTF	0.33	G2G	0.31	0	0
52207	PRTF	0.62	G2G	0.30	0	0
53119	PRTF	0.79	G2G	0.46	0	0
53120	PRTF	0.59	G2G	0.48	0	0
53122	PRTF	0.83	G2G	0.71	0	0
53131	PRTF	0.60	G2G	0.26	0	0
53134	PRTF	0.63	G2G	0.60	0	0
53135	PRTF	0.41	G2G	0.41	0	0
53136	PRTF	0.27	G2G	0.26	0	0
53139	PRTF	0.57	G2G	0.26	0	0
53143	PRTF	0.44	G2G	0.42	0	0
531116	PRTF	0.44	G2G	0.43	0	0

SOUTHERN

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS
Aru.Alfold	G2G	0.28	PDM	0.57
Aru.HalBri	G2G	0.36	PDM	0.43
Aru.IpiMil	G2G	0.38	PDM	0.50
Aru.Lodsbr	G2G	0.30	PDM	0.19
Aru.Pallin	G2G	0.41	ISIS	0.59
Aru.PriMar	G2G	0.04	PDM	0.56
Dar.Crayfo	G2G	0.35	PDM	0.44
EHS.NFareh	G2G	0.47	PDM	0.35
IWS.Budbri	G2G	0.36	PDM	0.38
IWS.BurntH	G2G	0.35	PDM	0.48
Med.Collie	G2G	0.32	PDM	0.32
Med.Hadlow	G2G	0.27	PDM	0.28
Med.Hendal	G2G	0.05	PDM	0.04
Med.Smard	G2G	0.50	PDM	0.23
Med.Summer	G2G	0.28	PDM	0.51

THAMES

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS
1100TH	G2G	0.17	TCM	0.20
1483TH	G2G	0.25	TCM	0.35
1489TH	G2G	0.28	ISIS	0.37
1790TH	G2G	0.27	TCM	0.22
1800TH	G2G	0.35	ISIS	0.35
3040TH	G2G	0.46	TCM	0.34
3240TH	G2G	0.44	ARMA TCM	0.43
3809TH	G2G	0.40	ISIS	0.36
3820TH	G2G	0.29	ISIS	0.49
3826TH	G2G	0.36	ISIS	0.42
3829TH	G2G	0.56	ISIS	0.49
3839TH	G2G	0.36	ISIS	0.56
5329TH	G2G	0.23	TCM	0.29

WALES

ID	Model 1	Model 1 OPS	Model 2	Model 2 OPS
058005_TG_201	PDM	0.53	G2G	0.43
058007_TG_203	PDM	0.60	G2G	0.04
058S0655W_TG_217	PDM	0.45	G2G	0.70

Model performance comparison displays

Model performance comparison displays (see Section 6.2.9) for all sites where multiple models exist are presented below. For conciseness, the displays omit the axis titles. Figure G.1 reproduces the example shown in Figure 6.13 as a convenient reference.

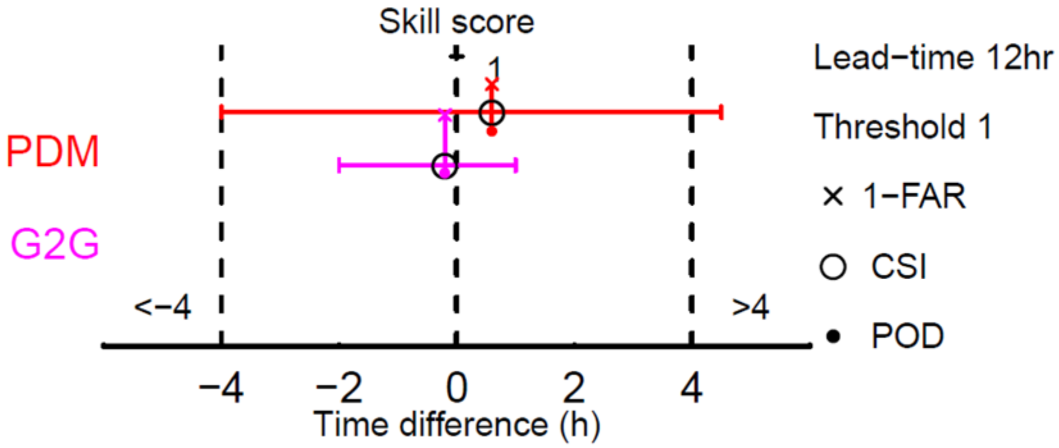
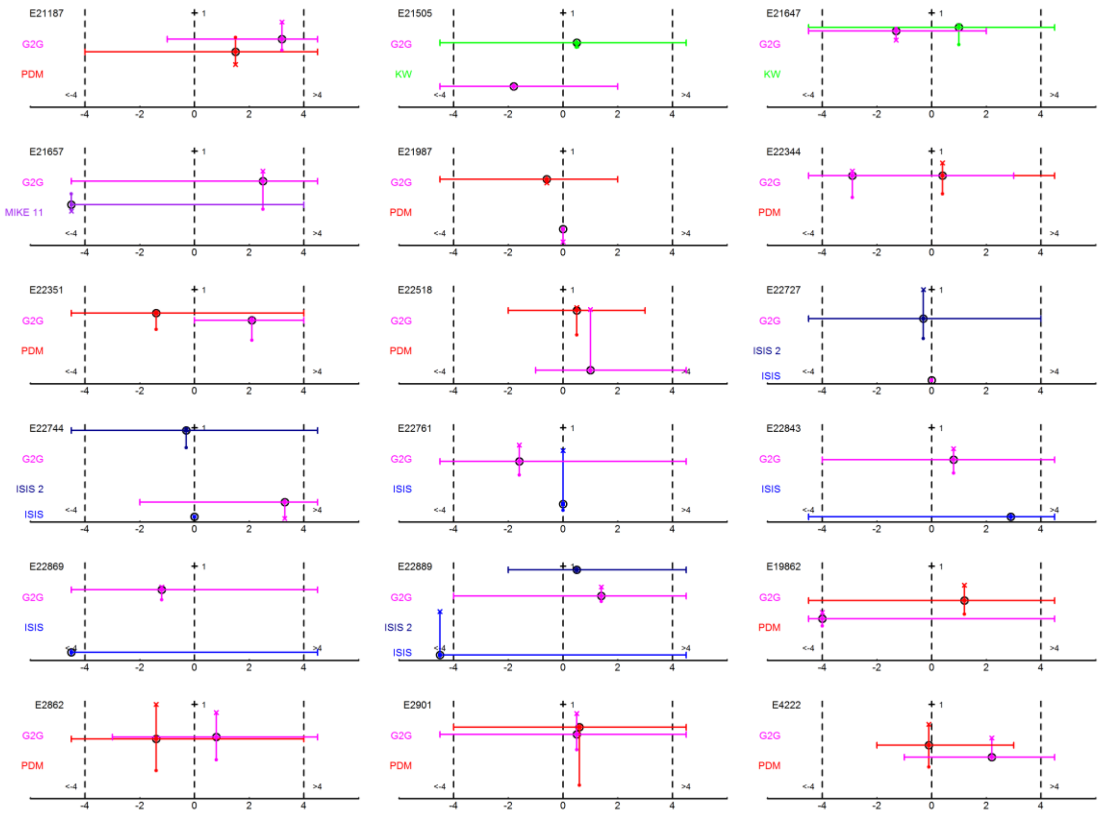


Figure G.1 Example of a model performance comparison display for all models with forecasts at a given site

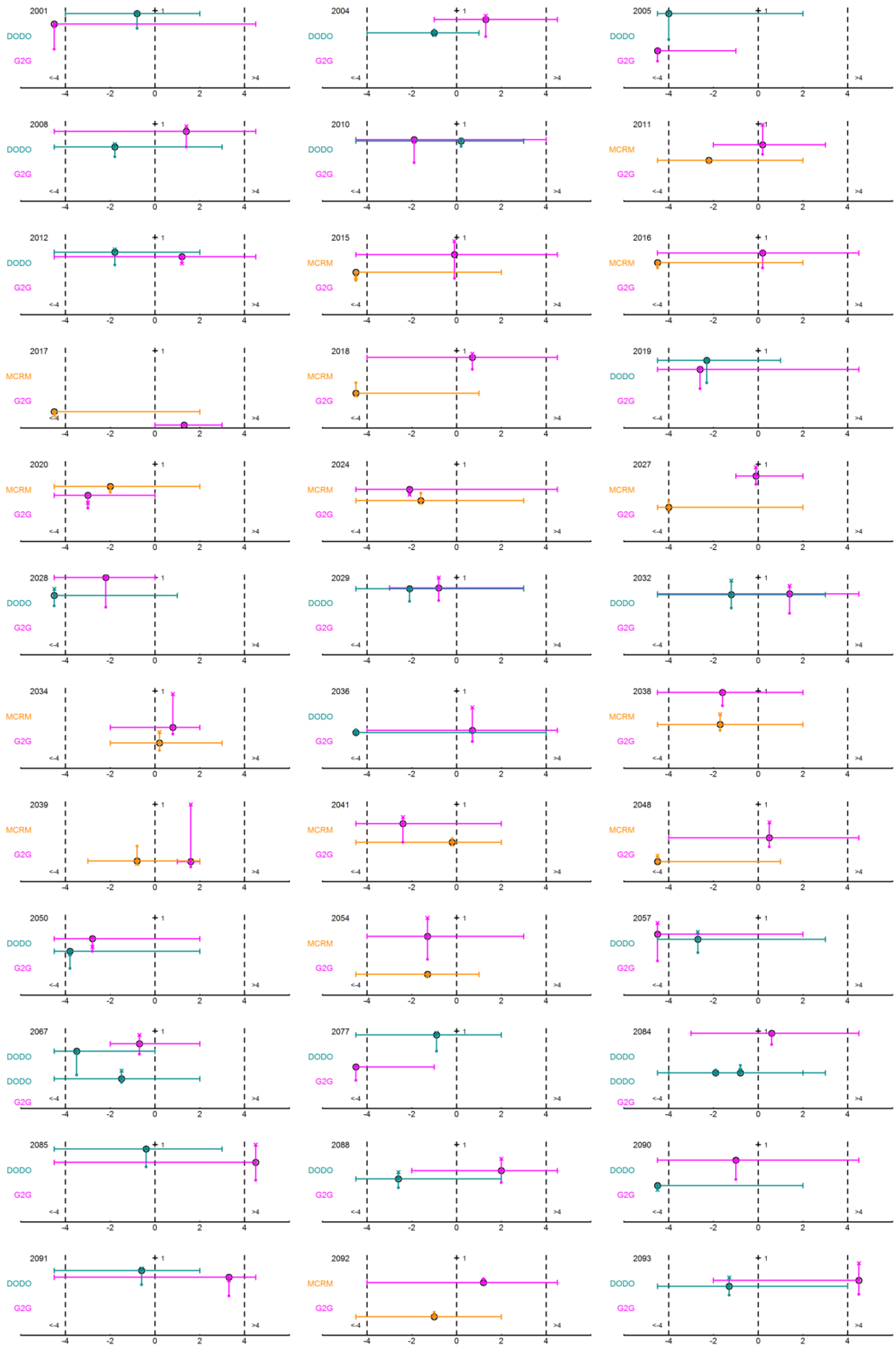
Notes: The horizontal bars illustrate the 90% range of timing differences at the 12 hour lead-time for the particular model.
The values of POD and Confidence (1-FAR) are included for each model and are designated by the coloured circle and the coloured cross respectively on the vertical coloured line.

