APPENDIX A

General Flood Forecasting Glossary and List of Abbreviations/Acronyms

Source: National Flood Warning Centre (Latest versions obtainable from the same location)

GLOSSARY

TERM	DEFINITION / DESCRIPTION
1-D *hydrodynamic* modelling:	A *modelling approach* based on the Saint-Venant equations capable of predicting discharge and water level for a wide range of rivers, reservoirs, complex floodplains and narrow estuaries.
2-D *hydrodynamic* modelling:	A *modelling approach* based on the *shallow water wave* equations capable of predicting flows and water surface elevations in two dimensions. The approach can cope with lateral variations in depth and velocity and is particularly useful in modelling wide estuaries and flows over side-weirs.
Attenuation:	A characteristic flattening of discharge hydrographs, reduction in the magnitude of peak flows and an increase in flood duration associatd with temporary storage along a river reach, reservoir or across a floodplain.
Automatic calibration:	The calibration of a mathematical model using optimisation methods by minimising some measure of error criterion called objective function.
Average Annual Damage (AAD):	Damage likely to occur over a one-year period expressed as an average value per year.
Base Model	A calibrated and verified model.
Baseline:	The present condition of the river or estuary.
Benefits:	Economic, environmental etc gain in terms of (flood defence – the damages avoided).
Calibration:	The process of back-calculating or estimating the values of empirical parameters inherent in the governing equations. The process is often carried out through trial-and-error comparisons of gauged and simulated values.
Code or Computer Program	A series of *algorithms* often capable of processing input data to produce output data.
Compensation flow	Water released from a reservoir or a diversion structure to meet the needs of downstream ('riparian') water users and/or to satisfy environmental requirements.
Conceptual Hydrological Models	A *modelling approach* transforming rainfall to runoff by allowing for a whole range of catchment storage reservoirs through notional storage volumes.
Continuous modelling	A flood forecasting practice based on continuously running flood-forecasting models.
Dataset	A collection of data that represents the physical characteristics or some other abstract description of a particular catchment or a river system.
Deterministic Models	Models that attempt replicate physical processes by explicitly modelling the laws of nature governing the process.
Empirical modelling:	A *modelling approach* often developed by fitting a mathematical function to observed data using regression analysis or some other mathematical methods. The classical example is the Manning equation for normal flows. In forecasting, threshold exceedence and level-to-level correlation techniques are also other examples.
Flood Forecasting	The prediction of peak flows and levels and the times that they will occur.
Flood Routing:	Routing is a term given to calculation procedures for determining the modification of waveforms as flood waves travel in open-channels. Broadly, there are two methods (**i**) *hydrological routing* (encompassing *channel routing* and reservoir routing), (**ii**) *hydraulic routing* (encompasses *kinematic routing*, diffusion analogy, and *hydrodynamic routing*.
Forecasting Platform	The hardware system used to host forecasting software.
Graphical User Interface (GUI)	A piece of software that can display raw or processed data and allow a user to control the performance and operation of software packages and modelling applications.
Hazard:	The potential for adverse outcomes. In the case of flooding, the hazard relates to the inundation of land by floodwater posing threats to life, inflicting damage and/or disruptions.
Household Equivalent (HE):	Unit of measurement for property susceptible to flooding.

Holistic Catchment Management:	A management philosophy allowing for interactions among a whole range of factors affecting catchment behaviours.
Hydrograph:	A time history or time-series of a certain hydraulic variable such as discharge or water level.
Hydrological Routing	A *modelling approach* for routing discharge hydrographs by a water budget equation (inflow-outflow = rate of change of storage). "Channel routing" or the Muskingum method refers to cases in which storage is a function of inflows and ouflows and "storage routing" to cases in which storage is a function of outflows.
Hyetograph	Time distribution of rainfall, which is also referred to as "rain profile." Hyetographs are normally bar chart displays of measured/forecasted depths of collected rainfall in regular intervals (say 15 minutes).
Intake:	Structure through which water is drawn out of a river.
Inter-tidal:	Between the levels of low tide and high tide.
Lead time:	The time by which the forecast of an incident precedes its occurrence (or non-occurrence).
Low water:	Lowest water level reached by each ebb tide.
Model (or Mathematical Model)	A program that processes data in its own specific format and then performs internal calculations to derive predicted flows or water levels.
Model Verification	A confidence building process in modelling, whereby the calibrated model is further used to independently predict an independently gauged event meeting the same criteria as used in calibration.
Modelling Packages or Proprietary Packages	It is now customary to develop user-friendly codes through front-end model development and back-end result processing facilities, in which case the codes are referred to as software. Modelling Packages are normally proprietary packages e.g. HEC-RAS, ISIS, Mike11.
Modelling Procedure	The life cycle of a modelling project. This includes inception, schematisation, data abstraction, building a preliminary model, calibration, verification and its eventual applications.
Modelling Shell	A proposed term to refer to *modelling/forecasting system* where a wide range of *software packages* and other software utilities and *modelling applications* are accessible for users. Software utilities include *Graphical User Interfaces* (GUI). Modelling shell does not normally refer to datafiles or result-files.
Modelling System	A proposed term to encompass *Modelling shell*, *software packages*, software utilities, *base model* and *modelling applications*. This may equally be referred to as modelling/forecasting system.
Monitoring:	Regular interrogation of hydrometric data (especially river levels) with a view to intensifying such activity, initiating forecasting, or issuing warnings if pre-set levels exceeded.
Neap tides:	Tides on the tow occasions per lunar month when the predicted range between successive high water and low water is least.
Opportunity Benefits:	Economic benefit available through achieving improved target standards of service.
Open Architecture:	A system that admits third party software packages or off-the-shelf products without the intervention of the system producers. This is only possible if the architecture of the system is modular and the various modules have published interfaces.
Post Event Appraisal:	Studies undertaken after a flood incidence for assessing the effectiveness of incidence management.
Post-audit:	Review of flood forecast or flood warning performance following a flood incidence or a flood season to quantify the performance of the forecast and warning system.
Rainfall-runoff models:	Models that transform rainfall to runoff. Rainfall-runoff models may be metric ('black-box'), conceptual, physically based or hybrid metric-conceptual: and may use an lumped input of catchment average rainfall, or a distributed input.
Reach:	A length of channel between defined boundaries.
Risk assessment:	A decision making approach often encompassing a formalised procedure.
Risk:	A risk is the likelihood of an adverse event. **Risk = likelihood x hazard**. Thus, risk is the combined effect of the probability of occurrence and hazard.

Sea level rise	Increase in mean sea level due to global warming and climate changes.
Sea State Forecasting	Prediction of offshore and near shore conditions based upon wave, wind, tide, weather, pressure and surge conditions
Sediment transport:	Movement of sediment under the action of waves and currents
Sensitivity analysis:	Assessment of the impacts of system parameters or other factors such as boundary conditions on model results by systematically varying their values.
Shallow water waves	Water waves in open channels driven by gravity with an appreciable displacement of bulk water in a direction parallel to the flow. Flood waves are *shallow water waves*.
Shell	A software system that receives and stores raw external data together with Model Datasets and model results. It controls the operation and performance of the hydraulic and hydrological or other Models that are included within it through an associated Graphical User Interface
Stochastic models:	Processes in which the processes are governed by extremely large number of causative factors that are therefore considered to be randomly governed.
Updating	Updating is the process of utilising measurements of water levels or discharges in the pre-forecast period to correct for minor deviations in simulated values during the forecast period.

ABBREVIATIONS and ACRONYMS

Abbreviation	Definition
1-D	One Dimensional
2-D	Two Dimensional
AFFMS	Anglian Flow Forecasting Modelling System
Agency	Environment Agency
AMAZON	An overtopping software application
ANN	Artificial Neural Network
ARCView	A proprietary GIS product
ARSP	Acres Reservoir Simulation Package
ARTS	Anglian Region Telemetry System
AVM:	Automatic Voice Messaging
CASCADE:	Catchment Assessment System Concerned with the Accurate Dissemination of Effective flood warnings.
CCTV	Closed Circuit Television
CEH:	Centre of Ecology and Hydrology (formerly IH : Institute of Hydrology)
CIS	(The Agency's) Corporate Information Services (department)
CNFDR:	Changing Needs in Flood Defence Review
CoBA	Cost Benefit Assessment
CRC	Cyclic Redundancy Check
CSCE	Canadian Society for Civil Engineering
CSM	Continental Shelf Model
DEFRA	Department of Environment, Food and the Environment
DELFT-FEWS	Delft Hydraulics' Flood Early Warning System.
DEM	Digital Elevation Model
DETR	Department of Environment, Transport and the Regions
DHI	Danish Hydraulics Institute
DL	Dynamic Logic – a Telemetry System & Outstation Supplier
DODO	Douglas and Dobson Routing Model
DOS	Disk Operating System
DSS	Decision Support System
DSSY	Data Storage System
DTM	Digital Terrain Model
DTS	Delta Technical Services
DWOPER	A Hydrodynamic Model produced by the United States National Weather Service
EFA:	Easter Floods Actions
EFAG:	Easter Floods Action Groups
EFAP:	Easter Floods Action Plan
EFFORTS	European Flood Forecasting Operational Real-Time Systems project
EFFS	European Flood Forecasting System (see EFFORTS)
ELFS	Emergency Level Forecasting System
EMS	Energy Management System
ERLOS:	Emergency Response Levels of Service
EURAQUA	EU initiative / project
EUROTAS	European River Flood Occurrence and Total Risk Assessment System
FEFLOW	Finite Element Flow software application
FFMS	Flood Forecasting Modelling System
FFP	Flood Forecasting Platform
FFS	Flow Forecasting System – part of the Midlands Region system
FFWRS:	Flood Forecasting and Response Warning System.
FHRC	Flood Hazard Research Centre at Middlesex University
FRA	Flood Risk Area
FRONTIERS:	Forecasting Rain Optimised Using New Techniques of Interactively Enhanced Radar and Satellite Data. An interactive radar rainfall based system system developed by the

	Met Office for forecasting rainfall for up to six hours ahead. Predecessor of NIMROD.
FTP	File Transfer Protocol
GANDOLF	Generating Advanced Nowcasts for Deployment in Operational Land-based Flood Forecasts. A system developed by the Met Office for forecasting convective rainfall.
GEO BASE	Geological Database
GEOHEC -1	Watershed Modelling System (old version)
GIS	Geographical Information System
GMS	Groundwater Modelling System
GUI	Graphical User Interface
HARP	Hydrometric Archive Replacement Program. Currently the Environment Agency are seeking to procure a National System for archiving hydrometric data.
HE	Household Equivalent
HEC	Hydrologic Engineering Centre (an Office of the US Army Corps of Engineers).
HEC-RAS	Open channel River Analysis System using steady state solver
HEC-RAS3	The latest version of the above, uses hydrodynamic solver
HR Wallingford	Hydraulics Research Wallingford
HYDRO-1D	A Hydrological and Hydrodynamic Modelling System developed and marketed by Mott McDonald Ltd
HYRAD	Weather Radar Display software developed by CEH
IAHR	International Association Hydraulic Engineering & Research
ICA	Information Control Algorithm, a component of RFFS
IHACRES	Rainfall-Runoff model developed by IH an d the Australian Centre for Research into Environmental Systems.
IH	(The) Institute of Hydrology, now know as CEH
IPC	Integrated Pollution Control
ISIS	Hydrological and hydrodynamic Modelling System developed and marketed by the joint venture between Wallingford Software and Sir William Halcrow and Partners Ltd.
IT	Information Technology
JCH-MR	Joint Centre for Hydrological & Meteorological Research. A joint Met Office / CeH centre located at CeH Wallingford.
JTP	Joint Telemetry Project
KW	Kinematic Wave model – part of RFFS
LAN	Local Area Network
LIDAR	Laser Induced Direction And Ranging
MAFF	Ministry of Agriculture Fisheries and Food (superseded by DEFRA)
MATRICES	A Sea State software application
MCC	Meteor Communication Centre
MCL	Meter Communications (Europe) Ltd
MDS	Model Development System – see OMDF
Met Office	UK National Meteorological Office
MFFS	Midland Flow Forecasting System – term used for the new system for the Midlands Region to replace the current FFS
Mike 11	The Hydrological and Hydrodynamic Modelling System developed and marketed by the Danish Hydraulic Institute
Mike ACS	The Mike11 module for Multi-layer Cohesive Sediment
MIKE BASIN	River Basin Modelling
Mike DB	The Mike11 module for Dam Bursts
Mike HD	The Mike11 hydrodynamic module
Mike NAM	The Mike11 module for Rainfall Runoff
MIKE SHE	Distributed Hydrological Modelling
Mike SO	The Mike11 module for Structure Operations
MIKE SWMM	Stormwater and Wastewater Modelling Package
Mike UD	The Mike11 module for Urban Drainage
Mike WQ	The Mike11 module for Water Quality
MIKE ZERO	Common Platform for DHI Products
MIST	Meteorological Information Self-briefing Terminal – a Met Office display system for

