Appendix

Ecosystem services of peat – Phase 1

Project code: SP0572

Appendix 1. Start-up Meetings and Conference Participants, Conference Programme

Start-up Meetings

Defra Peat Partnership	28 January 09
Thorne & Hatfield	13 March 09
Peak District	19 March 09
Migneint	23 March 09

Start-up Meeting Delegates

Name	Surname	Affiliation	email	Start-Up Meeting
Adam	Baylis	Environment Agency	adam.baylis@environment-agency.gov.uk	Peak District
Nesha	Beharry-Borg	University of Leeds	n.c.beharry-borg@leeds.ac.uk	Peak District
Aletta	Bonn	Moors for the Future	aletta.bonn@peakdistrict.gov.uk	Peak District/Thorne & Hatfield/Defra start up
Tatiana	Boucard	Defra	Tatiana.Boucard@defra.gsi.gov.uk	Defra start up
Richard	Bradbury	RSPB	richard.bradbury@rspb.org.uk	Peak District
Richard	Brassington	Environment Agency Wales	richard.brassington@environment-agency.wales.gov.uk	Migneint
Helen	Buckingham	National Trust (M)	Helen.Buckingham@nationaltrust.org.uk	Migneint
Kevin	Bull	Natural England (T&H)	Kevin.Bull@naturalengland.org.uk	Thorne & Hatfield/ Defra start up
Pippa	Chapman	University of Leeds	P.J.Chapman@leeds.ac.uk	Thorne & Hatfield
R	Dafydd	CCW	R.Dafydd@ccw.gov.uk	Migneint
Helen	Dunn	Defra	helen.dunn@defra.gsi.gov.uk	Defra start up
Steven	Dury	Somerset Council	SDury@somerset.gov.uk	Migneint
Bridget	Emmett	CEH Bangor	bae@ceh.ac.uk	Migneint
Chris	Evans	CEH Bangor	cev@ceh.ac.uk	Migneint/Defra start up
Ken	Greene	Lincolnshire Wildlife Trust	dbromwich@lincstrust.co.uk	Thorne & Hatfield
Andy	Hammon	English Heritage	Andy.Hammon@english-heritage.org.uk	Thorne & Hatfield
Mark	Haslam	Environment Agency	mark.haslam@environment-agency.co.uk	Peak District
Will	Hewson	Moors for the Future	Will.Hewson@peakdistrict.gov.uk	Peak District
Joseph	Holden	University of Leeds	J.Holden@leeds.ac.uk	Thorne & Hatfield
Mike	Innerdale	National Trust (PD)	michael.innerdale@nationaltrust.org.uk	separate meeting
Angela	Johnson	PDNPA	angela.johnson@peakdistrict.gov.uk	Peak District
Peter	Jones	CCW	P.Jones@ccw.gov.uk	Migneint
Helen	Kirk	T&H Moors Conservation	helen_kirk@tiscali.co.uk	Thorne & Hatfield
Tim	Kohler	Natural England (T&H)	Tim.Kohler@naturalengland.org.uk	Thorne & Hatfield
Ed	Lawrance	United Utilities	Edward.Lawrance@uuplc.co.uk	separate meeting
Chris	Lloyd	CEH Wallingford	crl@ceh.ac.uk	Migneint
Helen	Markland	Doncaster Council	helen.markland@doncaster.gov.uk	Thorne & Hatfield
Richard	May	Moorland Association	richard@lionlike.co.uk	Peak District
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Harriet	Orr	Environment Agency	harriet.orr@environment-agency.gov.uk	Migneint
Heath	Owen	Snowdonia National Park	heath.owen@eryri-npa.gov.uk	Migneint

Laura	Owen	Yorkshire Water	Laura.Owen@yorkshirewater.co.uk	separate meeting
Mark	Parnell	Moors for the Future	Mark.Parnell@peakdistrict.gov.uk	Peak District/ Migneint/ Thorne & Hatfield/Defra start up
David	Patrick	JBA Consulting (Int.Drainage Board)	David.Patrick@jbaconsulting.co.uk	Thorne & Hatfield
Mike	Pearson	Yorkshire Water	Mike.D.Pearson@yorkshirewater.co.uk	separate meeting
Sean	Prendergast	PDNPA	Sean.Prendergast@peakdistrict.gov.uk	Peak District
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Mike	Rhodes	PDNPA	Mike.Rhodes@peakdistrict.gov.uk	Peak District
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Ed	Rowe	CEH Bangor	ecro@ceh.ac.uk	Migneint
Shaun	Russell	Welsh Environment Research Hub	s.russell@bangor.ac.uk	Migneint
Davison	Sharon	Moors for the Future	sharon.davison@peakdistrict.gov.uk	Peak District
Matthew	Shepherd	Natural England	Matthew.J.Shepherd@naturalengland.org.uk	Defra start up
James	Skates	WAG	James.Skates@wales.gsi.gov.uk	Migneint
Kate	Snow	United Utilities	kate.snow@uuplc.co.uk	separate meeting
Jon	Stewart	Natural England	jon.stewart@naturalengland.org.uk	Peak District
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Wiseman	Tom	PDNPA	Tom.Wiseman@peakdistrict.gov.uk	Peak District
Andrew	Walker	Yorkshire Water	andrew.c.walker@yorkshirewater.co.uk	separate meeting
Ruth	Waters	Natural England	Ruth.Waters@naturalengland.org.uk	Peak District
Jared	Wilson	RSPB	Jared.Wilson@rspb.org.uk	Migneint
Reuben	Woodford	Environment Agency Wales	reuben.woodford@environment-agency.wales.gov.uk	Migneint
Fred	Worrall	University of Durham	fred.worrall@durham.ac.uk	Thorne & Hatfield

Conference Peat Ecosystem Services - Phase I

Losehill Hall - Peak District National Park Centre for Environmental Learning,Castleton, 15-16 October 2009