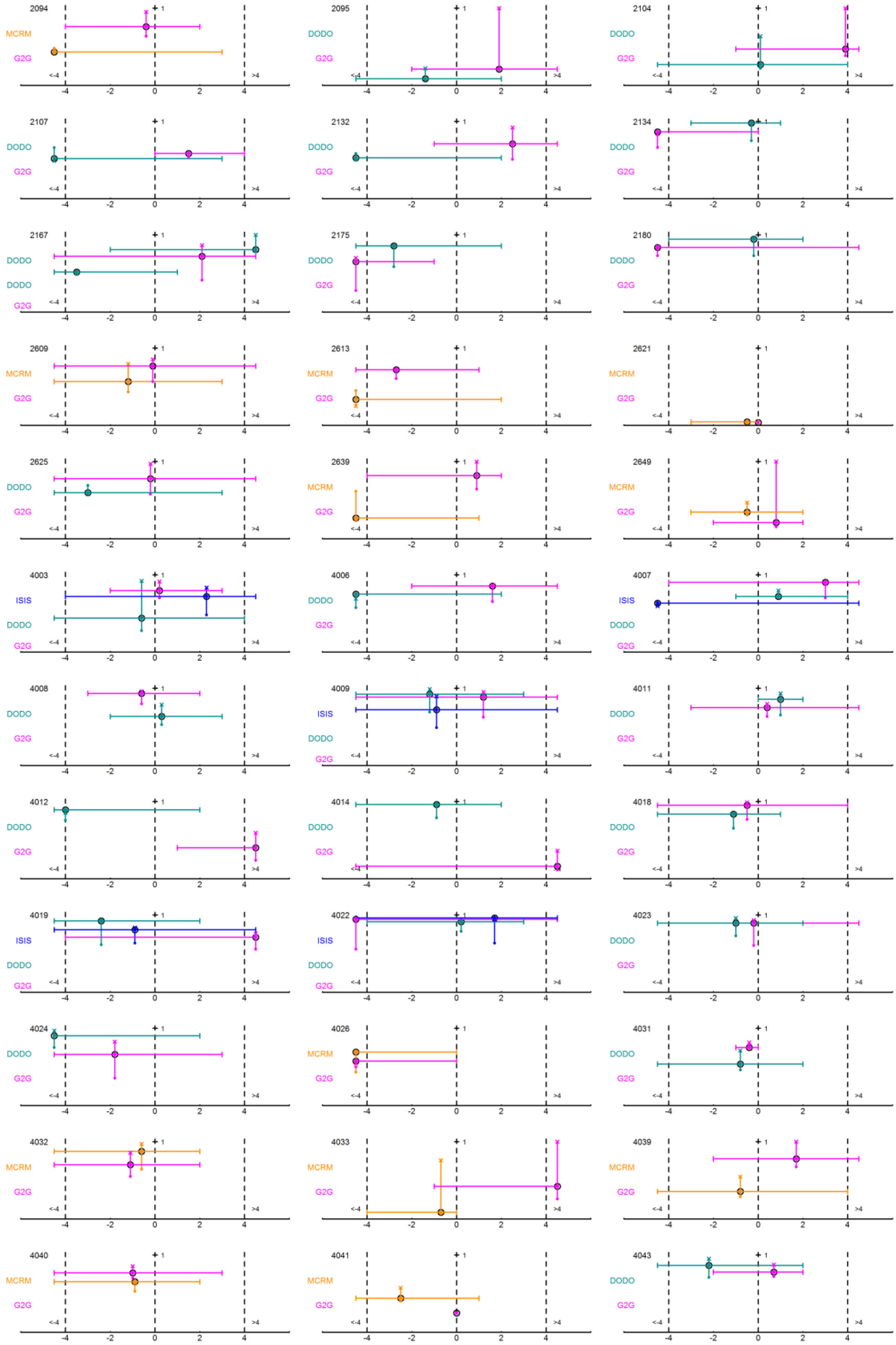
ANGLIAN

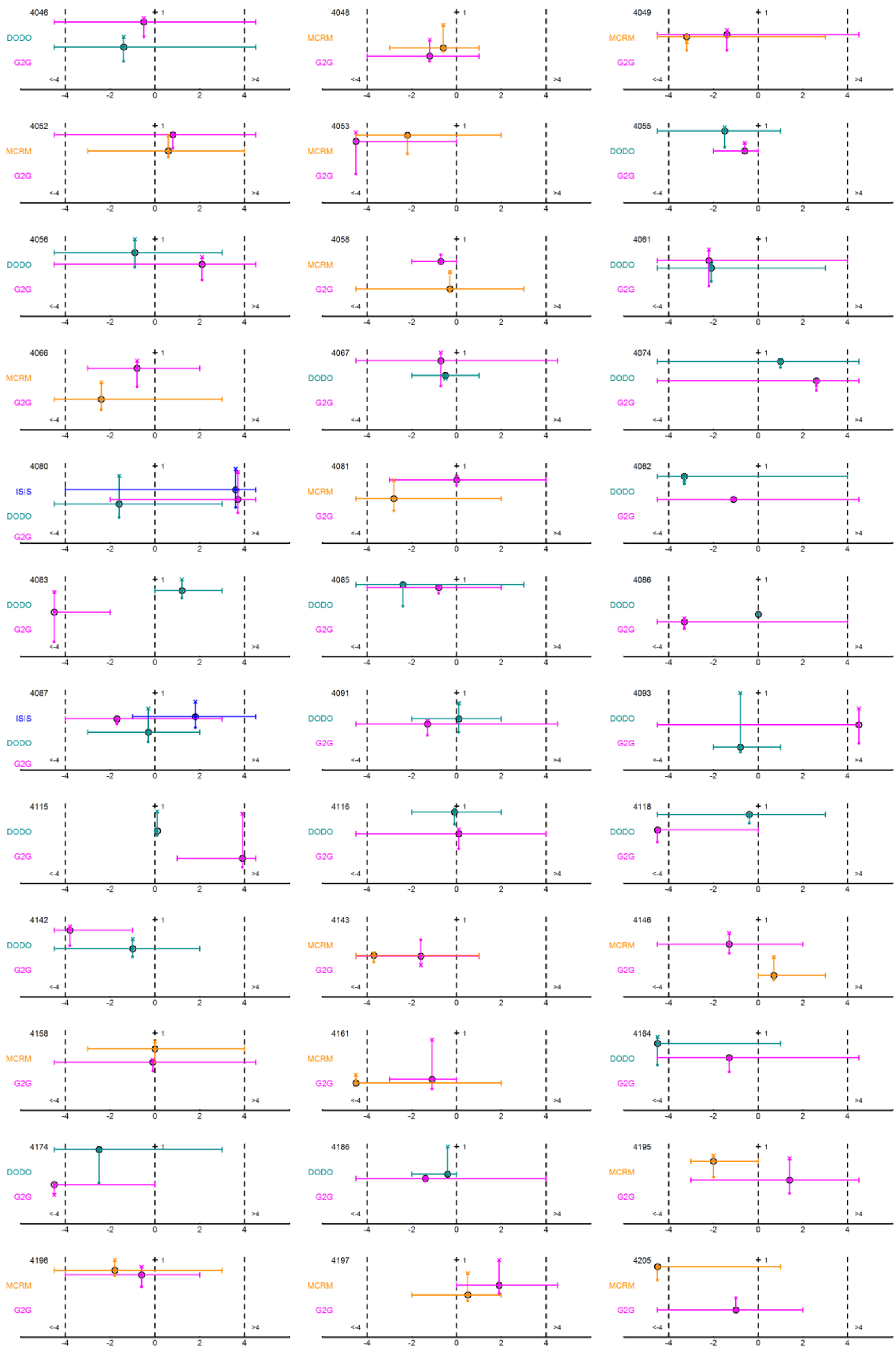


E21187
G2G
PDM
E21505
G2G
KW
E21647
G2G
KW
E21657
G2G
MIKE 11
E21987
G2G
PDM
E22344
G2G
PDM
E22351
G2G
PDM
E22518
G2G
PDM
E22727
G2G
ISIS 2
ISIS
E22744
G2G
ISIS 2
ISIS
E22761
G2G
ISIS
E22843
G2G
ISIS
E22869
G2G
ISIS
E22889
G2G
ISIS 2
ISIS
E19862
G2G
PDM
E2862
G2G
PDM
E2901
G2G
PDM
E4222
G2G
PDM
<-4
>4
-4
-2
0
2
4