	viewing a range of their products.
MORECS	Met Office Rainfall and Evaporation System - Soil Moisture Information Service operated by the Met Office
NAM	The Mike11 module for Rainfall Runoff (now renamed to MKE11-RR)
NERC	Natural Environmental Research Council
NFFMS	National Flood Forecasting Modelling Systems
NFWC	National Flood Warning Centre
NFWPS:	National Flood Warning Performance Specification
Nimrod	A fully automated system developed by the Met Office for forecasting (non-convective) rainfall for lead-times of up to six hours.
NMC	National Meteorological Centre at Bracknell
NTS	National Telemetry Specification
NWRS	National Weather Radar Strategy
NWSRFS	Stream Flow Forecasting System
ODIN	Outstation Data Interrogation System
OMDF	Off-line Model Development Facility
PBT	Parsons Brinckerhoff Ltd (in UK formerly Kennedy & Donkin)
PDM	Probability Distributed Moisture model - a rainfall-runoff model developed by CeH.
PHR:	Proportion of households able to respond to a warning.
POL	Proudman Oceanographic Laboratory, part of NERC
PRRS	Particular Regional Requirements Specification
PRTF	Physically Realisable Transfer Function model (developed at the University of Bristol)
PSTN	Public Switched Telephone Network
R&D	Research and Development
RADAR	Radio Detection and Ranging
RADARNET	Met Office Radar Communications Network
RCC	Regional Communications Centre
RECS	Regional Emergency Communications System
RECS/FFS	The telemetry and flood forecasting system currently used in Midlands region
REMUS	Remote User System (for FFS)
RFFS	River Flow Forecasting System
RMS	River Modelling System
ROFFMS	Real-Time Operational Flood Forecast Modelling System
RTI	Riverside Technology Inc
RTS	Regional Telemetry System
SAAR	Standard Average Annual Rainfall
SCS	Soil Conservation Service
SCX	Telemetry Kernel Software for Serck Controls systems
SEEP2D	Ground Modelling System (old version)
SEFFS	Southern (Region) Enhanced Flood Forecasting System
SEPA	Scottish Environmental Protection Agency
SMS	Surface Water Modelling System
SSADM	Structure Systems Analysis and Design Method
STFS	Storm Tide Forecasting Service
STOAT	WRC – Software application for STW Modelling
STORM SHED	Hydrology Modelling software application
TAG	Theme Advisory Group (to the joint Agency/MAFF R&D Programme)
TF	Transfer Function
TFF	Tidal Flood Forecasting
TFFP	Tidal Flood Forecasting Project
TideBase	A system for displaying tidal data used by the Agency.
TIDEBASE	A standalone system for displaying Met Office tidal data
TIDELINK	A system for displaying Met Office tidal data developed at the Thames Barrier
TIDEPOL	Software operated by the Met Office to poll the “A” class tidal gauge network with the ability to forward data to the Thames Barrier.
TREND2	Trend Standard Report Packaging
URS	User Requirement Specification

USACE	United States Army Corp of Engineers
USCS	Unified Soil Classification System
USGS	United States Geological Survey
WAN	Wide Area Network
WINDATA	Rain Rate Forecast Package
WMS	Watershed Modelling System
WRIP	A rainfall-runoff modelling system developed by the University of Bristol

APPENDIX B

Regional Forecasting Issues

(Source: EA Regions – in response to questionnaire)

LIST OF POTENTIAL CASE STUDY EXAMPLES FOR ASSESMENT OF COMMON FORECASTING PROBLEMS

NOTES to Respondents

Typical forecasting problems might include:	Flashy Upland Catchments Urban Catchments Forecasting Flood Levels at Confluence Forecasting Influence of Structures Forecasting Groundwater Flooding Forcasting for Low Benefit Locations *Upto three examples of each problem is sufficient*
Specific description of problem might be:	Forecasting for specified flood risk zones in upstream part of catchment Forecasting for specified flood risk zone upstream/downstream of a structure *Forecasting problems due to poor data availability not required*
Survey types might include:	In-bank topographic channel survey Full floodplain topographic survey LiDAR survey

EA REGION: MIDLANDS **PREPARED BY:** TIM HARRISON

Top Five Forecasting Problems (listed in order of priority)	River Exhibiting Problem	Specific Description of Problem	Model (specify)	Data Availability for River/Reaches Specified			
				Gauging (1-good to 3-poor)			Survey (specify)
				Flow	Level	Rainfall	
Forecasting flood levels at confluences	Severn/Teme	Floodplain storage & backing up.	Routing	3	1	1	?
	Severn/Vyrnwy	Floodplain storage & backing up.	Routing	3	1	1	?
	Sow/Penk	Floodplain storage & backing up.	Rainf/RO & Routing	3	1	1	?
	Middle Trent	Floodplain storage & backing up.	Routing	3	1	1	?
Flashy upland catchments	Wye		Rainf/RO	2	1	1	?
Forecasting influence of structures	Soar	Pillings Lock gauge & various radial gates.	Rain/RO & routing	1	1	1	?
Urban catchments	Upper Tame	Timing of forecast peak is poor, but critical.	Rain/RO & routing	2	1	1	?
Forecasting for low benefit locations	Leam	Perceived low benefit as thought there were only 9 properties which flooded- proved wrong at Easter 98!	Rain/RO & routing	3	2	1	?

Contact Shirely Greenwood at Sapphire East for survey data

EA REGION: NORTH WEST **PREPARED BY:** IAN PEARSE

Top Five Forecasting Problems (listed in order of priority)	River Exhibiting Problem	Specific Description of Problem	Model (specify)	Data Availability for River/Reaches Specified			
				Gauging (1-good to 3-poor)			Survey (specify)*
				Flow	Level	Rainfall	
Influence of Structures	Wyre to St Michaels	Upstream flood basins and hydrograph changes.	Correlation	1	1	1	
Confluence	Derwent at Cockermouth	One tributary affected by lake.	Summation of flows	2	1	2	
No Model	Yarrow at Croston	No Model.	RFRO	2	1	1	
Flashy Pumped Catchment	Glaze	Bedford and Lilford pumped catchment.	None	1	1	1	
Multiple Upstream Reservoirs	Etherow at Woolley Bridge	Multiple Upstream Reservoirs.	Spreadsheet	2	2	2	

* Survey information to be forwarded/available from Peter Spencer at RFH.

EA REGION: WALES (NORTH) **PREPARED BY:** S.MAYALL

Top Five Forecasting Problems (listed in order of priority)	River Exhibiting Problem	Specific Description of Problem		Data Availability for River/Reaches Specified			
				Gauging (1-good to 3-poor)			
			Model (specify)	Flow	Level	Rainfall	Survey (specify)
Llanrwst	Conwy	Flashy Upland Catchments.	Rainfall/Runoff	2	1	3	
		Forcasting for Low Benefit Locations.					
		Forecasting problems due to poor rainfall forecast data availability.					
Machynlleth	Dyfi	Flashy Upland Catchments.	Rainfall/Runoff	2	1	3	
		Forecasting Influence of Structures.					
		Forecasting problems due to poor rainfall forecast data availability.					
Dolgellau	Mawddach/Wnion	Flashy Upland Catchments.	Rainfall/Runoff	2	1	3	
		Forecasting Influence of Structures.					
		Forecasting problems due to poor rainfall forecast data availability.					
Lower Dee Floodplain	Dee	Impact of tidal effect.		1	1	2	
		Floodplain storage.					
		Forecasting Flood Levels at Confluence(s).					
Lower Glaslyn Floodplain	Glaslyn	Impact of tidal effect.		3	2	2	
		Floodplain storage.					
		Forecasting Flood Levels at Confluence(s).					

EA REGION: NORTH EAST **PREPARED BY:** DOUG WHITFIELD

Top Five Forecasting Problems (listed in order of priority)	River Exhibiting Problem	Specific Description of Problem	Model (specify)	Data Availability for River/Reaches Specified			
				Gauging (1-good to 3-poor)			Survey (specify)
				Flow	Level	Rainfall	
Flashy Urban upland Catchments	Walsden Water	Walsden (tributary of upper Calder)	PDM	3	1	2	In-bank topographic channel survey
	Upper Calder	Todmorden, Hebden Br and Mytholmroyd.	PDM + KW	3	2	2	In-bank topographic channel survey
	River Sheaf, Sheffield	Gauge at bottom of catchment, floods also influenced by debris screen at culvert entrance.	PDM	2	2	1	In-bank topographic channel survey
Levels at Confluences	Boroughbridge	Levels in Boroughbridge affected by River Ure confluence with Swale some distance downstream.	PDM + KW in addition to Muskingham based alternative.. Non real-time HD model also available	2?	1	1	Full floodplain topographic survey
	Castleford	Confluence immediately upstream + town bypassed by flood storage/bypass channel.	PDM +KW as well as other techniques	2?	1	1	Full floodplain topographic survey
Forecasting Influence of Structures	River Don basin (Dearne and Rother especially)	5 river regulators used to reduce peak flows in Doncaster. Control rules very loose. Difficult to apply what if modelling in RFFS with so many variables.	PDM + KW	2/3	1	1	Lidar + cross-sections
	River Tees	Tees Barrage affects levels in lower reaches.	PDM + KW + real time ISIS	1?	1	1	Various
Forecasting Groundwater Flooding	River Hull catchment	Fed by Yorkshire Wolds aquifer. Also under tidal influence with difficult gauging.	Non real-time HD	2?	1	1	Various
Uncontrolled Floodplain Storage	Many - good example Lower Tees	KW models do not represent floodplain storage. Resolved by implementation of real-time ISIS.	PDM + KW + real time ISIS	1?	1	1	Various

EA REGION: SOUTHERN **PREPARED BY:** MIKE VAUGHAN

Top Five Forecasting Problems (listed in order of priority)	River Exhibiting Problem	Specific Description of Problem	Model (specify)	Data Availability for River/Reaches Specified			
				Gauging (1-good to 3-poor)			Survey (specify)
				Flow	Level	Rainfall	
1= Flooding from groundwater dominated rivers	Lavant	Chichester	ISO Function	2	2	2	???
	Ems	Area 3A1	Linear TF	2	2	2	???
	Itchen	Winchester	N/A	3	2	2	???
1= Small catchments where rainfall forecasts required for adequate forecast leadtime	Cuckmere	Hellingly	Non-linear transfer function	3	2	2	???
	Tadburn Lake (Not a lake, but a stream)	Romsey	Linear TF	2	2	2	???
	Hamstreet Arm, Speeringbrook Sewer	Hamstreet	N/A	3	2	3	???
3 Forecasting flood levels at confluences	Medway	Yalding	None	3	2	2	???
4 River and tide combined	Ouse	Lewis	N/A	3	2	1	???
	Great Stour	Canterbury	N/A	2	2	2	???
	Medway	Maidstone	N/A	1	2	2	???
5 Groundwater flooding (away from watercourses)	Test	NW part of catchment	N/A	N/A	2	2	???
	Brighton Chalk Block	Patchams	N/A	N/A	2	2	???
	Nailbourne	Many places	N/A	N/A	2	3	???