Conference Delegates

Name		**Affiliation**	**email**
Mike	Acreman	CEH Wallingford	man@ceh.ac.uk
Adam	Baylis	Environment Agency	adam.baylis@environment-agency.gov.uk
Nesha	Beharry-Borg	University of Leeds	n.c.beharry-borg@leeds.ac.uk
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Richard	Bradbury	RSPB	richard.bradbury@rspb.org.uk
Richard	Brassington	Environment Agency Wales	richard.brassington@environment-agency.wales.gov.uk
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Fred	Worrall	Durham University	fred.worrall@durham.ac.uk

Conference Programme

Thursday 15 October 2009

10:30 –11:00	***reception***
11.00	**Welcome** *Sean Prendergast, Head of Field Services, PDNPA*
11.05	**Welcome – Introduction to Defra Soils Programme** *Claire Hill, R&D Manager, Soils Programme, Defra*
11.20	**Project presentation** Ecosystem Service mapping Project overview, Provisioning Services: Agriculture, Wind energy *Aletta Bonn, Mark Parnell, Moors for the Future* Regulating Services: Carbon and climate regulation *Fred Worrall, University of Durham* Regulating Services: Water quality regulation *Chris Evans, Pippa Chapman, CEH Bangor, University of Leeds* Regulating Services: Natural hazards – potential flood risk attenuation *Joseph Holden, University of Leeds*
12.40	***lunch***
13.40	**Project presentation** Ecosystem Service mapping Cultural Services: Recreation, UK Peat Geonetwork *Mark Parnell, Aletta Bonn, Moors for the Future* Biodiversity *Ed Rowe, Mike Acreman, CEH Bangor, CEH Wallingford*
14.15	**Workshop 1 - Ecosystem Service Supply** Case Study Sites Baselines Peak District, Migneint, Thorne & Hatfield & Somerset Levels • *What is the spatial configuration of service provision? What are limitations for providing each of the services? What are drivers of change?* • *Spatial synergies and trade-offs between services* • *Differences in ecosystem service provision between sites and transferability of results to other areas.*
15.30	***tea & coffee***
15.50	***Project Presentation*** *Ecosystem Service Valuation & Cost Benefit Analysis* Nesha Beharry-Borg, Mette Termansen, University of Leeds

16.10	**Workshop 2** **Valuation of Change & Ecosystem Service Demand** • *Analysis of Change* • *Valuation of services, cost-benefit flows* • *Who are the providers and beneficiaries of peatland ecosystem services and what are the cost-benefit flows?*
17.30 – 18.00	**Plenum – Brief reports from sessions**
18.15	***dinner***
19.40	**Project Presentation** Delivery of health aspects from peatlands *Aki Tsuchiya, University of Sheffield*
20.00 - 21.00	**Plenum – Presentations from case study sites** Thorne & Hatfield Moors – a fascinating history of peatland change *Tim Kohler, Natural England* Somerset Level and Moors - a place for people and biodiversity *Stephen Dury, Somerset County Council* Migneint – a jewel in the Welsh mountains *Iona Roberts, National Trust* Peak District – moorland management for sheep and grouse *Geoff Eyre, William Eyre & Sons, Moorland Association*
evening	***Bar***

Friday, 16 October 2009

8.00	***breakfast***
9.00	**Introduction to National Ecosystem Assessment** *Jonathan Winn UNEP-WCMC*
9.15	**Plenum -** Introduction to day 2
9.20	**Workshop 3 Synthesis** • *Priorities for Peatland Management – Case for Restoration* • *Ecosystem Service monitoring: top 10 indicators* • *Phase II - Discuss feasible work programme for next 2 - 5 years to collect additional information required on peatland ES, cost-benefit flows and prioritisation of management and restoration actions.*
10.00	***tea & coffee***
10.30	**Workshop 3 Synthesis** *(continued in break out rooms)*
11.30	**Plenum - Summary and Way forward** **Farewell**
12.00	***lunch***

Appendix 2. Data sources and supporting information

A2.1 Geographic datasets used during the study

Dataset Name	Weblink	Organisation	Used in Analysis
Wales - Sites of Special Scientific Interest	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	Y
Wales - Less Favourable Areas	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	N
Wales - Public Rights of Way	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	Y
Wales - Special Areas of Conservation	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	Y
Wales - Special Protection Areas	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	Y
Wales - RAMSAR	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	Y
Wales - National Nature Reserves	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	Y
Wales - Areas of Outstanding Natural Beauty	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	Y
Wales - Ancient and Semi Natural Woodland	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	Y
Wales - Biodiversity Action Plan habitats	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	N
Wales - Countryside Rights of Way	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	Y
England - Local Nature Reserves	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	N
England - Country Parks	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	N
England - Joint Character Areas	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	N
England - Areas of Outstanding Natural Beauty	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	Y
England - Less Favourable Areas	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	Y
England - Countryside Rights of Way	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	Y
England - National Parks	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	Y
England - Special Areas of Conservation	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	Y
England - Special Protection Areas	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	Y
England - RAMSAR	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	Y