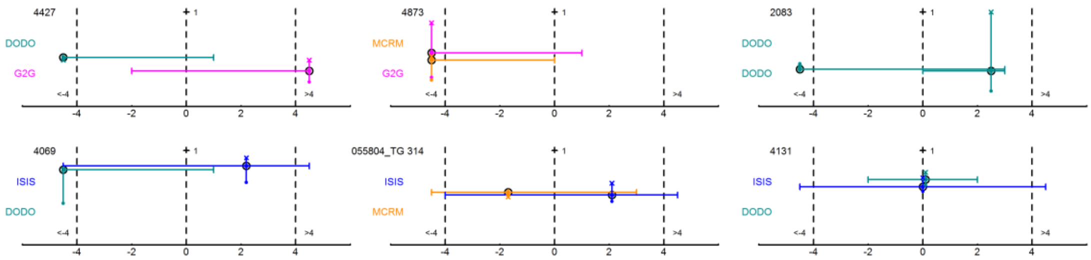
MIDLANDS

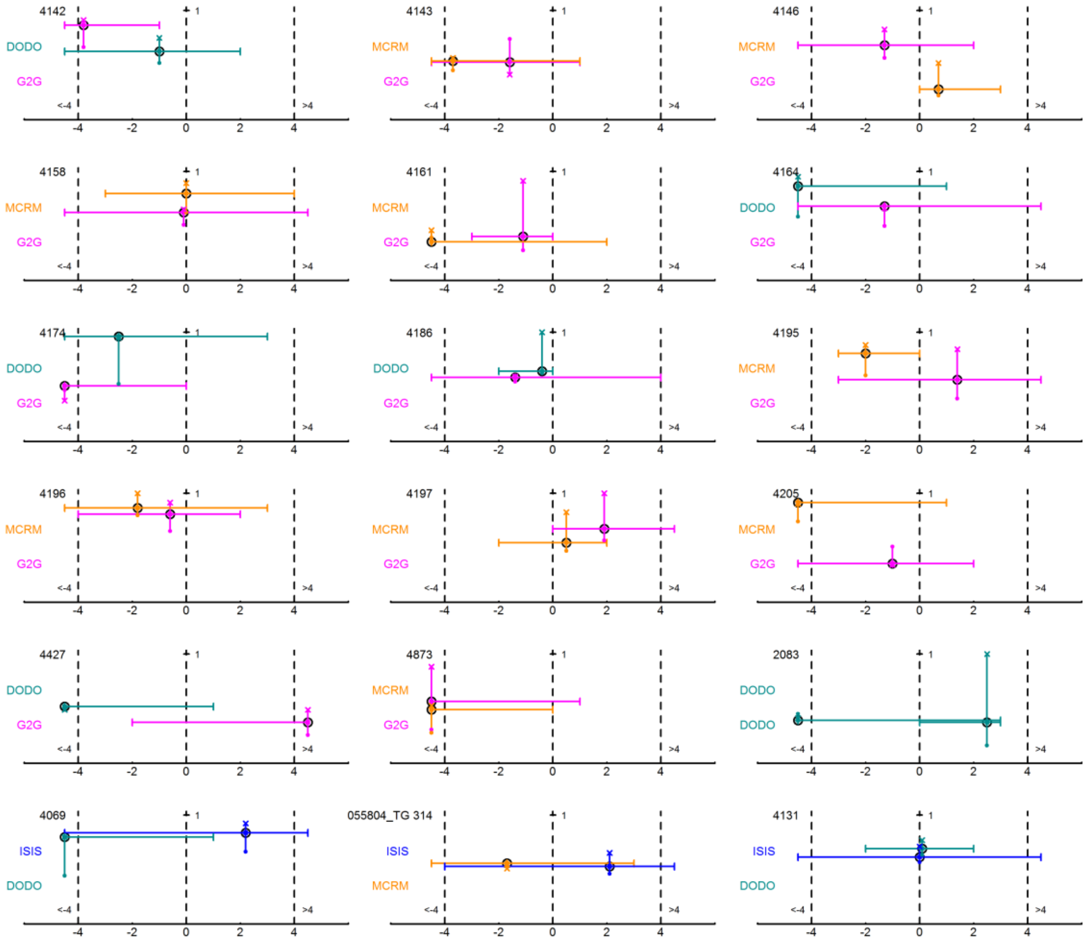



2094 MCRM G2G
2095 DODO G2G
2104 DODO G2G
2107 DODO G2G
2132 DODO G2G
2134 DODO G2G
2167 DODO DODO G2G
2175 DODO G2G
2180 DODO G2G
2609 MCRM G2G
2613 MCRM G2G
2621 MCRM G2G
2625 DODO G2G
2639 MCRM G2G
2649 MCRM G2G
4003 ISIS DODO G2G
4006 DODO G2G
4007 ISIS DODO G2G
4008 DODO G2G
4009 ISIS DODO G2G
4011 DODO G2G
4012 DODO G2G
4014 DODO G2G
4018 DODO G2G
4019 ISIS DODO G2G
4022 ISIS DODO G2G
4023 DODO G2G
4024 DODO G2G
4026 MCRM G2G
4031 DODO G2G
4032 MCRM G2G
4033 MCRM G2G
4039 MCRM G2G
4040 MCRM G2G
4041 MCRM G2G
4043 DODO G2G
<-4 -4 -2 0 2 4 >4