EA REGION: THAMES **PREPARED BY:** N.OUTHWAITE

Top Five Forecasting Problems (listed in order of priority)	River Exhibiting Problem	Specific Description of Problem	Model (specify)	Data Availability for River/Reaches Specified			
				Gauging (1-good to 3-poor)			Survey (specify)
				Flow	Level	Rainfall	
Rapid response of urban catchments, particularly coupled with convective rainfall events	River Ravensbourne	Time-to-peak at Kyd Brook Close is approx. 1 hour, although can be as little as 15 mins. Sudden development of 'clear air' convective events means that achieving 2hr lead time is a problem.	ISIS Model	3	1	2	Full floodplain topographic survey
Complex channel networks, with small (<0.1m) differences in level resulting in considerable variations in property flooding	River Thames at Oxford	River Thames splits into a no. of different channels as it passes through Oxford. Some structures to influence flow splits. Small increases in level ie. 0.1m can mean no properties flooding or 90 properties flooding – 0 properties in November 2000, 92 in December .	ISIS/ONDA	2	2	1	Full floodplain topographic survey
	Lower River Colne	River Colne splits into a large number of channels in lower reaches, each of which has its own flooding problems. Difficult to forecast flows/levels in each individual channel.	ISIS/ONDA	1	1	1	In-bank topographic channel survey
Flooding at confluences	River Loddon	Properties at risk of flooding from either Thames or Loddon or combination of both. Uncertainty of flooding processes makes it difficult to forecast need for warnings.	ISIS model of Thames, nothing for Loddon	1	1	2	Full floodplain topographic survey
Groundwater flooding	River Lambourn	High groundwater levels result in prolonged periods of high river levels at Lambourn.	No models	3	2	2	No survey data
	River Misbourne	High groundwater levels result in prolonged periods of high river levels at Missenden.	No models	2	2	2	No survey data

EA REGION: SOUTH WEST **PREPARED BY:**

Top Five Forecasting Problems (listed in order of priority)	River Exhibiting Problem	Specific Description of Problem		Data Availability for River/Reaches Specified			
				Gauging (1-good to 3-poor)			
			Model (specify)	Flow	Level	Rainfall	Survey (specify)
Overtopping of Flood Defences	River Tone, Somerset	4-6 hours lead time required to issue a reliable flood warning to trigger a Major Incident Plan (MIP) for Taunton.	Rainfall runoff using total rainfall (WRIP)	1	2	1	Check with Robin Bendell, Bridgwater Office
Flashy Upland Catchments	River Sid, Devon	Insufficient time to issue a 2-hour flood warning.	Level criteria	3	2	2	Check with Andrew Latham, Exminster Office
Flashy Upland Catchments (2nd choice)	River Wey, Dorset	Insufficient time to issue a 2-hour flood warning.	Level criteria	1	2	1	Check with Duncan Riches, Blandford Office
Forecasting Groundwater Flooding	River Avon, Hampshire	Salisbury flood defences nearly overtopped. No rainfall runoff model to predict impact of rain on river flows.	Level criteria	1	3	1	Check with Duncan Riches, Blandford Office
Tidal/fluvial interaction	River Taw, Devon	Barnstaple – difficult to quantify the interaction between river flood and tidal level.	Level criteria, wind surge and forecast	1	3	2	Check with Andrew Latham, Exminster Office
Mixed storage catchments	River Stour, Dorset	Hammoon flow station, rapid response which levels off and is sustained for several days.	Rainfall runoff using total rainfall (WRIP)	1	2	1	Check with Duncan Riches, Blandford Office

EA REGION: WALES – SW AREA **PREPARED BY:** JR FROST

Top Five Forecasting Problems (listed in order of priority)	River Exhibiting Problem	Specific Description of Problem	Model (specify)	Data Availability for River/Reaches Specified			
				Gauging (1-good to 3-poor)			Survey (specify)
				Flow	Level	Rainfall	
Flashy Upland Catchment	Ogmore	Fast rising river with time to peak of less than 3 hours – needs good rainfall forecast.	Trigger levels used at present	1	1	2	
	Tawe	Fast rising river with time to peak of less than 3 hours – needs good rainfall forecast.	Trigger levels used at present	2	1	2	
	Afan	Fast rising river with time to peak of less than 3 hours – needs good rainfall forecast.	Trigger levels used at present	2	1	2	
Low Benefit Locations	Teifi	$800km^2$ with isolated properties affected. Poor correlation relationships between 3 level gauges because of variability of rainfall in time and space, and shape of catchment, and raised peat bog in upper catchment.	In-house hybrid rational rainfall runoff model.	2	1	1	
	Solva	Problem is forecasting when upstream on-stream flood alleviation scheme will fill.	In-house hybrid rational rainfall runoff model.	2	1	1	
Floodplain Storage	Cynin/Dewi Fawr	River rises steeply and then flattens out as river overtops into floodplain upstream of flood risk area. This makes updating of forecast with measured levels very difficult in real time.	In-house hybrid rational rainfall runoff model.	2	1	1	
	Taf	River rises steeply and then flattens out as river overtops into floodplain upstream of flood risk area. This makes updating of forecast with measured levels very difficult in real time.	In-house hybrid rational rainfall runoff model.	1	1	1	
Hydropower Generation	Rheidol	70% of catchment upstream of flood risk area is part of hydropower scheme. We have threshold for onset of flooding but reservoir storage and power operation procedures make forecasting of peak and time difficult. Largest reservoir has not filled in last 30+ years but it might one day.	In-house hybrid rational rainfall runoff model.	2	2	1	

APPENDIX C

DEFRA / EA Short Form A for R&D Outline Project Proposals for 2003/04

TITLE: *REAL TIME OPERATION AND UPDATING OF HYDRODYNAMIC MODELS*

Purpose (Key Customer) - Why is the R&D needed?
Hydrodynamic models are increasingly being used within the Agency for modelling river reaches in which complex effects (tidal, structures etc) make use of simpler routing models unsatisfactory. Research and best practice guidelines are required into best practice use of these models in real time, particularly when converted from Section 105 models, and including evaluation of techniques for real time updating and regular recalibration

Summary (Overall) Objectives
To develop best practice guidelines for the conversion of simulation models to real time use with particular emphasis on updating techniques and stability in real time operation. To examine the resource implications for the Agency of using and maintaining such models and compare this with the benefits of improved flood forecasts

Context (Background)
Hydrodynamic models are increasingly being used within the Agency for modelling river reaches in which complex effects (tidal, structures etc) make use of simpler routing models unsatisfactory. The many Section 105 models that have been calibrated since the Easter 1998 floods also have potential for conversion to real time use. Although the process of converting a simulation model is straightforward, approximations are sometimes required (e.g. a reduced spatial extent) and failures due to initialisation errors, problems at low flows etc are not acceptable in an operational system. In particular, the issue of real time updating, considered essential for many other types of real time model, is more difficult to implement for hydrodynamic models, since mass must always be conserved and disturbances arising from flow adjustments may propagate through the system. Evaluation of appropriate updating techniques for hydrodynamic models is required (e.g. state updating via tributary inflows, or parameter updating via roughness coefficients), and general guidelines on best practice in converting simulation models (e.g. Section 105 models) to real time use, with particular emphasis on calibration for high flows/uncertain ratings. The review should also consider possible new applications for real time use; for example, real time inundation mapping, and techniques for simulating event-specific problems (e.g. blockages by debris, breaches of flood defences, partial or complete failures at river flow control structures etc) and making use of related instrumentation (e.g. differential level sensors, CCTV). Interfacing this work with the Agency's overall Forecast Model Systems Strategy will be essential.

Main Outputs / User / Benefits
Research report and best practice guidelines
Flood forecasting and warning staff
Improved practice in use of hydrodynamic models for flood forecasting

Timescale / Costs / Costs by year: 15 months £120k

Other Funders (internal or external)?
One of the modelling houses may be interested in contributing (HR, DHI, Delft)

PREPARED BY: Andrew Grime
e-mail address: andrewgrime@weetwoodservices.demon.co.uk

Which one of the following types of R&D would this project come under:

Operational	Policy	Strategy

Which would be the main EA Theme that this project would come under:

Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife

Principal DEFRA / EA Theme: Flood Forecasting & Warning

<table>
<tr><td colspan="3">TITLE: IMPROVED MODELS FOR GROUNDWATER DOMINATED FLOODING</td></tr>
<tr><td colspan="3">Purpose (Key Customer) - Why is the R&D needed?
Groundwater dominated flooding has been a major issue in recent flood events particularly in Southern and Anglian Regions. The current modelling techniques could possibly be developed through improved monitoring and modelling of groundwater conditions and flows and of the interaction between groundwater and surface water flows</td></tr>
<tr><td colspan="3">Summary (Overall) Objectives
To develop improved procedures for forecasting groundwater dominated flood events and guidelines for use by flood forecasting practitioners.</td></tr>
<tr><td colspan="3">Context (Background)
Groundwater-related flooding has been a serious problem in recent flood events; for example, spring flows being much higher than usual (or appearing in new locations), and increased river runoff due to saturated soil conditions. The risk is particularly high in urban areas. At present, a range of correlation and simple rainfall runoff modelling procedures are used to forecast this type of event, but there remains the potential for improvement; for example, use of real time monitoring of well levels (e.g. by piezometers) and soil moisture, and development of improved groundwater flow components in semi distributed and distributed conceptual rainfall models (with allowance for pumped abstractions/recharge etc). Existing three dimensional numerical aquifer models, developed for water resource applications, could possibly also be adapted for quasi real time use e.g. daily runs. Research is required into both improved monitoring techniques and models. However, there are several concerns with potentially using detailed groundwater modelling as a prediction tool. The high number of variables and the apparent lack of groundwater data to correlate it to represent a problem. This is compounded by the high variability of hydrogeological conditions along individual river reaches. It is probable that any modelling approach would be limited in the extent over which it could be applied. The development of a predictive tool for forecasting should concentrate on correlation analysis. Initial findings may show that without significant increases in monitoring it is not possible to apply catchment wide groundwater models at the sub-catchment level</td></tr>
<tr><td colspan="3">Main Outputs / User / Benefits
Site characterisation and correlation analysis followed by a review stage to develop the best way forward and identify improved techniques for forecasting groundwater dominated flooding (based on simplified catchment models?)
Flood forecasting and warning staff
Improved methods for forecasting groundwater dominated flooding</td></tr>
<tr><td colspan="3">Timescale / Costs / Costs by year: 8 months £60k</td></tr>
<tr><td colspan="3">Other Funders (internal or external)?</td></tr>
<tr><td colspan="3">PREPARED BY: Andrew Grime
e-mail address: andrewgrime@weetwoodservices.demon.co.uk</td></tr>
<tr><td colspan="3">Which one of the following types of R&D would this project come under:</td></tr>
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<tr><td>Using Natural Resources Wisely</td><td>Improving Inland/Coastal Waters</td><td>Protecting / Restoring the Land</td></tr>
<tr><td>Greening the Business World</td><td>Quality of Life</td><td>Enhancing Wildlife</td></tr>
<tr><td colspan="3">Principal DEFRA / EA Theme: Flood Forecasting & Warning</td></tr>
</table>