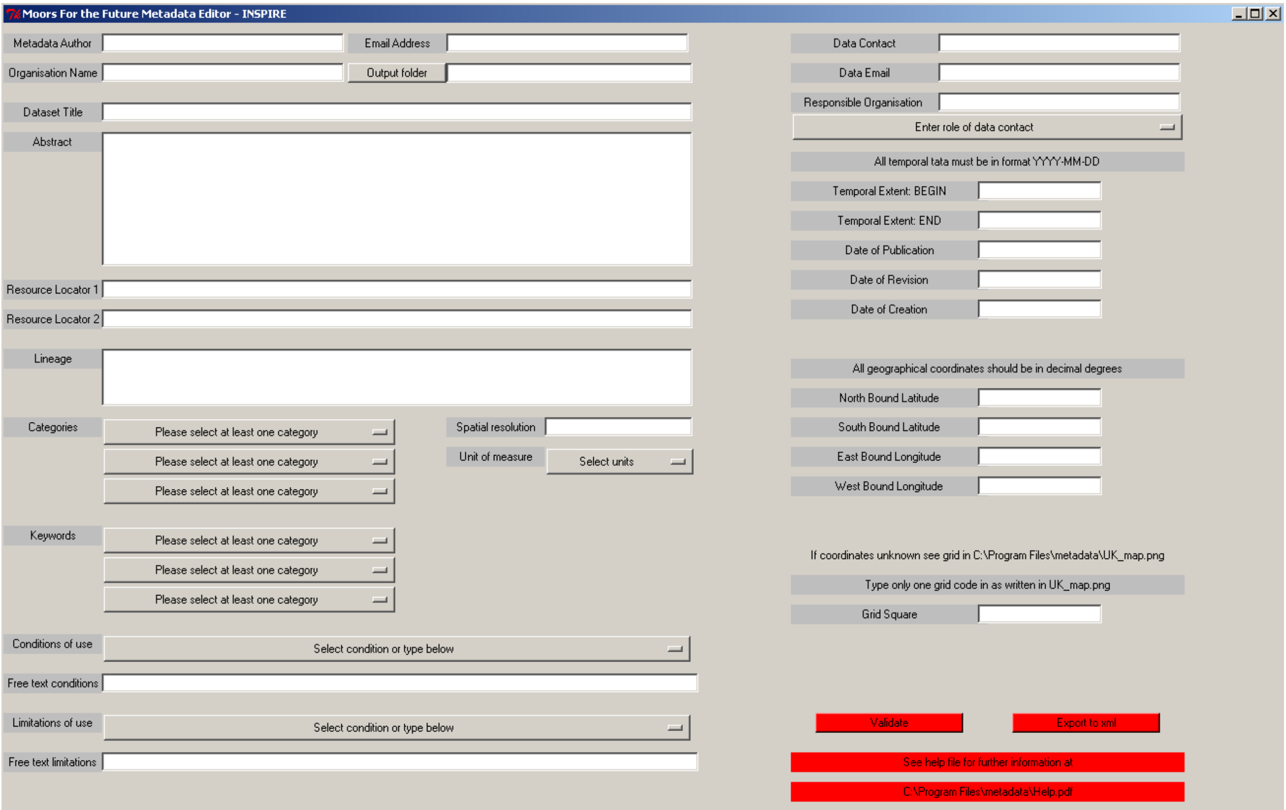
England - Countryside Stewardship Agreements (polygon)	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	
England - National Nature Reserves	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	Y
England - Natural Areas	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	
DECC - Windspeed Database	http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/explained/wind/windsp_databas/windsp_databas.aspx	Department of Energy and Climate Change	Y
EDINA - AgCensus	http://edina.ac.uk/agcensus/	Edinburgh University Data Library	Y
Detailed River Network	http://www.eduserv.org.uk/licence-negotiation/potential_agreements/environmentagency/Detailed%20River%20Network%20Sample%20Data%20&%20Guide%202008/EA_DRN_TechDecription Guide4.0b.pdf	Environment Agency	Y
UKCIP - Mean Monthly Maximum Temperature (centigrade)	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Mean Monthly Minimum Temperature (centigrade)	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Monthly Mean Temperature (centigrade)	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Number of Days of Frost	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Number of Days of Ground Frost	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Mean Monthly Sea Level Pressure	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Mean Monthly Vapour Pressure	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Mean Monthly Relative Humidity	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Mean Monthly Wind Speed	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Mean Monthly Cloud Cover	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Monthly Duration of Bright Sunshine	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Number of Days per Month having Rainfall >1mm	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Number of Days per Month having Rainfall >10mm	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Number of Days per Month with Snow	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Number of Days per Month with Snow Cover >50mm	http://www.ukcip.org.uk/	Met Office	N
UKCIP - Total Monthy Precipitation	http://www.ukcip.org.uk/	Met Office	N

LiDAR Coverage	http://www.geomatics-group.co.uk/GeoCMS/Products/LIDAR.aspx	Geomatics Group	Y
NATMAP Vector	http://www.landis.org.uk/index.cfm	Cranfield University	Y
SOILSERIES - Hydrology	http://www.landis.org.uk/index.cfm	Cranfield University	Y
SOILSERIES - Agronomy	http://www.landis.org.uk/index.cfm	Cranfield University	Y
SOILSERIES - Pesticides	http://www.landis.org.uk/index.cfm	Cranfield University	Y
SOILSERIES - Info	http://www.landis.org.uk/index.cfm	Cranfield University	Y
HORIZON - Fundamentals	http://www.landis.org.uk/index.cfm	Cranfield University	Y
HORIZON - Hydraulics	http://www.landis.org.uk/index.cfm	Cranfield University	Y
WALES - Scheduled Ancient Monuments	http://www.cadw.wales.gov.uk/default.asp	CADW	Y
ENGLAND - Scheduled Ancient Monuments	http://www.english-heritage.org.uk/server/show/nav.00100200400d004	English Heritage	Y
British Wind Energy Association - Windfarm Database	http://www.bwea.com/xml/ukwed.xml	BWEA	Y
Next Perspectives Colour Aerial Photography Data - Survey		Next Perspectives	Y
Digital Terrain Model - 5m		Next Perspectives	Y
Ordnance Survey Mastermap	http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/	Ordnance Survey	Y
ENGLAND - Tranquility maps	http://www.cpre.org.uk/campaigns/landscape/tranquillity/national-and-regional-tranquillity-maps	CPRE	Y
Environment Agency Administrative Boundaries		Environment Agency	N
Flood Map	http://www.environment-agency.gov.uk/research/planning/93498.aspx	Environment Agency	Y
Water Flow Gauge Records		Environment Agency	Y
Headline Indicators for River Biology		Environment Agency	Y
Headline Indicators for River Chemistry		Environment Agency	Y
Historic Flood Map		Environment Agency	N
Historic Rain Gauge Data		Environment Agency	Y
Water Abstraction Permits		Environment Agency	Y
Water Sampling Locations		Environment Agency	Y
Rural Land Register - Options dataset		Natural England	Y