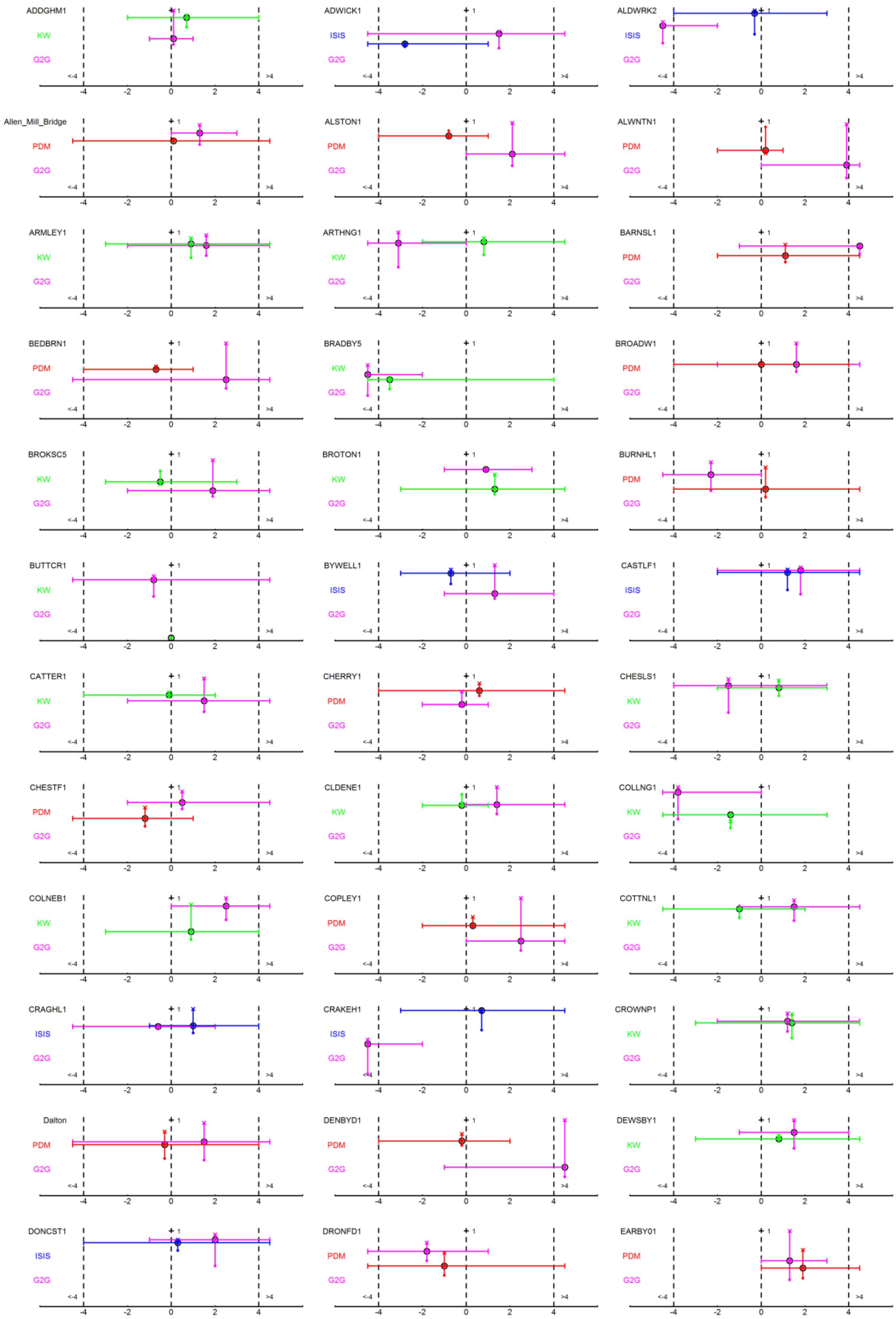


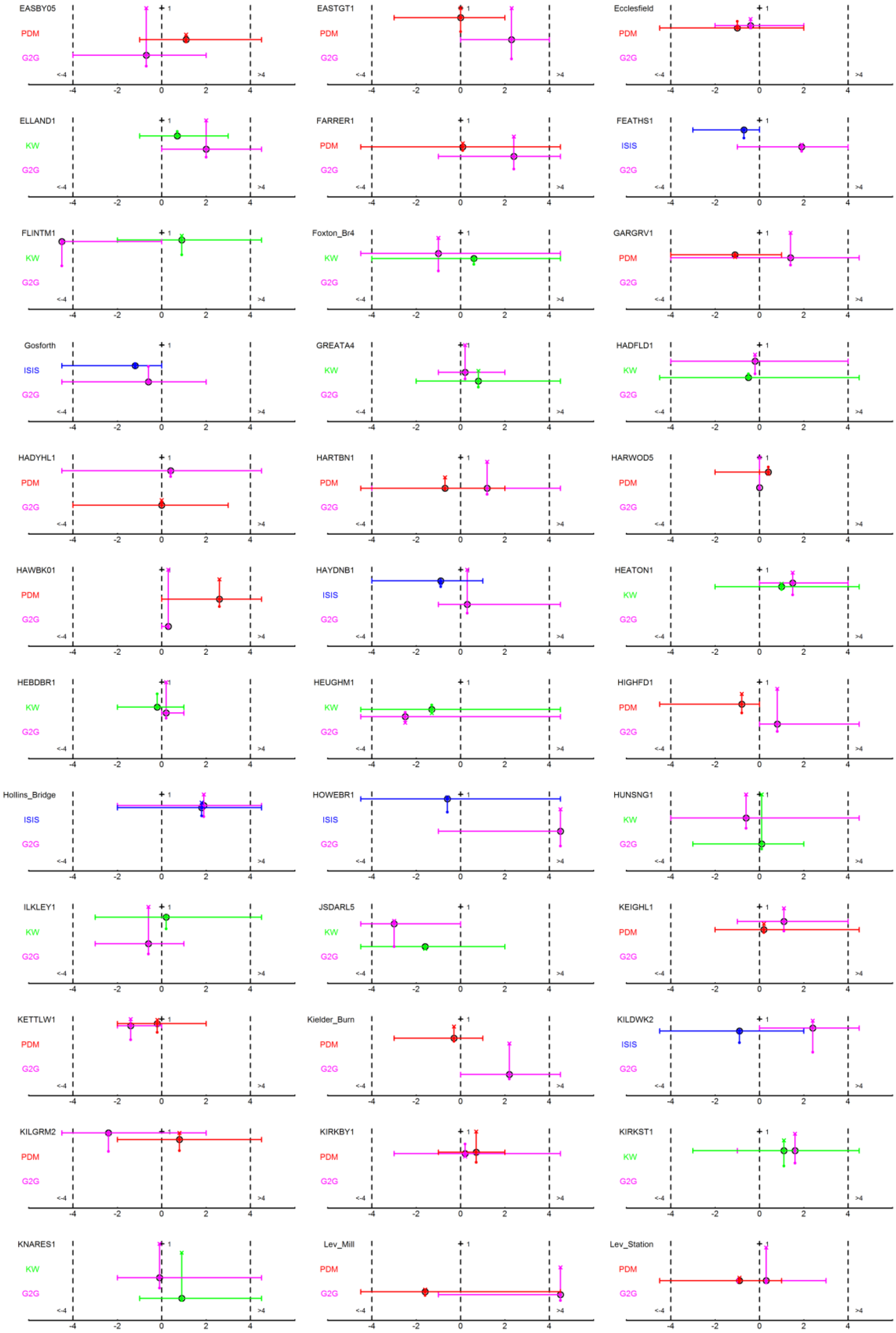
4046 DODO G2G
4048 MCRM G2G
4049 MCRM G2G
4052 MCRM G2G
4053 MCRM G2G
4055 DODO G2G
4056 DODO G2G
4058 MCRM G2G
4061 DODO G2G
4066 MCRM G2G
4067 DODO G2G
4074 DODO G2G
4080 ISIS DODO G2G
4081 MCRM G2G
4082 DODO G2G
4083 DODO G2G
4085 DODO G2G
4086 DODO G2G
4087 ISIS DODO G2G
4091 DODO G2G
4093 DODO G2G
4115 DODO G2G
4116 DODO G2G
4118 DODO G2G
4142 DODO G2G
4143 MCRM G2G
4146 MCRM G2G
4158 MCRM G2G
4161 MCRM G2G
4164 DODO G2G
4174 DODO G2G
4186 DODO G2G
4195 MCRM G2G
4196 MCRM G2G
4197 MCRM G2G
4205 MCRM G2G