TITLE: *NEXT GENERATION DISTRIBUTED RAINFALL RUNOFF MODELS*		
Purpose (Key Customer) - Why is the R&D needed? Recent developments in weather radar signal processing and forecasting systems (Cyclops, Nimrod, MOSES) mean that rainfall, snow cover and soil moisture data are available at a much higher spatial and temporal resolution than in the past. A review and comparative study of grid based distributed models is therefore timely, with possible advantages in flood forecasting for complex (e.g. urban) catchments and during thunderstorms.		
Summary (Overall) Objectives To review the latest distributed rainfall runoff modelling techniques and to evaluate selected models on catchments in England and Wales in an operational situation using the latest Nimrod and MOSES products.		
Context (Background) Most rainfall runoff models used within the Agency's flood forecasting systems are presently of the lumped or semi-distributed type, in which spatial variations in rainfall across a catchment (or subcatchment) are neglected. Grid based distributed models, combined with GIS/DTM datasets, offer the potential to take advantage of the higher resolution offered by weather radar data to better represent the effects of rainfall variations on runoff, particularly for convective storms and for complex catchments containing many control structures e.g. urban catchments. However, this type of model remains a research tool; for example, project W242 "Comparison of rainfall runoff models for flood forecasting, EA 2000" recommended further research using this type of model for real time flow forecasting of the impacts of convective rainfall events. Recent developments in weather radar signal processing (Cyclops), rainfall forecasting products (e.g. Nimrod), and related products (e.g. MOSES) mean that rainfall, snow cover and soil moisture data will soon be available in all Agency Regions at a much higher spatial and temporal resolution than in the past. A review is required of the model structures etc which could take advantage of this new high resolution data, and a comparative study performed on several typical catchments with results obtained from simpler lumped or semi distributed rainfall runoff models, particularly during thunderstorm rainfall events and in urban catchments with complex drainage pathways and influences from flow control structures. Studies should include evaluation under real time operational conditions, taking account of the types and quantity of real time monitoring required to support calibration and verification of this type of model.		
Main Outputs / User / Benefits Technical report on the performance of distributed rainfall runoff models under real time operational conditions Flood forecasting and warning staff Better understanding of the potential of distributed models in flood forecasting for complex catchments and thunderstorm events		
Timescale / Costs / Costs by year: 12 months £95k		
Other Funders (internal or external)? Water Companies and the Met Office may be interested in joint funding this work.		
PREPARED BY: Andrew Grime e-mail address: andrewgrime@weetwoodservices.demon.co.uk		
Which one of the following types of R&D would this project come under:		
Operational	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal DEFRA / EA Theme: Flood Forecasting & Warning		

<table>
<tr><td colspan="3">TITLE: RAINFALL RUNOFF AND OTHER MODELLING FOR UNGAUGED/LOW BENEFIT LOCATIONS</td></tr>
<tr><td colspan="3">Purpose (Key Customer) - Why is the R&D needed?
Ungauged and low benefit locations present a particular problem when a flood warning service is required and most Regions currently only implement a general Flood Watch service. However, there are several technical possibilities for offering a more targeted service which would form the basis of this research e.g. adapting FEH techniques for real time use, rainfall runoff modelling using parameters based on catchment characteristics, and probabilistic/statistical techniques making use of instrumentation in neighbouring catchments.</td></tr>
<tr><td colspan="3">Summary (Overall) Objectives
To develop and evaluate improved techniques for flood forecasting at ungauged and low benefit locations with the aim of providing a more targeted/technically sound flood warning service at such locations.</td></tr>
<tr><td colspan="3">Context (Background)
A common flood forecasting problem which arises is that a new or improved flood warning service is required for a Flood Warning Area, but there is no river level instrumentation in the catchment either at or above the location at which warnings are required. Even if instrumentation could be installed immediately, it could take several years to collect suitable calibration data, and there might be technical or economic reasons which rule out any such installation (e.g. low benefit/low risk flooding problems). At present, only a general Flood Watch service can be offered in this case but real time models provide the potential to offer a more targeted service. Possible techniques could include real time application of Flood Estimation Handbook techniques, and transference of model parameters (e.g. for conceptual models) from nearby or analogue catchments. The work could also include development of probabilistic/statistical techniques which estimate the likelihood of flooding in a catchment based on catchment response, meteorological understanding, and the observed response in neighbouring catchments and raingauge/Nimrod etc observations and forecasts of rainfall. The benefits afforded by improved weather radar rainfall estimates (actual and forecast) and soil state (MOSES) could be explored. This project could link into the Next Generation Distributed Rainfall Run-off Models project</td></tr>
<tr><td colspan="3">Main Outputs / User / Benefits
Research report and guidelines on forecasting techniques for ungauged/low benefit locations
Flood forecasting and warning staff
Possible extension of flood warning coverage based on technically sound principles</td></tr>
<tr><td colspan="3">Timescale / Costs / Costs by year: 12 months £90k</td></tr>
<tr><td colspan="3">Other Funders (internal or external)? Recognising that this project would also benefit non-main river sites DEFRA may wish to contribute. There is also synergy between this proposal and ongoing work by CEH under FD2106 National River Catchments Flood Frequency Method Using Continuous Simulation.</td></tr>
<tr><td colspan="3">PREPARED BY: Andrew Grime
e-mail address: andrewgrime@weetwoodservices.demon.co.uk</td></tr>
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<tr><td>Using Natural Resources Wisely</td><td>Improving Inland/Coastal Waters</td><td>Protecting / Restoring the Land</td></tr>
<tr><td>Greening the Business World</td><td>Quality of Life</td><td>Enhancing Wildlife</td></tr>
<tr><td colspan="3">Principal DEFRA / EA Theme: Flood Forecasting & Warning</td></tr>
</table>

TITLE: *BEST PRACTICE IN TRANSFER FUNCTION RAINFALL-RUNOFF MODELLING*		
Purpose (Key Customer) - Why is the R&D needed? Transfer function models are used operationally by several Agency Regions for real time flood forecasting but further research is required to develop best practice guidelines on the selection and use of these models; particularly regarding estimation of effective rainfall and choice of model structure.		
Summary (Overall) Objectives To research alternative model structures and ways of using real time data in order to develop best practice guidelines to assist flood forecasting practitioners in the selection, calibration and operation of transfer function models for real time flood forecasting		
Context (Background) Although transfer-function models have been used in various guises by the Agency for the last twenty years, the structure, identification, calibration and application of the models varies greatly. Research is required to identify best practice in terms of transfer-function model structure, calibration (including parameter estimation algorithms), input data (total rainfall or effective rainfall), calibration for a specific lead time, and updating methods (state and parameter). An objective inter-comparison on test catchments is suggested as a suitable way forward with key themes being automated updating of forecasts (as opposed to the manual procedures used at present in some models), and procedures for estimating effective rainfall from total rainfall. The aim would be to review existing approaches, to estimate the accuracy and uncertainties in the proposed modeling approaches, and to explore whether generalised non-linear relationships can be developed for a range of different catchment types based on catchment soil/geological characteristics, current flows, and a range of antecedent conditions (possibly obtained via the new MOSES product). A standard set of non-linear filters that could be used as an ‘off-the-shelf’ real-time tool would improve forecast quality and consistency.		
Main Outputs / User / Benefits Technical report and guidelines on best practice in transfer function modelling Flood forecasting and warning staff Consistent approach to use of transfer function models for flood forecasting		
Timescale / Costs / Costs by year		
Other Funders (internal or external)?		
PREPARED BY: e-mail address:		
Which one of the following types of R&D would this project come under:		
Operational	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal DEFRA / EA Theme:		

TITLE: *EVALUATION OF NEW APPROACHES TO RAINFALL RUNOFF MODELLING*		
Purpose (Key Customer) - Why is the R&D needed? Despite many decades of research, the problem of estimating the non linear response of river flows to rainfall remains one of the most challenging in hydrology, with uncertainties arising from both the input rainfall data and variations in the catchment response. The Agency needs to remain aware of new approaches and to periodically review their potential for operational use compared to those techniques used at present.		
Summary (Overall) Objectives To review new and emerging techniques for rainfall runoff modelling in the UK and internationally and to evaluate their performance on a number of representative test catchments.		
Context (Background) Rainfall runoff models play a key role in flood forecasting by using rainfall data and forecasts to extend the lead time of flood forecasts. The two main techniques used operationally at present are conceptual models and transfer function models but the Agency has also funded a limited amount of research into newer (but not necessarily better) techniques such as neural network models, and other techniques such as fuzzy rule-based models and nearest neighbour forecasting have been identified as having potential. A review and comparative study of these and other emerging techniques is required to evaluate their potential for real time flood forecasting and to compare their ease of use/calibration with current procedures.		
Main Outputs / User / Benefits Research report on new approaches to rainfall runoff modelling Flood forecasting and warning staff Possible identification of improved methods for real time modelling		
Timescale / Costs / Costs by year		
Other Funders (internal or external)?		
PREPARED BY: e-mail address:		
Which one of the following types of R&D would this project come under:		
Operational	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal DEFRA / EA Theme:		

TITLE: *REVIEW OF HIGH LEVEL TARGETS FOR FLOOD FORECASTING*		
Purpose (Key Customer) - Why is the R&D needed? The Agency has set targets for the Accuracy, Reliability and Timeliness of flood warning systems but these targets relate to performance of the whole system (detection, dissemination, modelling) and further work is required to interpret (and possibly revise) these targets in a way which is useful to practitioners involved in designing real time modelling systems. In particular, Accuracy targets need to be defined in a more precise way to take account of the forecasting problem, the level of risk/consequences of flooding, and the target audience for flood warnings (public, professional partners, Agency operational staff etc).		
Summary (Overall) Objectives To review and possibly rationalise the Agency's targets for flood warning to meet the needs of real time modellers and to produce best practice guidelines for practitioners how these targets relate to the design of the modelling component of systems, and those which relate to performance of the whole flood warning system. Also, to advise on how best to design real time modelling systems to meet these revised targets.		
Context (Background) The Agency sets a number of high level targets for the Accuracy, Reliability and Timeliness of flood forecasting systems but some fundamental problems faced by practitioners responsible for designing real time models for these systems include: The targets relate to performance of the whole warning system (including dissemination, telemetry etc) and do not relate specifically to the real time modeling component Some parameters (e.g. reliability) by definition cannot be estimated at the design stage meaning that a system cannot be designed to meet the required performance Also, although the targets for Reliability and Timeliness are well understood, further work is required to set appropriate targets for Accuracy depending on the target audience (the public, professional partners etc), the consequences of flooding, and the type of forecasting problem. A thorough review is required of both the definitions of these targets, and their values, with particular emphasis on how practitioners can estimate future performance relative to targets at the design stage, rather than only in post event analyses.		
Main Outputs / User / Benefits Guidelines and technical report on flood warning targets and (possibly) recommended improvements Flood forecasting and warning staff A consistent approach to the design of real time modelling system to meet national targets		
Timescale / Costs / Costs by year		
Other Funders (internal or external)?		
PREPARED BY: e-mail address:		
Which one of the following types of R&D would this project come under:		
Operational	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal DEFRA / EA Theme:		

TITLE: *FRAMEWORK FOR EVALUATION OF THE PERFORMANCE OF REAL TIME MODELS*

Purpose (Key Customer) - Why is the R&D needed?
Post event analyses provide the route to understanding how real time models perform in operational use, and how model performance depends on model type, catchment type, storm type, experience of the model developer/user etc both regionally and nationally. At present, analyses of this type are time consuming and must be performed in an ad-hoc manner depending on the type of model and related data and forecast archiving facilities. A national framework is required for this type of post event analysis which model developers and operational staff can follow.

Summary (Overall) Objectives
To develop procedures and tools to assist operational staff, model developers and researchers in performing post event analyses of the performance of individual real time models (rainfall runoff, routing etc) which comprise a real time flood forecasting system.

Context (Background)
During a flood event, real time models generate forecasts of future levels and flows but, at present there is no standard approach to post event analysis of model performance and no national or regional databases to support such analyses. This means that it is a time consuming and difficult task for operational staff to evaluate model performance as a basis for future improvements, and in particular to evaluate the performance of individual models within the system, as opposed to the whole system. Also, more wide ranging research studies which compare model performance across the Agency also need to physically obtain the models used (and possibly recalibrate them) and to reconstruct forecasts as best as possible based on the data which was archived during (and after) the event. This necessarily restricts the quality and breadth of analyses which can be performed. A national specification is required for the information which should be archived (and related standards) and on how it can best be analysed and presented, together with development of automated tools to assist operational staff in performing these analyses.