England - Agricultural Land Grades (Provisional)	http://www.defra.gov.uk/foodfarm/landmanage/land-use/documents/alc-guidelines-1988.pdf	Defra	Y
Wales - Agricultural Land Grades (Provisional)	http://www.defra.gov.uk/foodfarm/landmanage/land-use/documents/alc-guidelines-1988.pdf	Welsh Assembly Government	Y
England - Public Rights of Way	www.geodata.soton.ac.uk	Defra	Y
1:10,000 Colour Raster			
Forestry Commission - National Inventory of Woodlands and Trees	http://www.forestry.gov.uk/inventory	Forestry Commission	Y
Fine Resolution Atmospheric Multi-pollutant Exchange	http://www.frame.ceh.ac.uk/	Centre for Ecology and Hydrology	Y
UK Backdrop - Detailed and Coarse		Ordnance Survey	Y
England - Community Forests	http://www.magic.gov.uk/datadoc/metadata.asp?dataset=7	Forestry Commission	N
Counties and Unitary Authorities	http://www.ordnancesurvey.co.uk/oswebsite/products/boundaryline/	Ordnance Survey	N
Urban Areas	http://www.ordnancesurvey.co.uk/oswebsite/products/boundaryline/	Ordnance Survey	Y
CEH Land Cover Map 2000	http://www.countrysidesurvey.org.uk/archiveCS2000/	Centre for Ecology and Hydrology	Y
England - Moorland Line	http://www.magic.gov.uk/datadoc/tocmetadata.asp?datasetname=Moorland%20Line%20(England)	Rural Payments Agency	Y
OS Mastermap ITN	http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/itn/	Ordnance Survey	Y
National Public Transport Access Node	http://www.dft.gov.uk/naptan/	Department for Transport	Y
England - Forestry Commission Wooland	http://www.magic.gov.uk/datadoc/metadata.asp?dataset=25	Forestry Commission	N
England - National Cycle Network	http://www.sustrans.org.uk/	Sustrans	N
National Air Traffic Service - Wind Turbine Conflicts	http://www.bwea.com/aviation/nats.html	NATS	Y
Ordnance Survey 1:10,000 Colour Raster	http://www.ordnancesurvey.co.uk/oswebsite/products/10kraster/	Ordnance Survey	Y
Ordnance Survey 1:25,000 Colour Raster	http://www.ordnancesurvey.co.uk/oswebsite/products/25kraster/	Ordnance Survey	Y
Ordnance Survey 1:250,000 Colour Raster	http://www.ordnancesurvey.co.uk/oswebsite/products/250kraster/	Ordnance Survey	Y
Ordnance Survey Strategi	http://www.ordnancesurvey.co.uk/oswebsite/products/strategi/	Ordnance Survey	Y
Ordnance Survey Codepoint	http://www.ordnancesurvey.co.uk/oswebsite/products/codepoint/	Ordnance Survey	Y
Ordnance Survey Codepoint Polygons	http://www.ordnancesurvey.co.uk/oswebsite/products/codepointpolygons/	Ordnance Survey	Y
RSPB - Windfarm Sensitivity Maps		RSPB	Y

Slope (DTM) - 5m		Next Perspectives	Y
England - Sites of Special Scientific Interest	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp	Natural England	Y
Transport Direct Car Park Database	http://www.dft.gov.uk/transportdirect/community/parkingfacilities	Department for Transport	Y
Wales - Agricultural Land Grades (Provisional)	http://www.defra.gov.uk/foodfarm/landmanage/land-use/documents/alc-guidelines-1988.pdf	Welsh Assembly Government	Y
Wales - Local Nature Reserves	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	N
Wales - National Parks	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	N
Wales - Habitats of Wales, Phase 1 data	http://www.ccw.gov.uk/landscape--wildlife/habitats--species/terrestrial/habitats/habitat-surveys.aspx	Countryside Council for Wales	Y
Wales - Access Land	http://www.ccw.gov.uk/interactive-maps/gis-download-welcome.aspx	Countryside Council for Wales	N
Tir - Gofal	http://wales.gov.uk/about/cabinet/cabinetstatements/2002/140202CJTirgofal;jsessionid=1TJJKncDFvLtL1shbqcKT6cGQ4FhhLyhL8yLL0yDGt49QGTL3Yk3!1761965113?lang=en	Welsh Assembly Government	Y
Woodland Grant Scheme	http://www.forestry.gov.uk/ewgs	Forestry Commission	Y
Peak District National Park - Woodland Opportunities	http://www.peakdistrict.gov.uk/index/looking-after/grants/sdf/sdf-reports/sdf-woodlandsphd.htm	Peak District National Park	Y
Peak District National Park - Footpath database		Peak District National Park	Y
Civil Aviation Aerodromes	http://www.restats.org.uk/planning.htm	Civil Aviation Authority	Y
Ministry of Defence and Air Traffic Control Radar Coverage	http://www.restats.org.uk/planning.htm	Civil Aviation Authority	Y
Ministry of Defence Low Flying Zones	http://www.restats.org.uk/planning.htm	Ministry of Defence	Y
Meteorological Zones	http://www.restats.org.uk/planning.htm	Met Office	Y
Scottish Natural Heritage - Windfarm Footprint Map	http://www.snh.org.uk/strategy/renewable/sr-rt01.asp	Scottish Natural Heritage	Y