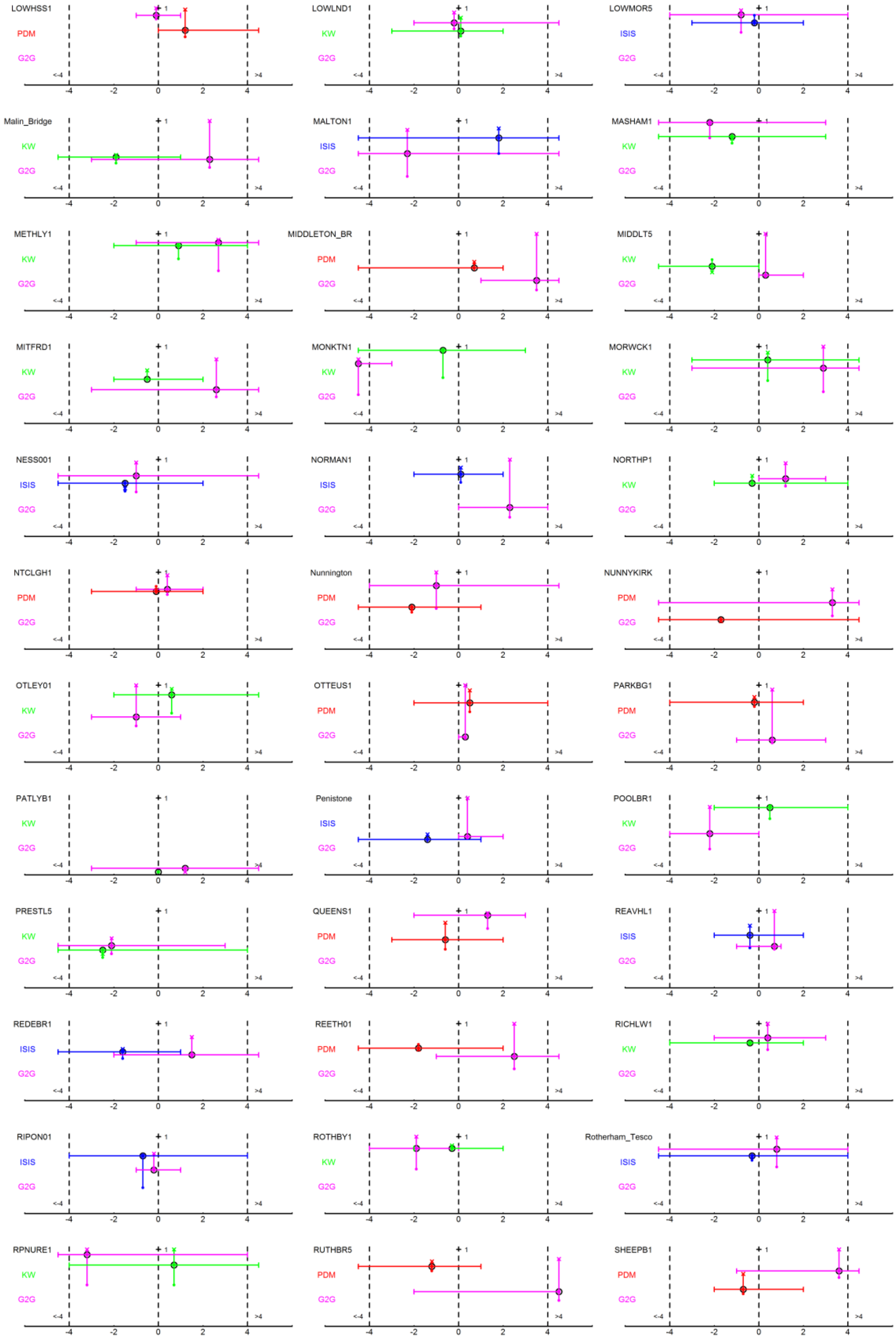

4427
DODO
G2G
4873
MCRM
G2G
2083
DODO
DODO
4069
ISIS
DODO
055804_TG 314
ISIS
MCRM
4131
ISIS
DODO

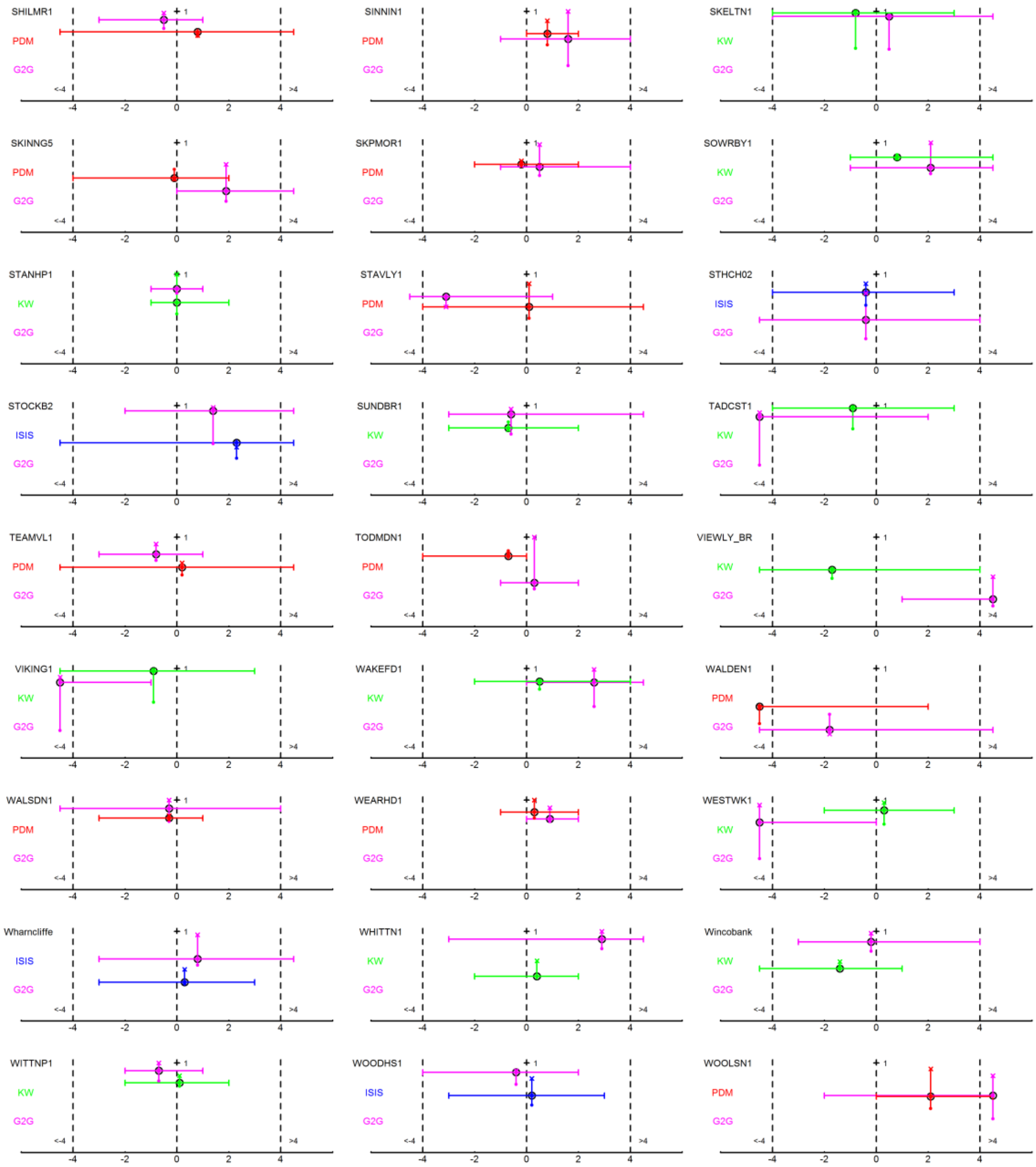

4142
DODO
G2G
4143
MCRM
G2G
4146
MCRM
G2G
4158
MCRM
G2G
4161
MCRM
G2G
4164
DODO
G2G
4174
DODO
G2G
4186
DODO
G2G
4195
MCRM
G2G
4196
MCRM
G2G
4197
MCRM
G2G
4205
MCRM
G2G
4427
DODO
G2G
4873
MCRM
G2G
2083
DODO
DODO
4069
ISIS
DODO
055804_TG 314
ISIS
MCRM
4131
ISIS
DODO

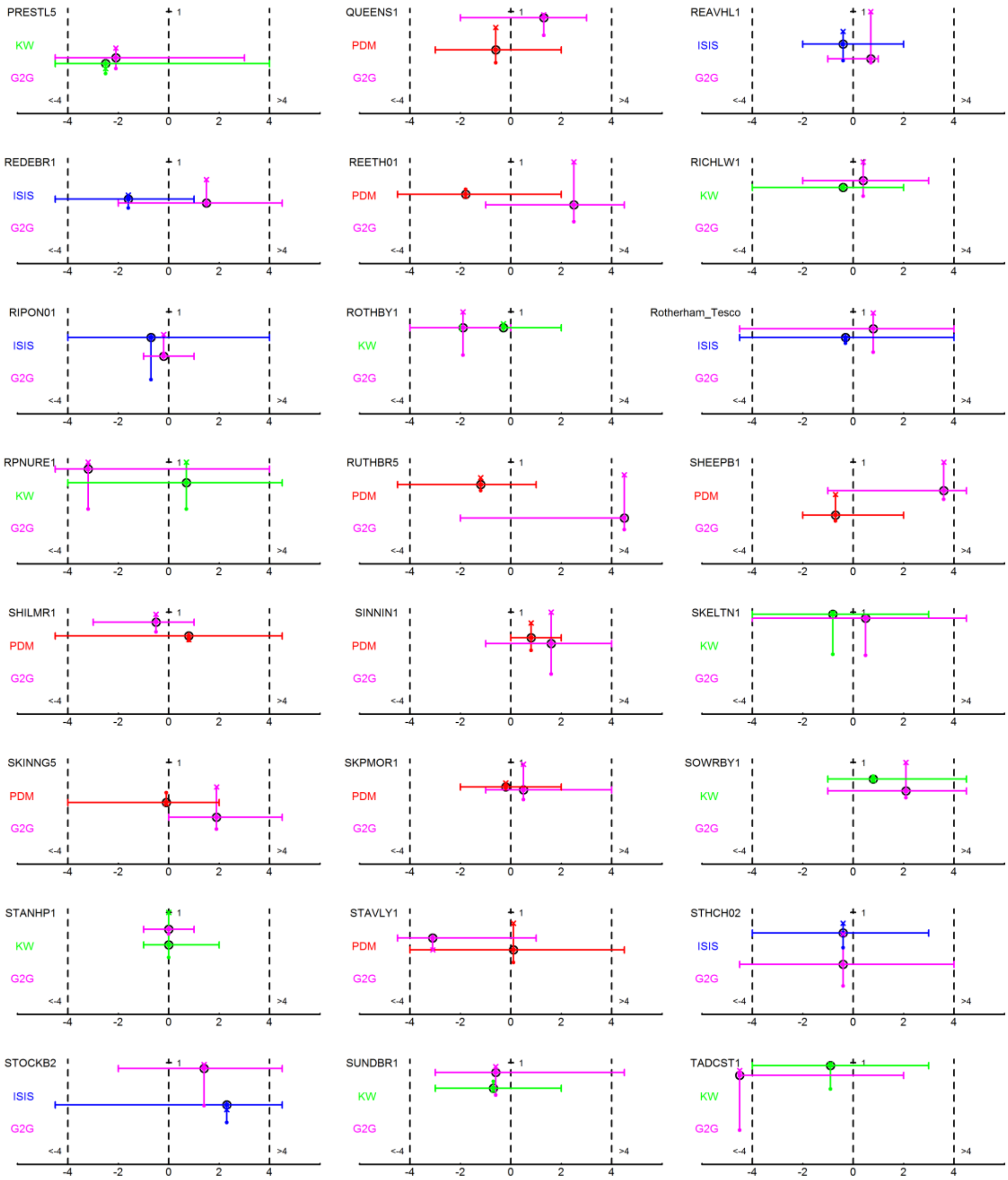
NORTH EAST


ADDGHM1
KW
G2G
ADWICK1
ISIS
G2G
ALDWRK2
ISIS
G2G
Allen_Mill_Bridge
PDM
G2G
ALSTON1
PDM
G2G
ALWNTN1
PDM
G2G
ARMLEY1
KW
G2G
ARTHNG1
KW
G2G
BARNSL1
PDM
G2G
BEDBRN1
PDM
G2G
BRADBY5
KW
G2G
BROADW1
PDM
G2G
BROKSC5
KW
G2G
BROTON1
KW
G2G
BURNHL1
PDM
G2G
BUTTCR1
KW
G2G
BYWELL1
ISIS
G2G
CASTLF1
ISIS
G2G
CATTER1
KW
G2G
CHERRY1
PDM
G2G
CHESLS1
KW
G2G
CHESTF1
PDM
G2G
CLDENE1
KW
G2G
COLLNG1
KW
G2G
COLNEB1
KW
G2G
COPLEY1
PDM
G2G
COTTNL1
KW
G2G
CRAGHL1
ISIS
G2G
CRAKEH1
ISIS
G2G
CROWNP1
KW
G2G
Dalton
PDM
G2G
DENBYD1
PDM
G2G
DEWSBY1
KW
G2G
DONCST1
ISIS
G2G
DRONFD1
PDM
G2G
EARBY01
PDM
G2G