Main Outputs / User / Benefits
Guidelines and tools for post event analysis of real time model performance
Flood forecasting and warning staff, researchers, model developers
Techniques to facilitate post event analysis of real time model performance

Timescale / Costs / Costs by year

Other Funders (internal or external)?

PREPARED BY:
e-mail address:

Which one of the following types of R&D would this project come under:

Operational	Policy	Strategy

Which would be the main EA Theme that this project would come under:

Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife

Principal DEFRA / EA Theme:

TITLE: *DECISION SUPPORT TOOLS FOR REAL TIME MODEL SELECTION*		
Purpose (Key Customer) - Why is the R&D needed? Recent research has led for the first time to a set of model selection guidelines for use by flood forecasting practitioners. The potential now exists to develop the basic logic underlying these procedures in combination with GIS/DTM datasets to develop advanced decision support tools combining information on storm meteorology, catchment response and economics into a single tool to assist practitioners in application of the guidelines.		
Summary (Overall) Objectives To develop a prototype intranet based decision support tool to assist flood forecasting practitioners in the application of the real time model selection guidelines developed under project WSC13/5.		
Context (Background) A recent research project has developed guidelines on the selection of real time models for use in flood forecasting systems. At present the methods are largely paper-based but decision support software could assist in a number of areas. At the simplest level, an intranet based tool could guide users through the model selection process through a series of 'question and answer' screens and forms, with possible solutions suggested based on the user's responses. The economic aspects (costs and benefits/damage avoidance) could also be included in this procedure. More advanced tools might use a GIS/DTM based approach to guide users on selection of model reaches and suitable sites for instrumentation, for example, to map times to peak and peak flows across the catchment (including ungauged tributaries), and to use simple hydraulic models to show regions in which backwater/tidal effects may be significant. Guidance might also be provided on the likely rainfall distributions and storm-history of the region/catchment, and on likely compliance with high level targets.		
Main Outputs / User / Benefits Research report and prototype decision support software Flood Forecasting and Warning Staff Further refinement of the real time model selection process for flood forecasting applications		
Timescale / Costs / Costs by year		
Other Funders (internal or external)?		
PREPARED BY: e-mail address:		
Which one of the following types of R&D would this project come under:		
Operational	Policy	Strategy
Which would be the main EA Theme that this project would come under:		
Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife
Principal DEFRA / EA Theme:		

TITLE: *DECSION SUPPORT TOOLS FOR FAST RESPONSE CATCHMENTS*

Purpose (Key Customer) - Why is the R&D needed?
Fast response catchments pose a particular flood risk particularly during thunderstorms. Existing rainfall runoff modelling approaches could possibly be supplemented by 'first alert' systems which rely on recognising combinations of conditions and trend which may lead to flood conditions.

Summary (Overall) Objectives
To review international approaches to flash flood forecasting and to evaluate and demonstrate their application under UK conditions for several representative high risk (e.g. urban) catchments.

Context (Background)
Fast response catchments pose a particular flood risk due to the short lead times available to disseminate warnings. This is particularly the case for thunderstorm generated events, which may develop over time periods of an hour or less. The classical approach of feeding rainfall data and forecasts into rainfall runoff models provides one way of forecasting possible flooding, but requires interpretation and, possibly, intervention by Flood Warning staff to make use of the information provided. This presents operational problems regarding alerting staff to fast response events, particularly when they occur 'outside' the usual flood season e.g. in summer. Several other countries (e.g. the USA, France) are investigating more automated web based approaches to flash flood forecasting, in which rapid decisions can be taken on flash flood potential based on catchment characteristics and conditions, trends in radar rainfall data, probabilistic and Monte Carlo assessments of risk, pattern recognition of combinations of conditions which might lead to flooding or have led to flooding in the past. These methods, combined with research into how to include the warnings provided into operational procedures, possibly also have potential in the UK

Main Outputs / User / Benefits
Research report and prototype decision support software
Flood Forecasting and Warning Staff
New approaches to supplement existing modelling procedures for fast response catchments

Timescale / Costs / Costs by year

Other Funders (internal or external)?

PREPARED BY:
e-mail address:

Which one of the following types of R&D would this project come under:

Operational	Policy	Strategy

Which would be the main EA Theme that this project would come under:

Adapting to Climate change	Reducing Flood Risks	Ensuring the Air is Clean
Using Natural Resources Wisely	Improving Inland/Coastal Waters	Protecting / Restoring the Land
Greening the Business World	Quality of Life	Enhancing Wildlife

Principal DEFRA / EA Theme:

APPENDIX D

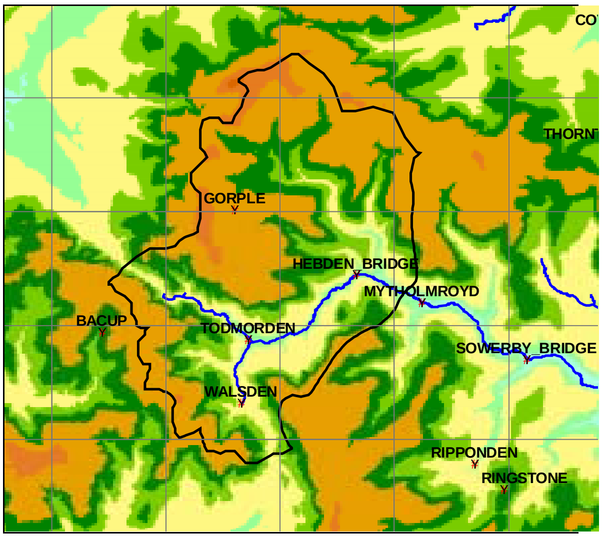
Factsheets – Flood Forecasting Issues

Method	Factsheet	Region	River/location
Fast Response Catchments	FF1	North East	Upper Calder
	FF2	South West	Sid
	FF3	Wales	Afon Clun
Confluence Flooding	FF4	Southern	Yalding
	FF5	North East	Ure
	FF6	Thames	Loddon
Influence of Structures	FF7	North East	Don
Low Benefit Locations	FF8	Anglian	East Suffolk rivers
		Wales	Teifi
		Midlands	Leam
Floodplain Storage	FF9	North East	Tees
Groundwater Flooding	FF10	South West	Avon
	FF11	Anglian	Slea
Urban Catchments	FF12	Thames	Ravensbourne
		Midlands	Tame
Reservoired catchments	FF13	Wales	Afon Rheidol
	FF14	Anglian	Eyebrook
Complex channels/catchments	FF15	South West	Tone
	FF16	Thames	Thames
	FF17	Thames	Lower River Colne

FF1. FAST RESPONSE CATCHMENTS

North East Region: Upper Calder

The Upper Calder flows through steep and narrow valleys on the south-eastern edge of the Pennines past several towns including Hebden Bridge, Todmorden, Walsden Mythomroyd.



The main forecasting issues are the rapid response of the river to rainfall and the proximity of the flood risk areas to the head of the catchment. Problems also arise from potential flooding due to snow-melt and from localised thunderstorms.

Flood forecasting techniques used are either empirical (trigger levels) or rainfall-runoff and hydrological routing models. Trigger levels are based on levels at upstream gauging stations and a reactive approach is often taken when setting thresholds. For example as a result of the failure of structures in the June 2000 Calder floods, amendments were made to the trigger levels at Todmorden and Walsden gauging stations.

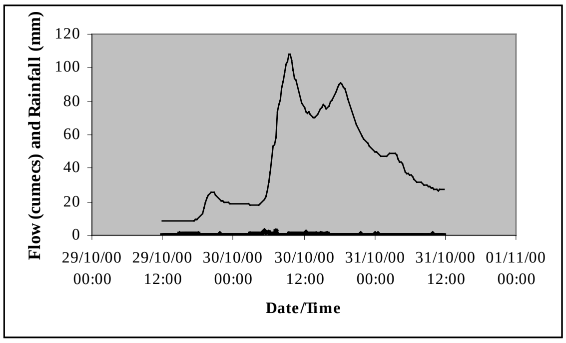


Figure 1: October 2000 event at Mytholmroyd

The RFFS (Regional Flood Forecasting System for the North East) contains PDM and kinematic wave components for the Upper Calder. However the PDM models need to be recalibrated using weather radar rainfall data if quantitative precipitation forecasts are to be used as a model input. The Upper Calder has some reasonable rainfall and level gauges, but there are no flow gauging stations.

FF2. FAST RESPONSE CATCHMENTS

South West Region: River Sid

The river Sid drains a small catchment to the north of Sidmouth. It rises at 205m above sea level and flows for about 5.5 km through a narrow, steep sided valley, through Sidbury and Sidford, before passing through Sidmouth to its outfall to the English Channel.

The main forecasting issues are the rapid response of the river to rainfall and the proximity of the flood risk areas to the head of the catchment. Time to peak to Sidbury is only 1.25 - 2.75 hours, while the travel time between here and Sidmouth is only about 0.5 - 1 hour. Time to peak graphs have been produced for the catchment, which, while they are not used in real time, are used to develop an understanding of flood behaviour within the catchment.

Flood forecasting techniques used are trigger levels based upon the levels

throughout the catchment. Forecasting in this catchment is further complicated by the lack of a flow gauge in the upper catchment. There is a level gauge at Sidbury, which could be developed for forecasting purposes. The following options could be investigated:

- Simple empirical relationships based upon catchment wetness index and rainfall depth and duration for the gauge at Gittisham compared to the river level gauge at either Sidford or Sidbury.
- Develop a rainfall-runoff model of the catchment. This model would be calibrated to the river level gauge at Sidbury, which would be converted to flow via a rating. The flood level in Sidmouth would be predicted using either:
- A level to level correlation between the gauges at Sidbury, Sidford and the tidal outfall;
- A straightforward relationship between flow and maximum defence scheme capacity, which is set at $40m^3/s$ (1 in 30 years).
- Run the above rainfall-runoff model during dry periods to establish the likely flood impact of different combinations of catchment condition, rainfall depth and duration. This risk matrix could then be used in real time to predict flooding based upon catchment and rainfall conditions.
- To increase lead-time to the statutory required for a major incident plan (4 - 6

hours) rainfall forecasting could be applied to either the empirical relationships or the models.

A rating has been developed for the level gauge at Sidbury, but this needs to be improved by developing another rating at a closest available river constriction (small bridge) to check.

FF3. FAST RESPONSE CATCHMENT

Wales: Afon Clun

The Afon Clun is a major tributary of the Afon Ely, draining an area of 32km^2 to the north-west of Cardiff in the south-east area of EA Wales. The underlying geology is primarily sandstone and an escarpment bisects the catchment. The elevation ranges from 240 m to approximately 45 m AOD at the confluence with the Ely. Approximately 18% of the catchment is defined as urban.

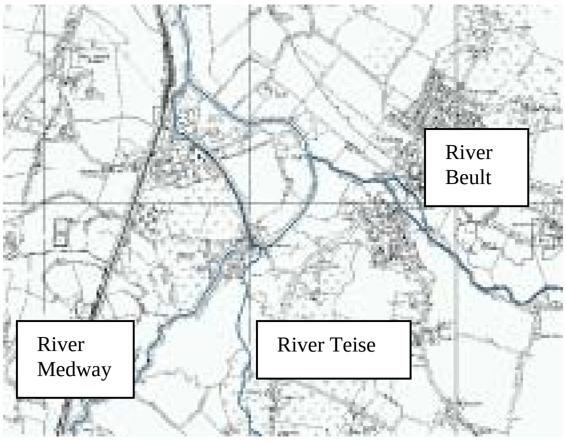
The steep slopes, shallow soils, large urban areas and high rainfall totals give rise to a catchment with a rapid response to rainfall and flooding problems throughout. Flooding at the confluence is also an issue when the river levels in the Afon Ely are high.