A2.2 Fields recorded in the Peat Geonetwork database



Appendix 3a. Moors for the Future Research Note on the Peat Geonetwork

UK Peat GeoNetwork

MOORS FOR THE FUTURE PARTNERSHIP

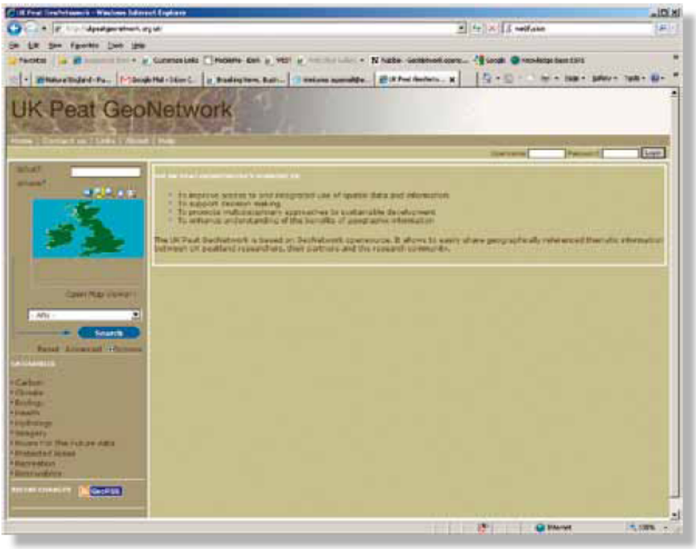
Moors for the Future Research Note No 13 September 2009

UK Peatlands

UK Peatlands are nationally and internationally important habitats for wildlife. They provide crucial ecosystem services for society, such as climate regulation (protection of carbon stores), water quality regulation, potential flood mitigation and provision of recreation opportunities.

However, peatlands face threats of intensive land management, land use change, atmospheric pollution and climate change.

To safeguard peatlands, there has been a surge in peatland restoration activities and peatland research in recent years. To facilitate better exchange and promote ongoing work, the UK Peat GeoNetwork provides a web based spatial information hub for sharing and visualising spatial data on projects and research data.



Homepage of the UK Peat GeoNetwork – www.ukpeatgeonetwork.org.uk

UK Peat GeoNetwork

The UK Peat GeoNetwork provides both a metadata catalogue and web map server to permit keyword and map based searches of spatial data, whilst respecting data licensing restrictions. In order to ensure the database succeeds, the UK Peat GeoNetwork employs EU INSPIRE metadata standards to Quality Assure data in the database.

The aim of the UK Peat GeoNework is to increase the sharing of spatial data and to promote collaboration between researchers and practitioners. We hope this tool will act as a high quality research database that can be used to share expert knowledge and project information and assist in planning new research activities.

The UK Peat GeoNetwork is open to all interested users and we welcome new uploads.

What is Metadata?

Metadata, commonly defined as "data about data" or "information about data", is a structured set of information which describes data (including both digital and non-digital datasets).

The European INSPIRE Directive aims to establish an INfrastructure for SPatial Information in the European Community (INSPIRE), contributing to environmental policy and sustainable development. It applies to digital environmental data held by public authorities.

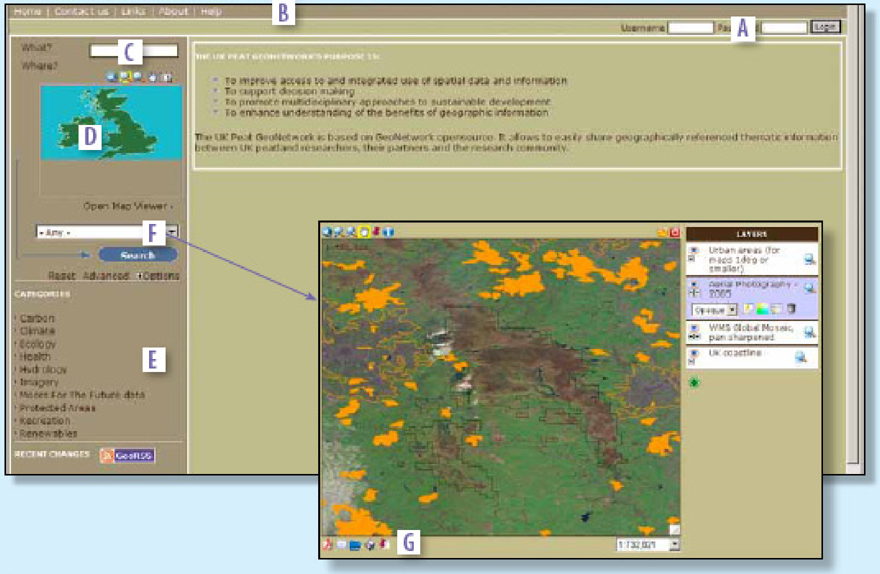
INSPIRE metadata must provide a short summary about the content, purpose, location of the data as well as information related to its conformity, quality, access and use constraints and responsible organisations. Standardised metadata allows for a quick search and data inventory, and make data utilisation easier.

EU INSPIRE directive will become compulsory across government departments over the next few years.

INSPIRE - Infrastructure for Spatial Information in Europe

UK Peat GeoNetwork - interface

The UK PeatGeoNetwork is based upon the United Nations (UN) Geonetwork open source software. This was developed by the UN world food program as a tool to share spatial data and metadata. Within the Defra funded project 'Peat Ecosystem Services' we have modified the web application to the aims of the UK Peat GeoNetwork.



A - Username and password

The UK Peat GeoNetwork can be found at www.ukpeatgeonetwork.org.uk. This website permits the unregistered user to search the metadatabase via a keyword or spatial search, see section C/D. Registered users who have been issued with a password will be able to access additional information and any uploaded datasets that are free from any licensing restrictions. Other datasets will only be accessible through direct contact with the data custodian.

B - Menu bar

Users can contribute information to the UK Peat GeoNetwork by uploading metadata through the menu bar. The menu bar also contains additional support information and links to partner organisations.

C D - Word and geographic search

Users can search via a typical word search by typing specific topic/keywords, for example "bird" for information on breeding bird survey datasets and reports. In addition, users can search via a spatial extent to identify what data may be available in an area that they are studying or trying to identify any possible collaborators. Please drag the mouse over the map (D).

E - Categories and RSS feed

Data can also be searched for via categories for specific research interests. Or keep up to date about new datasets and modifications via the UK Peat GeoNetwork RSS feed.