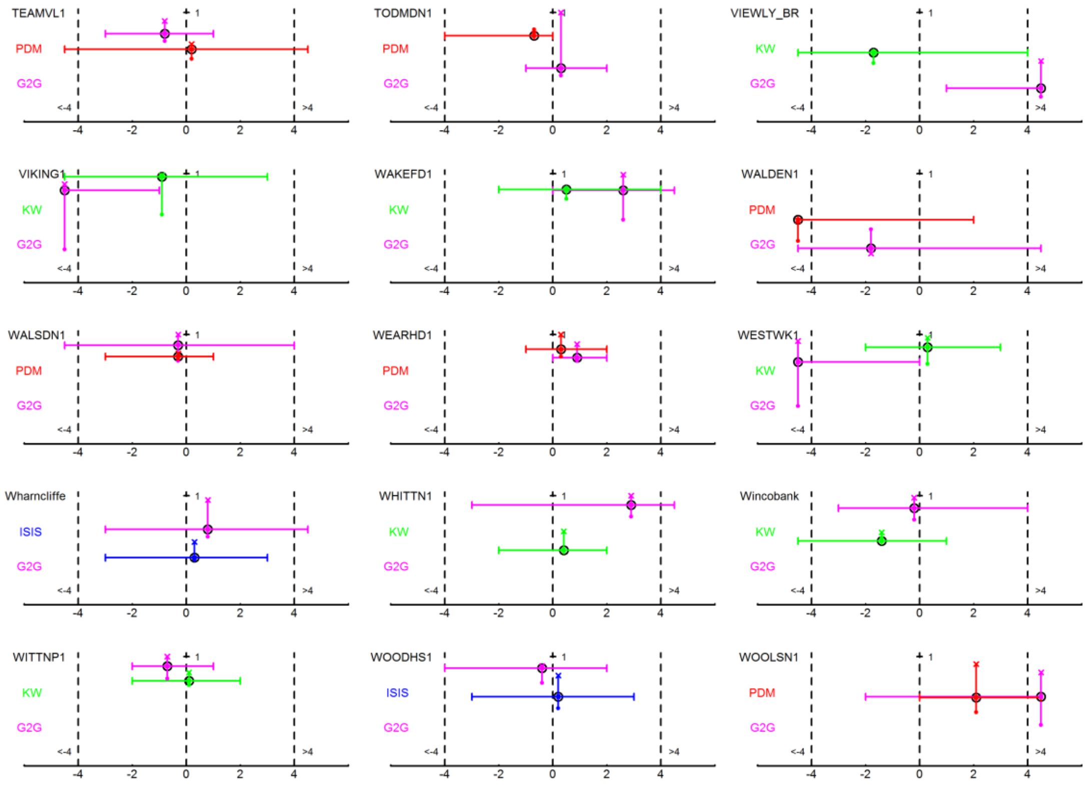

EASBY05
PDM
G2G
EASTGT1
PDM
G2G
Ecclesfield
PDM
G2G
ELLAND1
KW
G2G
FARRER1
PDM
G2G
FEATHS1
ISIS
G2G
FLINTM1
KW
G2G
Foxton_Br4
KW
G2G
GARGRV1
PDM
G2G
Gosforth
ISIS
G2G
GREATA4
KW
G2G
HADFLD1
KW
G2G
HADYHL1
PDM
G2G
HARTBN1
PDM
G2G
HARWOD5
PDM
G2G
HAWBK01
PDM
G2G
HAYDNB1
ISIS
G2G
HEATON1
KW
G2G
HEBDBR1
KW
G2G
HEUGHM1
KW
G2G
HIGHFD1
PDM
G2G
Hollins_Bridge
ISIS
G2G
HOWEBR1
ISIS
G2G
HUNSNG1
KW
G2G
ILKLEY1
KW
G2G
JSDARL5
KW
G2G
KEIGHL1
PDM
G2G
KETTLW1
PDM
G2G
Kielder_Burn
PDM
G2G
KILDWK2
ISIS
G2G
KILGRM2
PDM
G2G
KIRKBY1
PDM
G2G
KIRKST1
KW
G2G
KNARES1
KW
G2G
Lev_Mill
PDM
G2G
Lev_Station
PDM
G2G


LOWHSS1
PDM
G2G
LOWLND1
KW
G2G
LOWMOR5
ISIS
G2G
Malin_Bridge
KW
G2G
MALTON1
ISIS
G2G
MASHAM1
KW
G2G
METHLY1
KW
G2G
MIDDLETON_BR
PDM
G2G
MIDDLT5
KW
G2G
MITFRD1
KW
G2G
MONKTN1
KW
G2G
MORWCK1
KW
G2G
NESS001
ISIS
G2G
NORMAN1
ISIS
G2G
NORTHP1
KW
G2G
NTCLGH1
PDM
G2G
Nunnington
PDM
G2G
NUNNYKIRK
PDM
G2G
OTLEY01
KW
G2G
OTTEUS1
PDM
G2G
PARKBG1
PDM
G2G
PATLYB1
KW
G2G
Penistone
ISIS
G2G
POOLBR1
KW
G2G
PRESTL5
KW
G2G
QUEENS1
PDM
G2G
REAVHL1
ISIS
G2G
REDEBR1
ISIS
G2G
REETH01
PDM
G2G
RICHLW1
KW
G2G
RIPON01
ISIS
G2G
ROTHBY1
KW
G2G
Rotherham_Tesco
ISIS
G2G
RPNURE1
KW
G2G
RUTHBR5
PDM
G2G
SHEEPB1
PDM
G2G


SHILMR1
PDM
G2G
SINNIN1
PDM
G2G
SKELTN1
KW
G2G
SKINNG5
PDM
G2G
SKPMOR1
PDM
G2G
SOWRBY1
KW
G2G
STANHP1
KW
G2G
STAVLY1
PDM
G2G
STHCH02
ISIS
G2G
STOCKB2
ISIS
G2G
SUNDBR1
KW
G2G
TADCST1
KW
G2G
TEAMVL1
PDM
G2G
TODMDN1
PDM
G2G
VIEWLY_BR
KW
G2G
VIKING1
KW
G2G
WAKEFD1
KW
G2G
WALDEN1
PDM
G2G
WALSDN1
PDM
G2G
WEARHD1
PDM
G2G
WESTWK1
KW
G2G
Wharncliffe
ISIS
G2G
WHITTN1
KW
G2G
Wincobank
KW
G2G
WITTNP1
KW
G2G
WOODHS1
ISIS
G2G
WOOLSN1
PDM
G2G