A combined MIKE11 conceptual rainfall-runoff and hydrodynamic model developed for flood risk mapping could be converted to a real-time implementation for forecasting purposes.

A catchment with a short response time requires a rainfall-runoff model, which is able to use observed and/or forecasted rainfall to provide sufficient lead time for flood warning, whilst the application of a hydrodynamic model will ensure that flood levels and extents throughout the catchment and at the confluence are accurately predicted.

FF4. CONFLUENCE FLOODING

Southern Region: Yalding



The town of Yalding in Kent, is just downstream of the confluence of the rivers Medway, Teise and Beult. The Upper Medway and the Teise have their headwaters in south-west Kent and south-east Sussex while the River Beult rises on wealden clays in Kent.

Heavy rain during 9th – 11th October 2000, falling onto already wet catchments, caused severe flooding in this area. In Herstmonceux in East Sussex, 103 mm of rain fell in the three day period from 9th – 11th October, rainfall with a nominal return period of 50 years. For the UK as a whole, October 2000, was the wettest October since 1903: rivers overflowed their banks in many areas with extensive inundation of floodplains, some of which remained under water for several days or weeks. Many towns and villages within or on the edges of the floodplains were severely affected by the floodwater, often to depths greater than previously experienced by local residents. The smaller, upland catchments were the first to react to the heavy rainfall with villages such as Lamberhurst on the Teise and Robertsbridge on the Rother suffering. Edenbridge on the River Eden, an upper tributary of the Medway in West Kent, came within centimetres of major flooding with water lapping at the crest of the floodwalls for several hours. A similar situation occurred at Smarden on the River Beult.

The Leigh Barrier across the floodplain of the Medway was manned from early on 9th October, with excess flood water being impounded from October 12th, flooding the valley and reducing the volume of water passing through Tonbridge. The barrier was continuously manned by Agency staff for six days until the evening of 14th October. The severity of flooding at Tonbridge, Yalding and the villages downstream was significantly reduced by this operation.

Beyond the protection of the Leigh Barrier, downstream of Tonbridge, the village of Yalding adjacent to the confluence of the Beult, the Teise and the Medway was severely affected by flood water for two or three days (see photo).

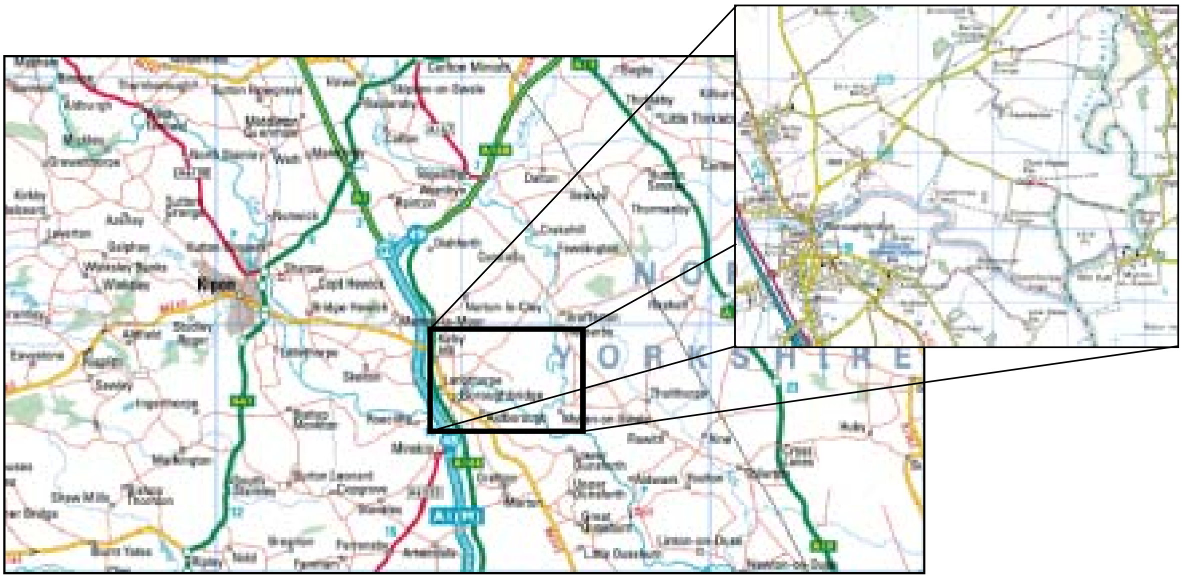
The flooding in Yalding on October 9th – 12th, while less extensive than if the Leigh Barrier had not been operating, still caused widespread flooding throughout the town. Levels through the middle of the town were sufficiently high to flood over 150 properties, generated by the combination of the high flows from all three rivers exceeding the conveyance capacity of the channel.

Many residents considered that the severity of the flooding was exacerbated by the lack of dredging of river channels over recent years and failure to clear field drains and culverts both during and prior to flood events (Environment Agency, 2001, Autumn 2000 Floods Review, Kent Area).

FF5. CONFLUENCE FLOODING

North East Region: River Ure

Boroughbridge is situated on the River Ure in the North-East Region of the Agency. The Ure drains a catchment area of approximately 930km^2 to Boroughbridge. The confluence of the Ure and the Swale is approximately 5km downstream of the town and flooding can be caused by backing up of flood water as a result of high levels in the Swale.



Current Forecasts at Boroughbridge are either:

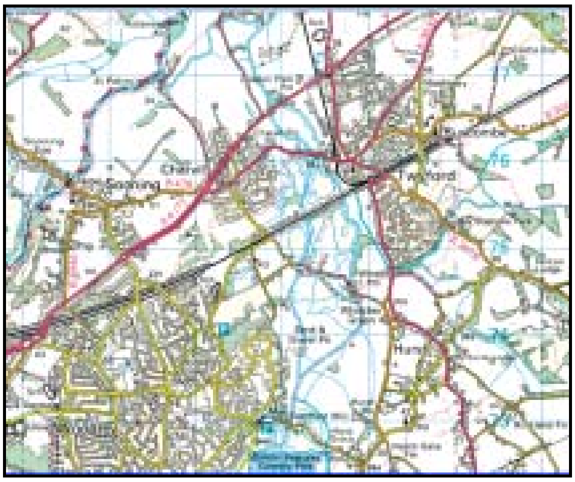
- Empirical relationships based on upstream levels reached at Kilgram and Ripon gauges on the Ure and Swale respectively.
- From the RFFS. The RFFS for the River Ure contains PDM and kinematic wave components, and also a level to level correlation component. A hydrodynamic model also exists, but this has not been converted to real-time.

The use of rainfall-runoff and routing models cannot accurately predict the behaviour of a confluence under conditions of high flow impoundment. To model confluence flooding accurately requires the use of an HD model. However, if flooding at this confluence is relatively predictable and related to flows and levels in the Swale, then simple level to level correlation might be used to predict flood levels.

FF6. CONFLUENCE FLOODING

Thames Region: River Loddon

The River Loddon (Thames Region) rises on chalk in the area around Basingstoke and flows for over 45km to its confluence with the Thames near Wargrave.



There are two main flooding issues:

- at the confluence with the Thames, there is insufficient channel capacity, which causes overtopping during high flows and properties may be at risk from the Loddon, the Thames or a combination of both.

- the lower reaches of the Loddon are noted for a large number of historic mills around which localised flooding can occur.

The uncertainty of the flooding processes makes it difficult to forecast the need for warnings.

The confluence area of the River Loddon and Thames was identified in 1995 by the NRA as the most significant area of flood risk in the catchment. During flood events high river levels in the Thames cause backing up of flows in the Loddon, which results in long duration flood conditions. For example in January 1990 a number of houses were flooded to a depth of 0.1 to 0.25 m for several days. There are good flow and level data and reasonable rainfall data available for the Thames and Loddon catchments.

Current forecasting is based on trigger level thresholds. There is a hydrodynamic model of the Thames, which is currently being converted to real time use. However no model exists of the Loddon.

In order to forecast flooding at the confluence, a model would be required for the flows along the River Lodden and the levels in the Thames. It is possible that a simple relationship would be very applicable in this situation. If reliable level-to-level correlations can be generated for the Thames, then levels can be predicted in this channel with a lead time of about six hours. A rainfall runoff model can be used to forecast flows in the River Loddon and from a matrix of historical flow and level conditions, expected flood elevations and durations could be determined.

FF7. INFLUENCE OF STRUCTURES

North East Region: River Don

In the River Don catchment there are five river regulators used to direct flow into washlands in order to reduce peak flows at Doncaster. These are manually controlled, and although there are procedures, structures are generally opened and closed based on the experience and judgement of the operators. It is therefore difficult to apply 'what if' modelling with so many variables.

In the RFFS the Upper Don is represented using PDM and KW models. Ideally, a flood forecasting model would include an allowance for the structures, but it is not possible to predict exactly how they will be operated.

FF8. LOW BENEFIT LOCATIONS

(i) Anglian Region: East Suffolk Rivers

The area of east Suffolk between the Waveney and the Gipping is drained by half a dozen small rivers (catchment areas not exceeding 150 km^2) including the Alde, the Hundred, the Yox, the Blyth and the Wang. Each of these rivers drain fast reacting, Boulder Clay, catchments. The population of the area is low in number and dispersed into a large number of small hamlets and villages.

Flood risk in the area is very real. In 1993 the villages of Debenham and Wrentham suffered severe flooding.

The key forecasting problem for the area is that there are a large number of flood risks, each often affected by a different river. When considered individually the flood risks are difficult to justify a significant investment in flood forecasting. However when considered as a group there is a significant forecasting need that requires addressing.

Flood warnings for the area are currently issued based on trigger levels at the nearest gauging stations. The gauges are often some distance from flood risk areas, and frequently in different catchments. During localised events it is possible either that flood warnings are not issued (as storms effect a flood risk zone but not the catchment draining to a trigger gauge) or that false alarms are raised.

(ii) Wales: River Teifi

The River Teifi drains approximately 800km^2 in South West Wales, and isolated properties are at risk of flooding. There is a poor correlation relationship between three level gauges because of the variability of rainfall in time and space, the catchment shape and the existence of a raised peat bog in the upper catchment. It is also difficult to forecast when the upstream on-line reservoir will fill.

The current forecasting procedures include the use of an in-house hybrid rational/rainfall runoff model. The catchment has good rainfall and level data, and reasonable flow data available (FEH only identifies 2 flow gauges, and the records from one are to be treated with caution).

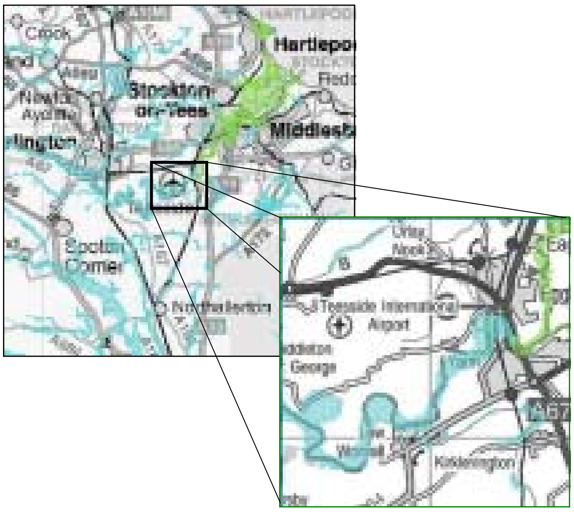
(iii) Midlands Region: River Leam

Only nine properties on the River Leam (Midlands Region) were thought to be at risk of flooding, and this was therefore deemed a low benefit location. During the floods of Easter 1998, extensive flooding occurred and, although a 5 hour lead time was provided, the warning infrastructure was not in place. New good quality gauges have now been installed to improve the service.

FF9. FLOODPLAIN STORAGE

North East Region: River Tees

The River Tees has a total catchment area of over 2000 km^2, which rises in the hills of the northern Pennines and flows east to Stockton and Middlesborough. It has two major tributaries in its lower and middle reaches, the Skerne and the Leven. The catchment contains very significant floodplain areas in the lower reaches, which strongly influence the forecast of flood levels for the urban centres downstream.