UK Peat GeoNetwork

F G H - View metadata and visualise data

After carrying out a keyword or spatial search, click on the button 'Metadata' (H). A form similar to the one shown below will open. The metadata will then provide information about the data characteristics, such as spatial and temporal resolution, quality and data ownership. The user can then either contact the data custodian directly for data access or seek out further information and explore any web links included.

Some data can also be visualised in the Map Viewer. Please click on 'Open Map Viewer' (F) below the inset map on the left. Users can add layers, zoom and change settings. Users can also mark locations, save views and pdf these. Please use the icons above and below the map (G). More information is available in the help menu.

Why share data?

Why lose time and repeat what has already been done before? Sharing data allows you to use your time and money for innovating projects, based on secure baseline data. Sharing baseline data improves also the collaboration and comparison between projects.

How to register

In order to start using the database to its full potential a user must be registered with the Moors For the Future Partnership who are implementing the database. This can be done by emailing **moors@peakdistrict.gov.uk** with your name, contact details and organisation. This data will then be used to establish an account and at which point all further contact will be with the relevant custodian of the data.

How to contribute

There are two types of data that a user is able to contribute to the UK Peat GeoNetwork, the first is the metadata for their geographic datasets. This only informs a user with the name and outline of what data that a custodian may have and is stored in the form of an xml file which can either be created with the UK Peat GeoNetwork web portal or via the standalone MFF Metadata Editor which is available free from the UK Peat GeoNetwork website.

The second data format is the actual GIS layer, which can be in supplied in all of the standard data formats for MFF to upload into the UK Peat GeoNetwork. Where the data can be visualised but not downloaded, thus maintaining the owners copyright – please contact **moors@peakdistrict.gov.uk** for further information regarding data security and access restrictions.

Acknowledgements/Data availability

- The development of the UK Peat GeoNetwork was funded through the Defra project 'Ecosystem Services of Peatland' (SP0572), a collaboration of Moors for the Future with the Universities of Leeds, Durham and Sheffield, and the Centre of Ecology and Hydrology (CEH).
- The project above is supported by the 'Peat Project', a partnership between Defra, Natural England, Environment Agency, Department of Energy and Climate Change, Forestry Commission, Welsh Assembly Government, Countryside Council for Wales, English Heritage, and Northern Ireland Environment Agency with the aim of facilitating and co-ordinating activity on peat in England and Wales.
- The UK Peat GeoNetwork has been set up by customising GeoNetwork Opensource by Eliane Roos and Mark Parnell. GeoNetwork Opensource has been developed conjointly by the Food and Agriculture Organisation (FAO) and the World Food Program (WFP), both United Nations organisations, following the principle of a Free and Open Source Software (FOSS).
- Installer and sources of the software UK Peat GeoNetwork are currently held by Moors for the Future.
- Views expressed in this research note do not necessarily reflect those of all Moors for the Future Partners.

References / Links

INSPIRE Directive: http://inspire.jrc.ec.europa.eu/index.cfm

INSPIRE Metadata Editor: http://www.inspire-geoportal.eu/inspireEditor.htm

Drafting Team Metadata and European Commission (2008) Draft Guidelines – INSPIRE metadata implementing rules based on ISO 19115 and ISO 19119

GeoNetwork Opensource Community website: http://geonetwork-opensource.org

One GeoNetwork node: FAO GeoNetwork: http://www.fao.org/geonetwork/srv/en/main.home

Moors for the Future Research notes

- No 1 Breeding Bird Survey of the Peak District Moorlands
- No 2 Gully Blocking in Deep Peat
- No 3 Peak District Moorland Stream Survey
- No 4 Heavy Metal Pollution in Eroding Peak District Moorlands
- No 5 Visitor Responsibility and the Moorlands
- No 6 Rapid Assessment Protocol for Monitoring Burning
- No 8 UK Peat GeoNetwork
- No 9 Air Pollution in the Peak District
- No 10 Peak District Moorland RELU Landscape Audit
- No 11 Wildfire Risk on Peak District Moorlands
- No 12 Carbon Flux from Peak District Moorlands

Contact Us

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Tel: 01629 816581
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The Moors for the Future Partners are:

Natural England, National Trust, Peak District National Park Authority, United Utilities, Severn Trent Water, Yorkshire Water, Sheffield City Council, Moorland Association, Defra, Country Land and Business Association, National Farmers Union

Appendix 3b. UK Peat Geonetwork continuation costs

The UK peat geonetwork is a webportal that permits spatial data and metadata to be shared between practitioners and researchers working in peatland ecology in the UK. The portal is driven by user content and therefore is self managed but does require some administration and other associated costs. At present the administration is coordinated by the Moors for the Future Partnership as part of the DEFRA SID3 contract.

Administration costs
The geonetwork requires a site administrator to update software, issue user access credentials, verify geospatial data, check metadata and liaise with users to promote engagement for the UKgeonetwork to become and remain a useful one-stop point for peatland research information. Consequently, we would envisage the requirement for 30 days/year of a GIS/data specialist's time which would have an approximate cost of £5,000 - £6,000 per annum.

Hardware costs
The geonetwork is hosted on an external server at a cost of £500 per annum. At present this provides 464GB of storage space (where half is used for the portal and the other half acts as a backup) and a server with a 1.2GHz processor which, with the present data load seems more than sufficient.

Software requirements
The geoenetwork is a free opensource piece of software that is regularly updated by the development team and draws on industry standard tools such as TOMCAT and geoserver. In addition, data manipulation from contributors is conducted by the GIS specialist within ArcView 9.3.1 and MapInfo 10, allowing all industry standard data to be manipulated and uploaded onto the server.

The UKPeatGeonetwork has an associated running cost but we believe that the potential benefits that it offers to the peatland research and practitioner community far out way these costs. The geonetwork presents a valuable resource to Phase 2 of the project and will enhance other peatland projects by providing a database of known spatial data and also act as an expanding resource. The database can then be used to store data from other projects and therefore act a central resource similar to that operated by COWRIE at their data management centre (http://data.offshorewind.co.uk).