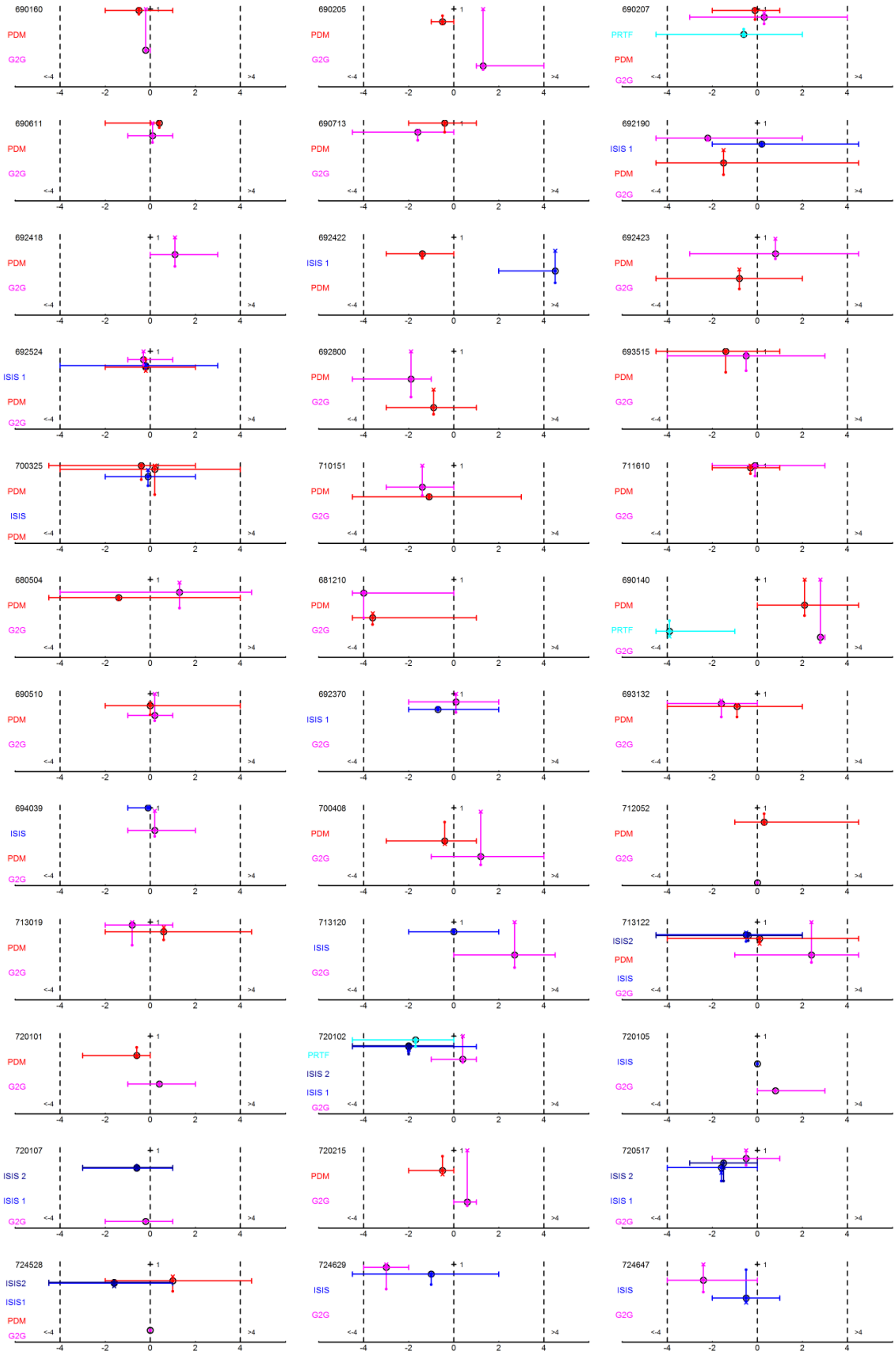


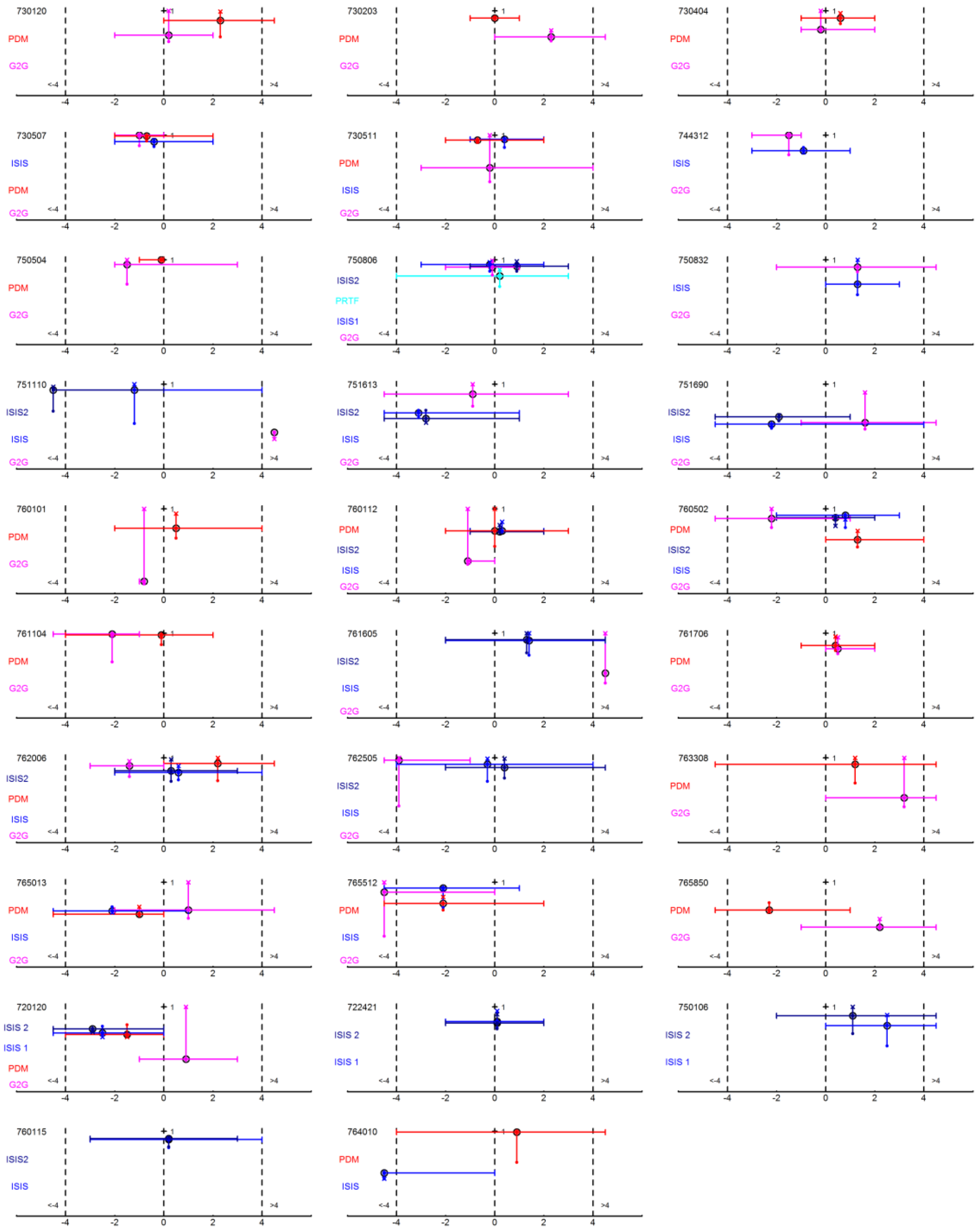
PRESTL5
KW
G2G
QUEENS1
PDM
G2G
REAVHL1
ISIS
G2G
REDEBR1
ISIS
G2G
REETH01
PDM
G2G
RICHLW1
KW
G2G
RIPON01
ISIS
G2G
ROTHBY1
KW
G2G
Rotherham_Tesco
ISIS
G2G
RPNURE1
KW
G2G
RUTHBR5
PDM
G2G
SHEEPB1
PDM
G2G
SHILMR1
PDM
G2G
SINNIN1
PDM
G2G
SKELTN1
KW
G2G
SKINNG5
PDM
G2G
SKPMOR1
PDM
G2G
SOWRBY1
KW
G2G
STANHP1
KW
G2G
STAVLY1
PDM
G2G
STHCH02
ISIS
G2G
STOCKB2
ISIS
G2G
SUNDBR1
KW
G2G
TADCST1
KW
G2G



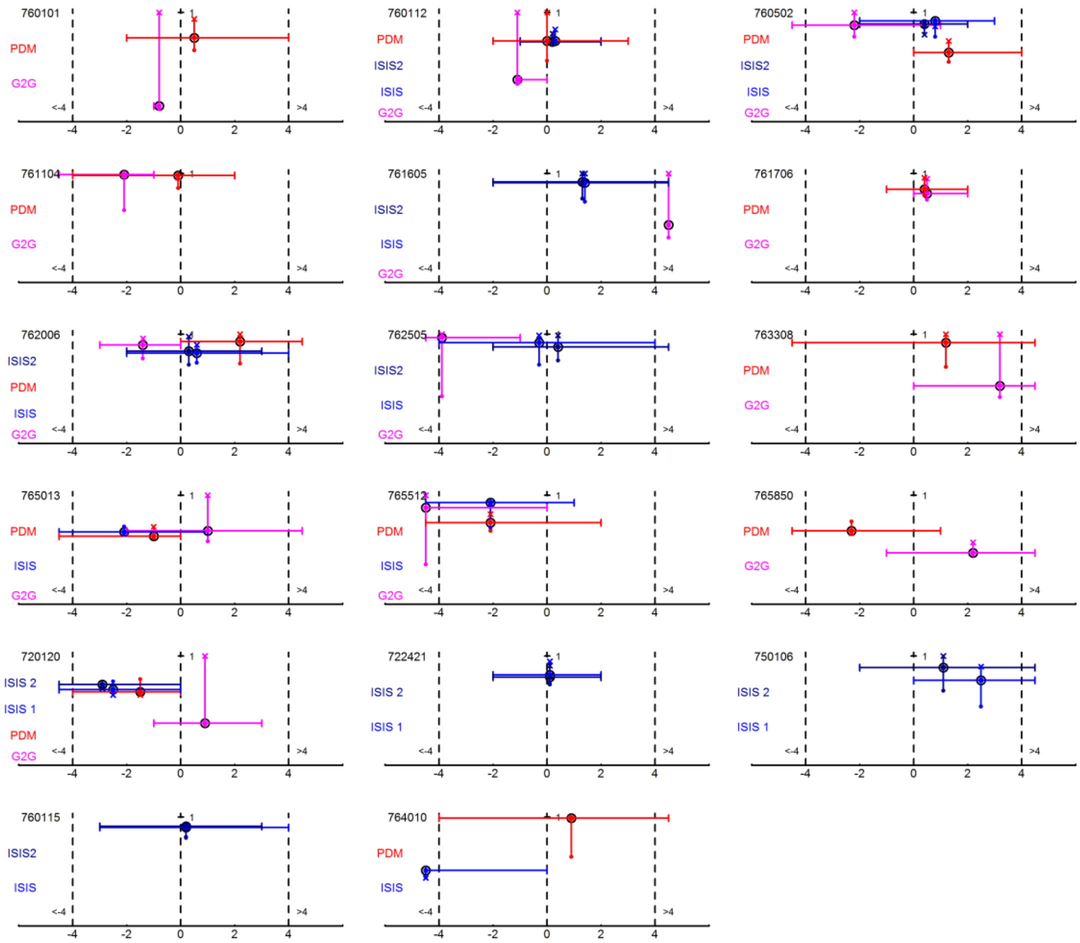
TEAMVL1
PDM
G2G
TODMDN1
PDM
G2G
VIEWLY_BR
KW
G2G
VIKING1
KW
G2G
WAKEFD1
KW
G2G
WALDEN1
PDM
G2G
WALSDN1
PDM
G2G
WEARHD1
PDM
G2G
WESTWK1
KW
G2G
Wharncliffe
ISIS
G2G
WHITTN1
KW
G2G
Wincobank
KW
G2G
WITTNP1
KW
G2G
WOODHS1
ISIS
G2G
WOOLSN1
PDM
G2G

NORTH WEST


690160 PDM G2G
690205 PDM G2G
690207 PRTF PDM G2G
690611 PDM G2G
690713 PDM G2G
692190 ISIS 1 PDM G2G
692418 PDM G2G
692422 ISIS 1 PDM
692423 PDM G2G
692524 ISIS 1 PDM G2G
692800 PDM G2G
693515 PDM G2G
700325 PDM ISIS PDM
710151 PDM G2G
711610 PDM G2G
680504 PDM G2G
681210 PDM G2G
690140 PDM PRTF G2G
690510 PDM G2G
692370 ISIS 1 G2G
693132 PDM G2G
694039 ISIS PDM G2G
700408 PDM G2G
712052 PDM G2G
713019 PDM G2G
713120 ISIS G2G
713122 ISIS2 PDM ISIS G2G
720101 PDM G2G
720102 PRTF ISIS 2 ISIS 1 G2G
720105 ISIS G2G
720107 ISIS 2 ISIS 1 G2G
720215 PDM G2G
720517 ISIS 2 ISIS 1 G2G
724528 ISIS2 ISIS1 PDM G2G
724629 ISIS G2G
724647 ISIS G2G
<-4 -4 -2 0 2 4 >4 +1