The (now superceded) model of the River Tees was based around a set of kinematic wave routing models. These do not represent floodplain storage at all and hence were not successful at forecasting flood levels on the lower river.

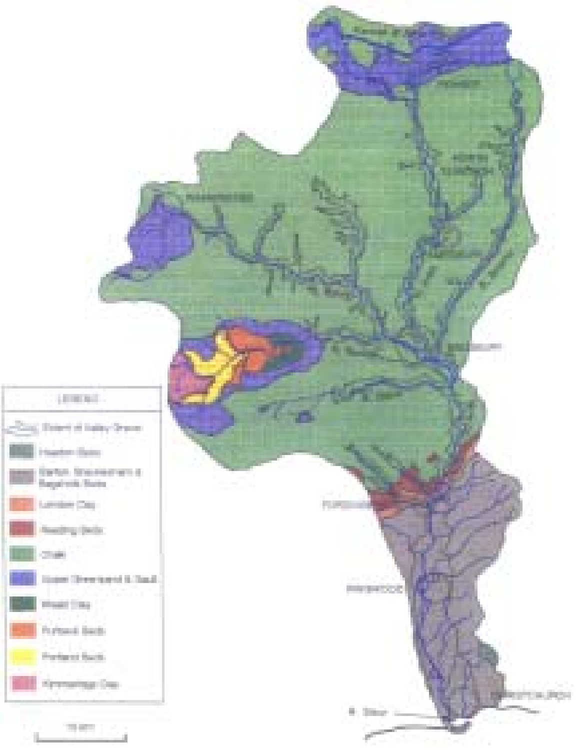
These problems have been resolved by the implementation of real time hydrodynamic model. This HD model was originally built to assist in the design of the Tees Barrage and has been modified in order to use in real-time and added into the RFFS as a component. The forecasting model of the River Tees consists of rainfall-runoff models for the Upper Tees, kinematic wave routing models for the middle reaches and a HD model for the lower section. The model has not been tested for a large event as yet, but early results are encouraging.

FF10. GROUNDWATER FLOODING

South West Region: River Avon

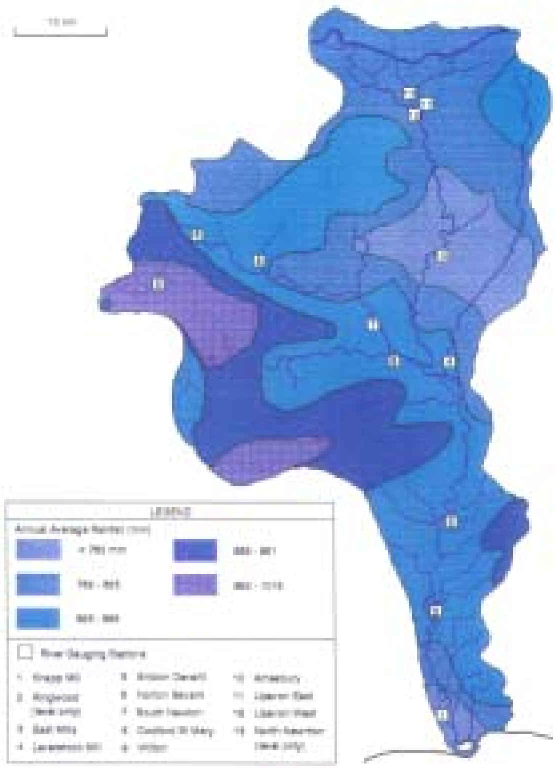
The Hampshire Avon is a large chalk dominated catchment rising in the hills to the north of Salisbury, flowing through the town and down to its outfall at Christchurch. The catchment area is over 1700 km^2 and includes the rivers Avon, Bourne, Wylye, Nadder and Ebble.

The rivers are largely spring fed from the large chalk block on which they rise and this gives rise to significant groundwater flood risk. The geology is illustrated on the following map.



The main forecasting issues are the relatively slow increase in groundwater levels generating high spring flow values, and groundwater flooding. Groundwater generated floods are significant and the flood risk to major urban centres is great. The highest recorded flow was observed by flow gauging on 1st November 1960 at Fordingbridge on the lower Avon, and measured 116 m3/s.

Long lead times should be available and forecasts could be generated from telemetered groundwater levels.



If boreholes throughout the catchment were telemetered, then the levels in these could be correlated to the river flow at various points throughout the catchment (see map below for network of flow gauges) and predictions of river flow could be made based upon groundwater level.

The large catchment area means that groundwater levels are likely to be relatively slow to react to rainfall and by creating correlations throughout the catchment, from the upper reaches, through Salisbury, to the outfall, flow predictions should be possible for the whole area.

A set of rainfall-runoff models could also be developed to provide a further forecasting capability during the scenario of full groundwater stores and surface runoff being the main factor causing flood flows.

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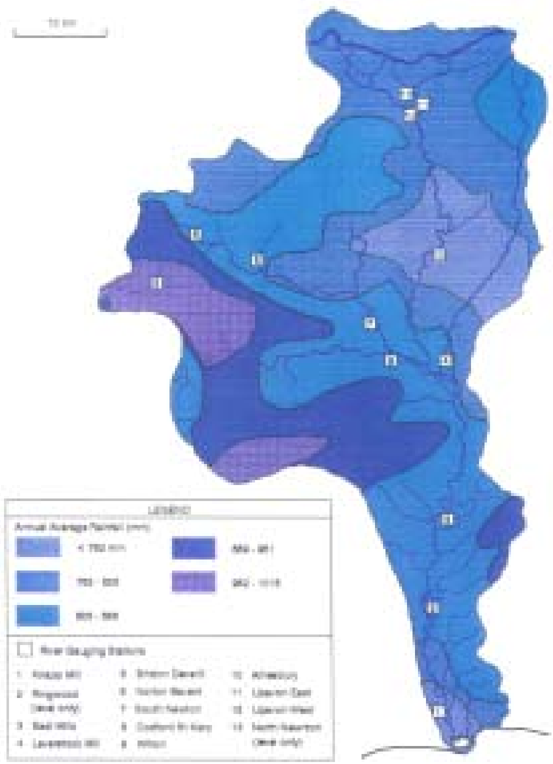

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FF11. GROUNDWATER FLOODING

Anglian Region: River Slea

The River Slea, a baseflow dominated catchment draining part of the Lincolnshire Limestone ridge south of Lincoln, was modelled by WS Atkins as a sub-catchment of the Witham flow forecasting model, a pilot for the Anglian Flow Forecasting System. Two approaches were considered to represent runoff from the catchment:

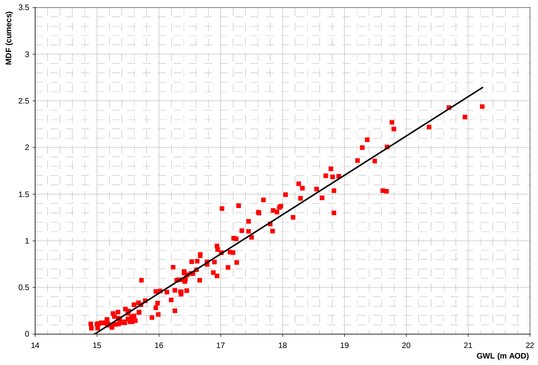
- conceptual rainfall-runoff modelling
- combined conceptual rainfall-runoff modelling and a regression between groundwater levels and average daily flows. The rainfall-runoff models simulating surface runoff and inter-flow and the regression simulating baseflow.

Although the conceptual rainfall-runoff modelling approach provided a conceptually sound and flexible framework within which to undertake the calibration of the catchment model, the method has two key disadvantages.

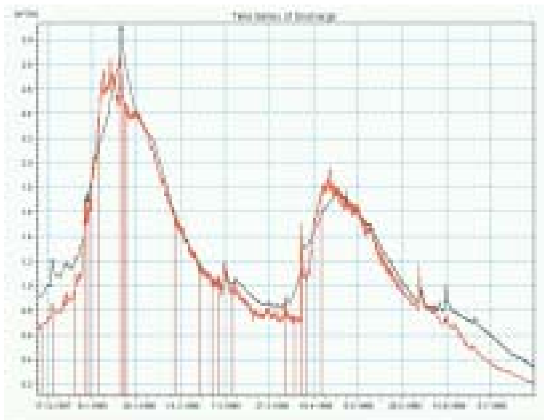
- it was difficult to represent the complex groundwater processes of the catchment using simple lumped rainfall-runoff models.
- the rain gauges available for use in the model calibration period were unsuitably located and had sporadic records (when using a continuous rainfall-runoff models to simulate baseflow dominated catchments, an unbroken rainfall input is imperative in order that the model stores are sustained).

Following trials it was decided to adopt the mixed rainfall-runoff / groundwater regression approach. The groundwater regression was developed to allow flow at time *t* to be forecast from groundwater levels at time t – 5 days.

The regression between groundwater levels at Leasingham Borehole with flow at Leasingham gauging station is shown in the following figure.



The model calibration achieved using this method at Leasingham gauging station is shown in the following figure.



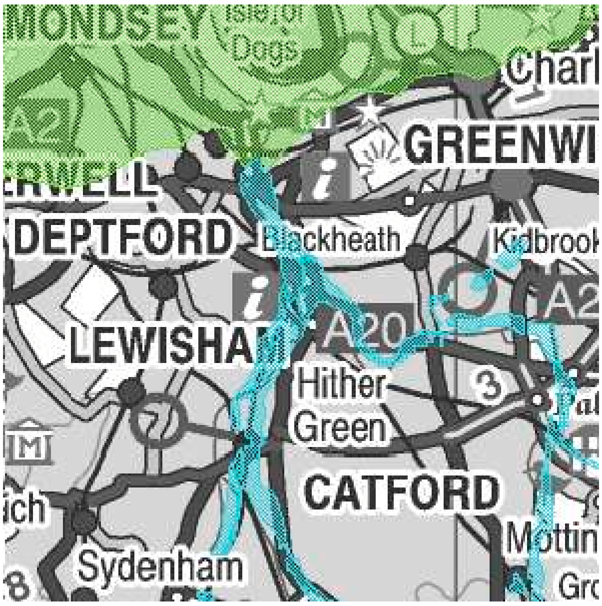
The assumptions, strengths and weaknesses of this approach are presented in the main report.

FF12. URBAN CATCHMENTS

Thames Region: River Ravensbourne

The River Ravensbourne drains an urban area in South London. The river rises to the south east of London on Bromley Common and flows north, through Catford and Lewisham, to its confluence with the Tidal Thames at Blackheath (opposite the Isle of Dogs). The river has a catchment area of only about 150 km^2, the majority of which is heavily urbanised and subject to extremely rapid runoff rates.

Achieving the required lead time of 2 hours is a problem, not only due to the urbanised nature of the catchment, but also since the sudden development of 'clear air' convective events means that times to peak can be as short as 1 hour.