Item	**Cost/annum**
Hardware- external server	£ 500
GIS administration 30d/yr	£ 5,000- 6,000
Supervision 2d/yr	£ 600
TOTAL	**£ 6,100 – 7,100**

Appendix 4. Technical components of flood service

1. TOPMODEL basics

In the TOPMODEL routine, rainfall is separated into three distinct categories (Beven and Kirkby, 1979; Lane *et al*., 2004). Some rainfall contributes directly to overland flow, some recharges the groundwater store in the unsaturated zone, and finally, some contributes to subsurface saturated zone flow. Application of the Topographic Wetness Index (TWI; see below) allows the water table position to be determined. When rain falls on saturated soil no groundwater recharge is possible and the resultant OLF is routed to the channel network. Saturated zone flow is modelled according to two main assumptions (Beven, 1997 p.1071):

1. "The dynamics of the water table can be approximated by uniform subsurface runoff production per unit area over the area, *a*, draining to a point."
2. "The hydraulic gradient of the saturated zone can be approximated by the local surface topographic slope, tan *β*."

To simplify reality TOPMODEL also assumes that the soil transmissivity is uniform across the catchment; However, in peatlands saturation-excess OLF dominates but there can also be some preferential subsurface flow (Holden and Burt, 2003a, 2003c).

The recognition that all hydrographs have a shape characterised by a steep rising limb followed by a gentler recessional limb allows the use of only five main parameters (Table A4.1; Kirkby, 1997).

Table A4.1: The TOPMODEL parameters (Beven, 1998).

TOPMODEL parameter	Description and units
m	The exponential transmissivity function or recession curve (units of depth, m).
$ln(T_0)$	The natural logarithm of the effective transmissivity of the soil when just saturated (units of $m^2\ h^{-1}$).
SR_{max}	The soil profile storage available for transpiration (units of depth, m).
SR_{init}	The initial storage deficit in the root zone (units of depth, m).
Ch_{Vel}	An effective surface routing velocity for scaling the distance/area or network width function (units of $m\ h^{-1}$).

The TWI (*an index of hydrological similarity*; Kirkby and Weyman, 1974) is used to quantify topographic control on hydrological processes (Sorensen *et al*., 2006) by providing an estimate of flow accumulation at any point in the catchment (Quinn *et al*., 1995) and is given by:

$$\mathbf{TWI} = \ln\left(\frac{a}{\tan\beta}\right)$$

where *a* = the local upslope area draining through a certain point per unit contour length and tan *β* = the local slope acting on a cell. The exploitation of the TWI by TOPMODEL dictates that calculations need only be performed for values of the TWI within the study catchment's distribution rather than for each individual point (Beven, 1997; Quinn *et al*., 1995). Areas with a high TWI will saturate quickest and have a greater propensity to contribute runoff (Sorensen and Seibert, 2007). A term is sometimes included in the TWI equation that represents the lateral transmissivity of the soil when the profile is saturated; however, it has been demonstrated that topography is considerably more important than any potential heterogeneity in soil transmissivity across the catchment and this term can commonly be disregarded (Wood *et al*., 1990).

2. Topographic data pre-processing

A 5 m resolution Digital Terrain Model (DTM) was used for each study site. The elevation data has a vertical accuracy root mean square error (RMSE) of 1.0 m. Although debate concerning the optimum resolution of elevation data for hydrological applications continues (e.g. Lane *et al*., 2004; Kienzle, 2004; Wu *et al*., 2007; Dixon and Earls, 2009), the DTM data was resampled to a resolution of 10 m. Through comparison to 90, 30, 4 and 2 m resolution grids, a resolution of 10 m has proven to be a suitable compromise between the computational demands associated with data volume and the acceptable simulation of hydrologic processes in many landscapes (Zhang and Montgomery, 1994). Resampling techniques employing bilinear interpolation can introduce systematic error, reducing the elevation of peaks and ridges while raising valley floors (Becek, 2009); an alternative nearest-neighbour algorithm in ArcInfo was employed.

Topographic depression removal from digital elevation models (DEMs) is crucial in hydrological modelling approaches that rely on continuous flow routing to a pour point (Burrough and McDonnell, 1998). Traditionally, depressions have either been filled (e.g. Planchon and Darboux, 2001; Jenson and Domingue, 1988) or breached (e.g. Rieger, 1998), often with significant impacts on the base DEM (Lindsay and Creed, 2005a). The *Impact Reduction Approach* module was implemented in *Terrain Analysis System* GIS (TAS GIS version 2.0.9; Lindsay, 2005). The module minimises DEM modification by selectively employing filling and breaching algorithms to ensure a continuous flow path from watershed to catchment outlet (Lindsay and Creed, 2005a). The approach simultaneously employs the algorithm of Jenson and Domingue (1988) to force drainage over flat areas. However, in considering all depressions to be data artefacts and undertaking their systematic removal, actual topographic depressions are removed from the data. Past justifications of blanket depression removal include low DEM resolution and accuracy relative to the size and depth of depressions respectively, and the relative frequencies of actual (low frequency) and artefact (high frequency) depressions. Recent application of high resolution topographic data renders these justifications less relevant (Lindsay and Creed, 2006).

Although Wechsler (2007) argues that the RMSE is insufficient to effectively communicate a DEM's accuracy it is the only error value quoted for the *NEXTMap® Britain* DTM. A stochastic simulation modelling (SSM) approach (Lindsay and Creed, 2006) was used to identify cells that are likely to represent actual topographic depressions based on the Monte Carlo application of a DTM error model. The error distributions used in the SSM had a mean of zero, a standard deviation of 1.0 m, reflecting the DTMs' RMSE, and a low degree of autocorrelation[1]. Although not infallible, the method is attractive, particularly where ground validation is impossible (Lindsay and Creed, 2005b; Lindsay and Creed, 2006). The Peak District and Migneint simulations ended after 308 and 334 iterations respectively, beyond which the differences between consecutive iterations were minor (RMS difference between iterations ≤ 0.001). The SSM output details the probability that a cell belongs to a depression (p_{dep}). An arbitrary threshold of 0.7 was set to identify actual depressions ($p_{dep} \geq 0.7$) where the topographic variation (signal) is greater than the elevation uncertainty (noise; Table A4.2; Lindsay and Creed, 2006). It must be acknowledged that the resampling procedure, necessary for computational speed, may have introduced further uncertainty, altering the data's error distribution.