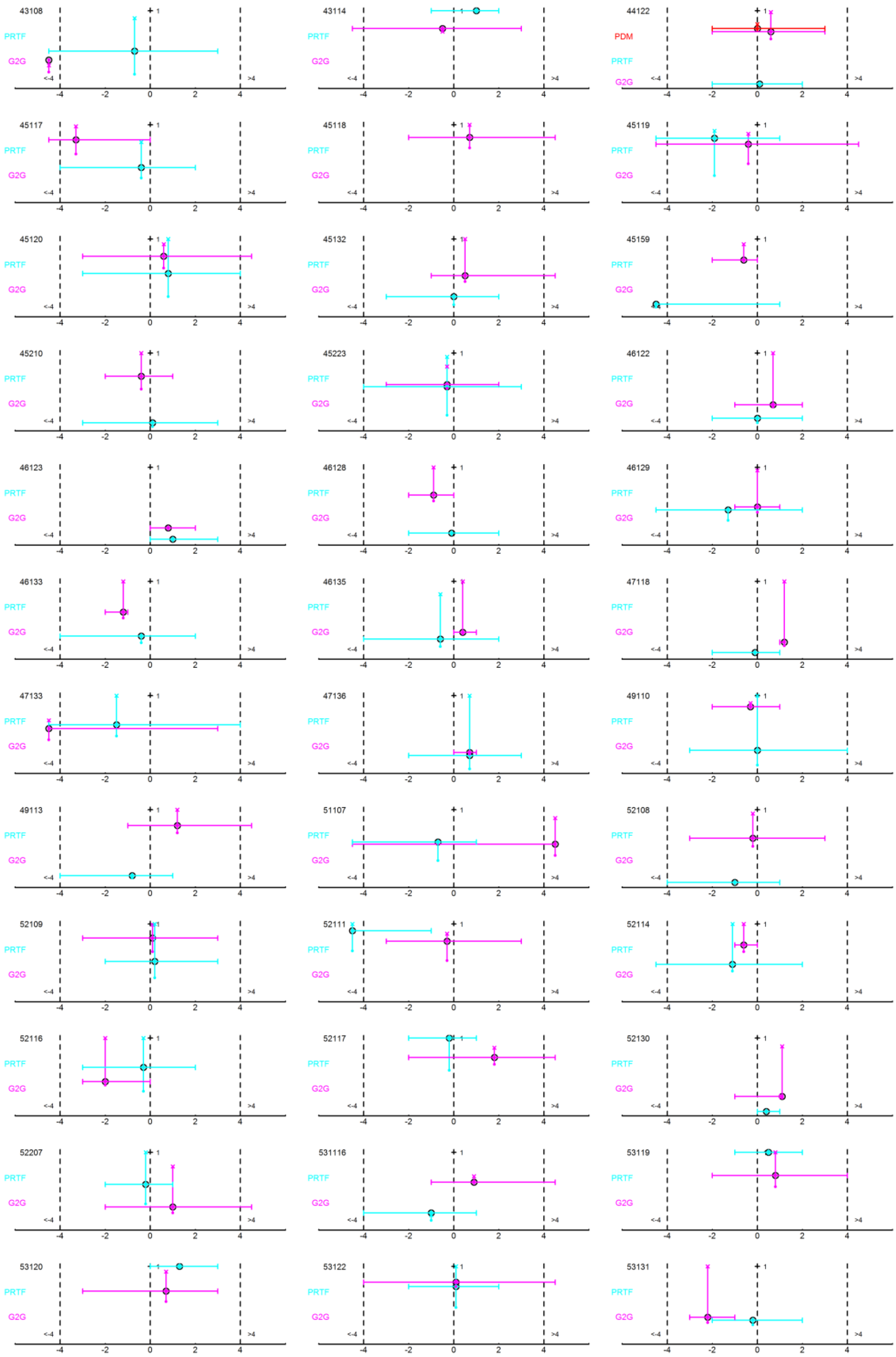


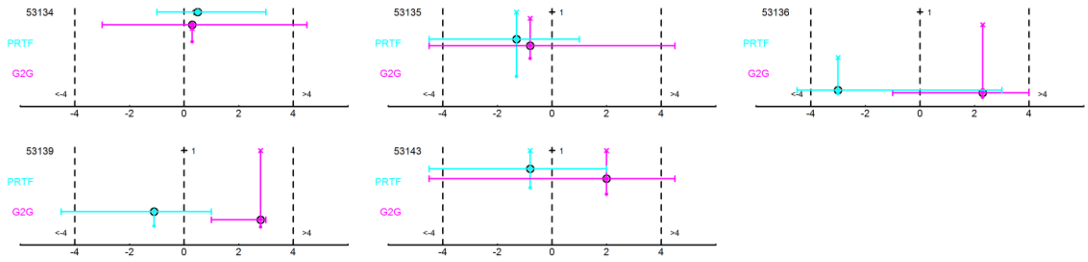
730120
PDM
G2G
730203
PDM
G2G
730404
PDM
G2G
730507
ISIS
PDM
G2G
730511
PDM
ISIS
G2G
744312
ISIS
G2G
750504
PDM
G2G
750806
ISIS2
PRTF
ISIS1
G2G
750832
ISIS
G2G
751110
ISIS2
ISIS
G2G
751613
ISIS2
ISIS
G2G
751690
ISIS2
ISIS
G2G
760101
PDM
G2G
760112
PDM
ISIS2
ISIS
G2G
760502
PDM
ISIS2
ISIS
G2G
761104
PDM
G2G
761605
ISIS2
ISIS
G2G
761706
PDM
G2G
762006
ISIS2
PDM
ISIS
G2G
762505
ISIS2
ISIS
G2G
763308
PDM
G2G
765013
PDM
ISIS
G2G
765512
PDM
ISIS
G2G
765850
PDM
G2G
720120
ISIS 2
ISIS 1
PDM
G2G
722421
ISIS 2
ISIS 1
750106
ISIS 2
ISIS 1
760115
ISIS2
ISIS
764010
PDM
ISIS



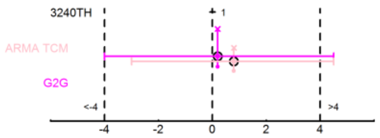
760101
PDM
G2G
760112
PDM
ISIS2
ISIS
G2G
760502
PDM
ISIS2
ISIS
G2G
761104
PDM
G2G
761605
ISIS2
ISIS
G2G
761706
PDM
G2G
762006
ISIS2
PDM
ISIS
G2G
762505
ISIS2
ISIS
G2G
763308
PDM
G2G
765013
PDM
ISIS
G2G
765512
PDM
ISIS
G2G
765850
PDM
G2G
720120
ISIS 2
ISIS 1
PDM
G2G
722421
ISIS 2
ISIS 1
750106
ISIS 2
ISIS 1
760115
ISIS2
ISIS
764010
PDM
ISIS

SOUTH WEST

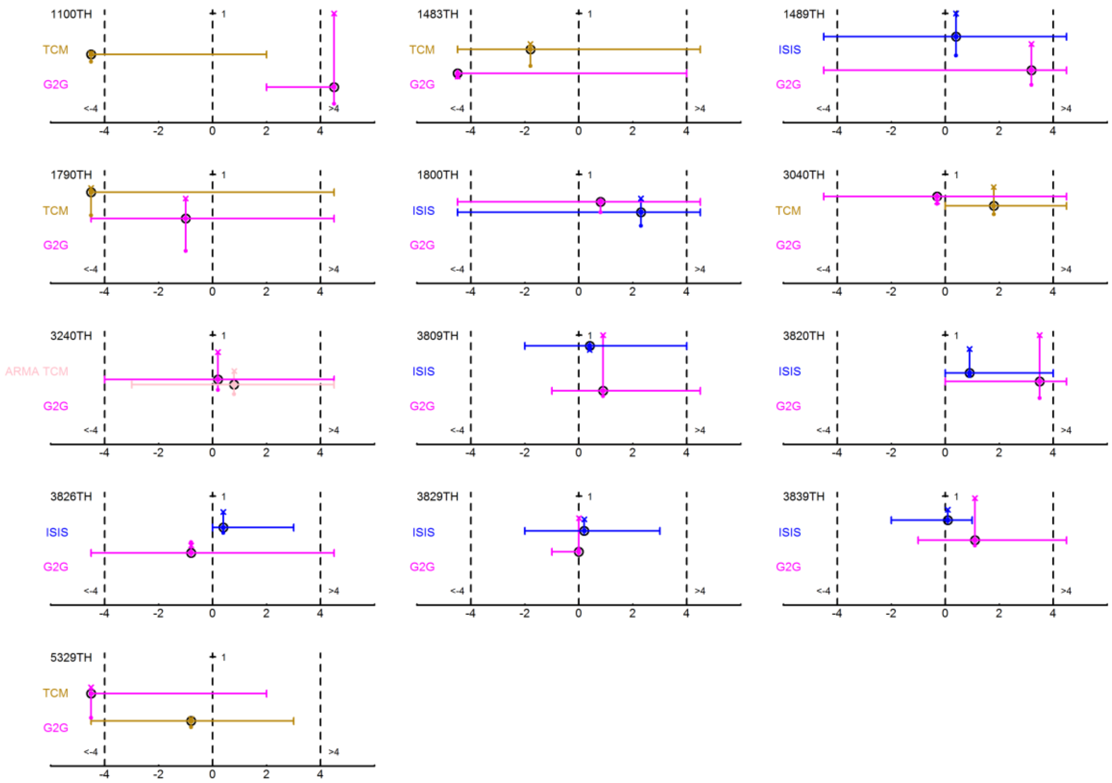

43108
43114
44122
45117
45118
45119
45120
45132
45159
45210
45223
46122
46123
46128
46129
46133
46135
47118
47133
47136
49110
49113
51107
52108
52109
52111
52114
52116
52117
52130
52207
531116
53119
53120
53122
53131
PRTF
G2G
PDM
<-4
>4
-4
-2
0
2
4



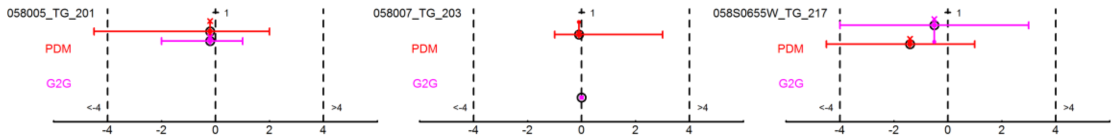
SOUTHERN



THAMES



WALES



058005_TG_201
PDM
G2G
1
<-4
>4
-4
-2
0
2
4
058007_TG_203
PDM
G2G
1
<-4
>4
-4
-2
0
2
4
058S0655W_TG_217
PDM
G2G
1
<-4
>4
-4
-2
0
2
4

Would you like to find out more about us or about your environment?

Then call us on
03708 506 506 (Monday to Friday, 8am to 6pm)

email
enquiries@environment-agency.gov.uk

or visit our website
www.gov.uk/environment-agency

incident hotline **0800 807060** (24 hours)
floodline **0345 988 1188 / 0845 988 1188** (24 hours)

Find out about call charges (www.gov.uk/call-charges)

Environment first: Are you viewing this on screen? Please consider the environment and only print if absolutely recessary. If you are reading a paper copy, please don't forget to reuse and recycle if possible.