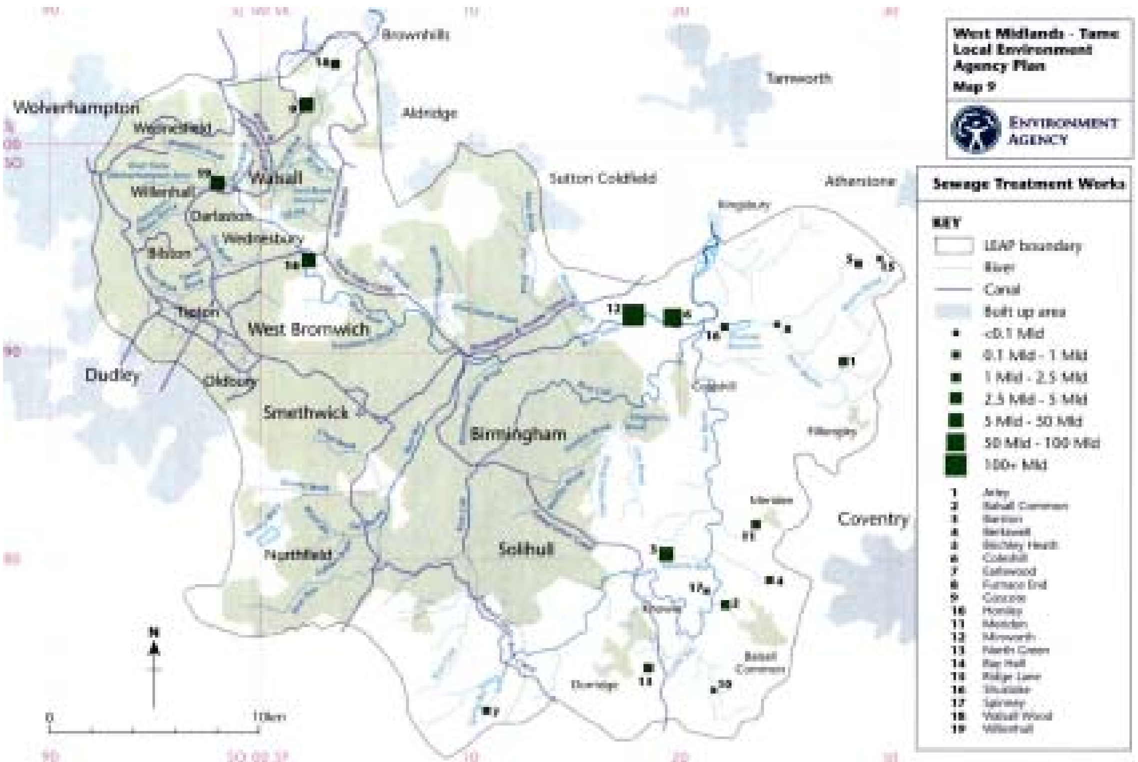


Midlands Region: River Tame

The River Tame drains the major urban area of Birmingham and forms a major tributary of the River Trent. The Tame has a catchment area of 1475 km^2 to the gauging station at Elford, just upstream of the Trent confluence.

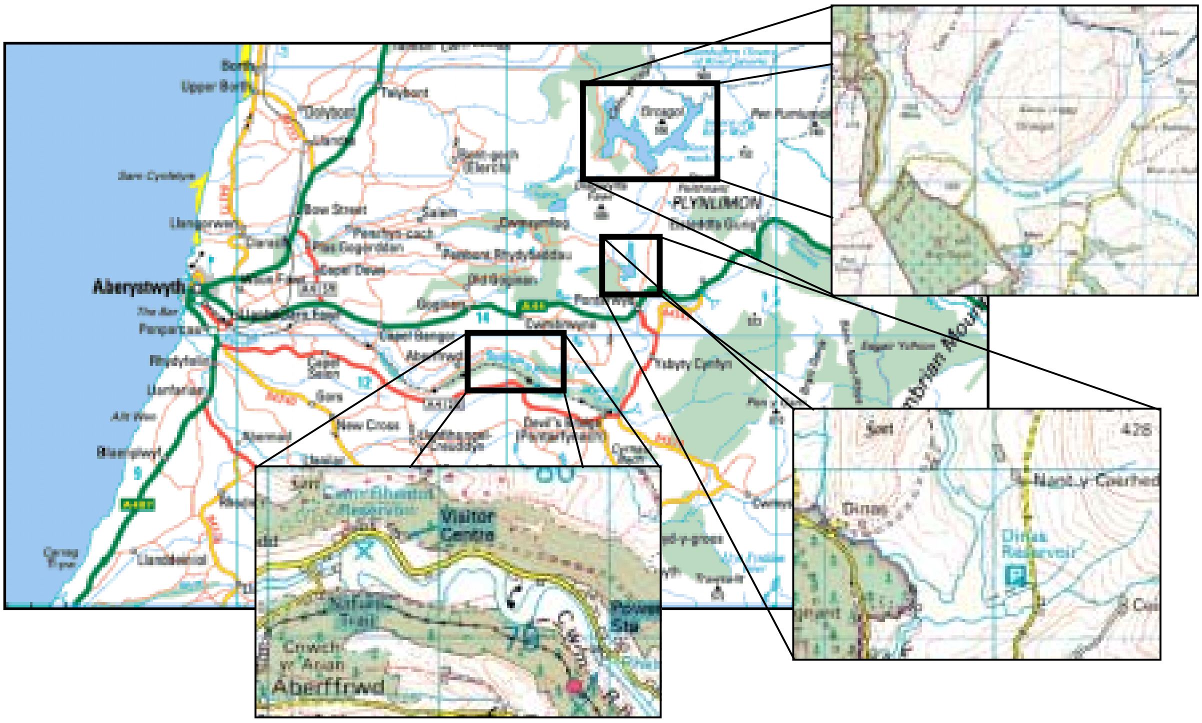
The figure below (from the River Tame LEAP) illustrates the River Tame catchment, and in particular the extent of the urban area that it drains.

Currently, the forecasting approaches for this catchment are a rainfall runoff model applied to each of the sub catchments, and a routing model applied to the main river reaches. The timing of forecasts produced is sometimes poor, particularly during convective events, due to a lack of any physical representation of the urban drainage characteristics and the complexity of the drainage network in this area.



FF13. RESERVOIRED CATCHMENTS

Wales: Afon Rheidol



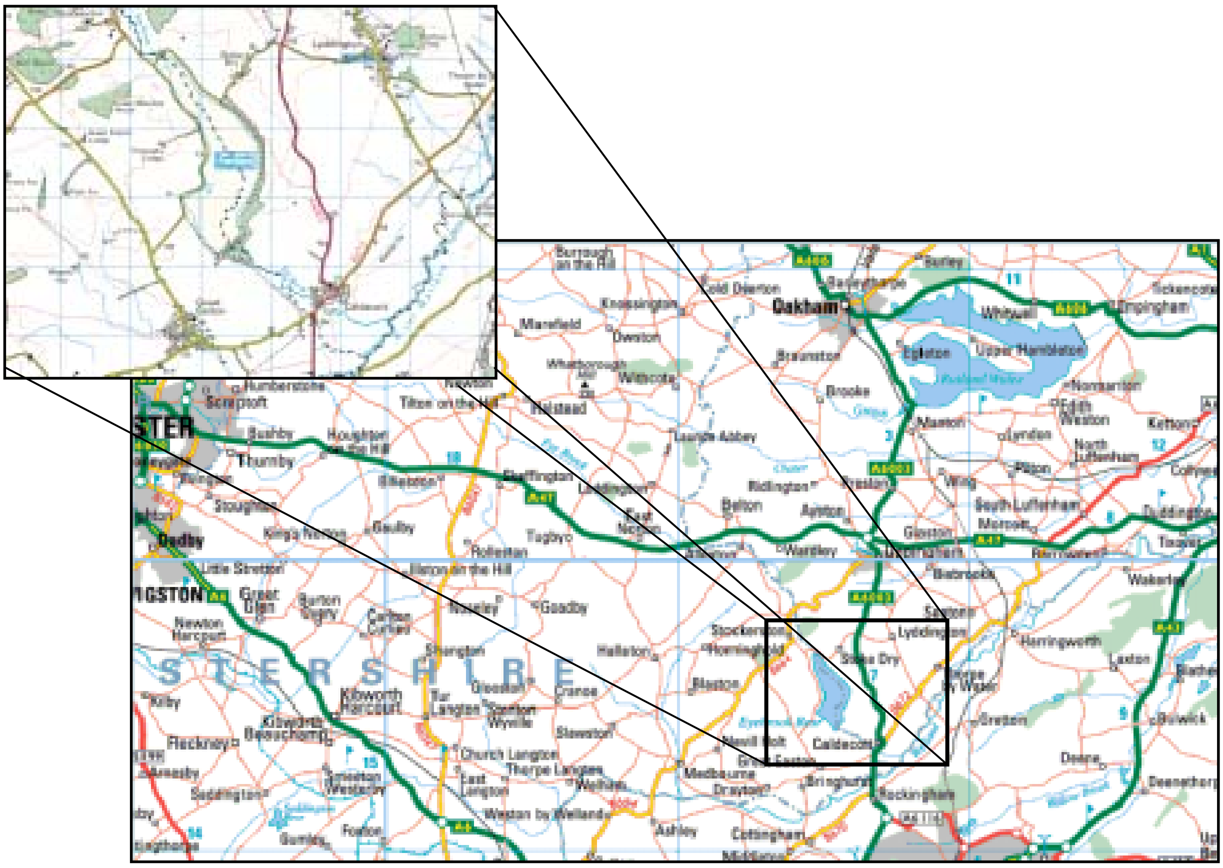
The River Rheidol rises in the mountains of eastern Wales and drains to the coast at Aberystwyth. The catchment area upstream of Aberystwyth is approximately 185 km^2. The upper catchment is extremely steep, with narrow gorges, and prone to very rapid runoff and short times to peak. The lower catchment, on the other hand, between Cwm Rheidol and Aberystwyth, is flatter with extensive floodplain reaches.

70% of the catchment upstream of the flood risk area of Aberystwyth is part of a linked 3-reservoir hydropower scheme. There is a forecasting threshold for the onset of flooding, but the reservoir storage and operation procedures make forecasting of the magnitude and timing of the peak difficult. An in-house rainfall runoff model exists to assist with forecasting and there are reasonable flow and level gauges and good rainfall gauges in the catchment.

The complexity, and interlinked nature, of the reservoir operation serves to ensure that simple forecasting approaches are unlikely to be successful. A methodology that accounts for the outflow control rules of the dam structures, the combined impact of the operation of all three reservoirs and the hydrological runoff between them is required to accurately predict flood flows downstream of Cwm Rheidol in Aberystwyth. A model that accounts for the impact on flood levels of the downstream tidal reaches of the river would also be needed.

FF14. RESERVOIRED CATCHMENTS

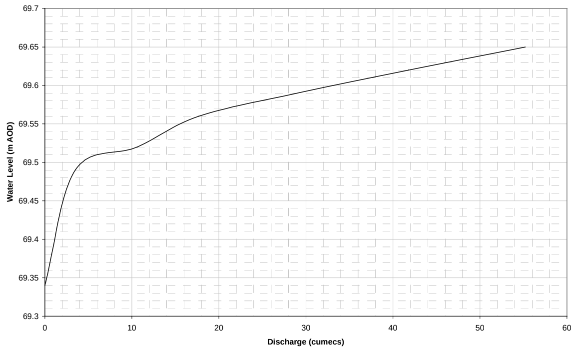
Anglian Region: Eyebrook



Eyebrook is a major tributary of the River Welland, just to the north of Market Harborough. The upper catchment includes a major water supply reservoir, draining a catchment area of approximately 57 km^2. Outflow from this reservoir is via 16 parallel siphons and a scour valve set just above bed level. The outflow from the reservoir flows into a large flood diversion channel and over two measurement structures: a high flow and a low flow crump weir. The low flow weir measures continual compensation releases (via a pump), and the larger structure measures flood outflow from the reservoir.

The downstream impact of outflow from this reservoir is very great. The siphons have a very sensitive Q-h relationship (see below) whereby small changes in reservoir level can result in large changes to outflow discharge and hence downstream flood risk.

The reservoir was modelled as part of a catchment model of the entire Welland and Glen system using an explicit 1-D representation. The cross sections for the reservoir were derived so that the stage - storage relationship mimicked reality. This ensured that the outflow for a given reservoir head would be correct.



Inflow to the reservoir was modelled using a rainfall-runoff model, calibrated to observed levels and observed outflow. The siphons and scour valve were modelled hydraulically and the outflow from the reservoir was calibrated to the down stream high flow gauge. The calibration plots are illustrated in the following figures, showing firstly, reservoir level and secondly, outflow discharge.