Table A4.2: Outputs of stochastic simulation modelling (SSM) to identify those cells with a high likelihood of representing actual topographic depressions based on the application of an elevation data error model using the *Stochastic Shape Analysis* module in *Terrain Analysis System* (TAS) GIS (Lindsay, 2005; Lindsay and Creed, 2006). The 'traditional method' of identifying sinks utilises the *Find Depressions* module in TAS GIS which is based on the sink filling algorithm of Planchon and Darboux (2001).

	% of DEM cells identified as depressions by traditional means	% DEM cells identified as actual topographic depressions using the SSM approach	% DEM cells identified as actual topographic depressions using the SSM approach that are not identified by traditional means	% of cells identified as depressions by traditional means that are also identified as actual topographic depressions using the SSM approach
Migneint	2.18	1.56	0.05	69.68
Peak District	2.76	1.85	0.04	65.70

In conjunction with coordinates of Environment Agency (EA) flow gauges the FLOWDIRECTION, FLOWACCUMULATION, SNAPPOUR and WATERSHED ArcInfo functions were used to delineate gauged catchments within the hydrologically corrected DEMs. A polygon coverage was generated for each catchment using the SELECT and GRIDPOLY functions. The GRIDCLIP command was used to extract elevation data for each catchment defined by the generated coverages.

3. The Topographic Wetness Index

The intention to implement the TOPMODEL module in *System for Automated Geoscientific Analyses* GIS (SAGA GIS version 2.0.3; Conrad, 2006) encouraged the use of the *Wetness Index* module. Although digital elevation data allows automated calculation of the TWI it raises further questions regarding the optimum resolution of gridded data (Quinn *et al.*, 1995; Lane *et al.*, 2004; Sorensen and Seibert, 2007; Wu *et al.*, 2007) and the algorithms used (Sorensen *et al.*, 2006), especially in calculating the upslope contributing area from various slope, aspect and flow direction algorithms prescriptively applied by different GIS packages (Wechsler, 2007). The *Wetness Index* module in SAGA calculates the upslope contributing area using a

[1] The *Stochastic Shape Analysis* module is optimised to run with a 'low' degree of spatial autocorrelation.

multiple flow direction algorithm (Freeman, 1991); slope is calculated using a Fit 2 Degree Polynomial (Zevenbergen and Thorne, 1987; Wichmann, 2008). A number of researchers (Chairat and Delleur, 1993; Wolock and Price, 1994; Zhang and Montgomery, 1994) have focused on the implications of DEM resolution on the TWI, fundamental to the application of TOPMODEL (Wilson and Gallant, 2000). The TWI distribution is influenced since the DEM resolution impinges on both upslope contributing area and the local surface slope. A 10 m DEM is a suitable compromise (Zhang and Montgomery, 1994).

4. Evapotranspiration data
Reference evapotranspiration, ET_o, was calculated according to the Penman-Monteith method presented by Allen *et al*. (1998). Daily temperature and hourly wind speed data were used. The variables required to calculate daily ET_o estimates were calculated using the method of Allen *et al*. (1998). Due to data structure, temperature measurement periods often run from 21:00 to 21:00 rather than from midnight to midnight; wind measurement periods run from 23:00 to 23:00.

5. Land cover determination for overland flow calculations and resampling to 1 km
Tables A4.3 and A4.4 present reclassification considerations for the case study sites to fit the overland flow data model while Figures A4.1 to A4.5 present catchment land cover detail as referred to in the main section of the report.

10 m DEMs were extracted for each study site and resampled to a resolution of 1 km using bilinear interpolation, and rescaled to a 0-255 scale in such a way as to not change the rasters' distributions (ESRI, 2006). The same extraction, resampling and rescaling procedure was undertaken on the TWI rasters generated in SAGA. Slope rasters generated from the extracted DEMs using the *Spatial Analyst Slope* tool in ArcMap were similarly resampled and rescaled. The LCM2000 datasets used in these small cartographic scale analyses differ in accordance to the coverage of the available data. In the Migneint the rasterized Level 2 vector data used previously was reclassified to equivalent average OLF velocities. In the Peak District, the entire extent of which was not encompased by the available Level 2 vector data, the 25 m raster dataset was reclassified to equivalent average OLF velocities. Both Peak District and Migneint datasets were resampled to a 1 km resolution using a nearest neighbour assignment to ensure that discreet values in the datasets endured the resampling process. The resampled datasets were rescaled to a 0-255 scale (ESRI, 2006). The elevation, slope, TWI and LCM2000 derived OLF velocity MCE factors were combined through weighted linear sumation. The MCE output rasters were ranked and reclassified into bands with equal frequencies.

6. Topmodel calibration
A series of storms between 19/12/2007 00:00:00 and 04/01/2008 00:00:00 were identified for initial TOPMODEL calibration in the Cynefail catchment. The catchment averaged OLF routing velocity was converted to m h^{-1} to allow use in the module. Rainfall and evapotranspiration data at Lake Vyrnwy were used (Figure A4.7) since the gauge's elevation is within the elevation range of the Cynefail catchment. A review of parameter sets used for modelling different catchments (Table 8; Beven, 1997) was used to determine appropriate parameter ranges for TOPMODEL calibration in the Cynefail catchment. The calibrated parameters are shown in Table A4.5. Metteorological data from Woodford was used in the modelling of the Tunstead House catchment (24/09/08 00:00 – 13/10/08 15:00) while that from the Leek: Thornecliffe station was used in the modelling of the Hollinsclough catchment (31/08/08 00:00 – 23/09/08 00:00; Figure A4.7). The TOPMODEL module was calibrated for each catchment; however, disappointment in the module's ability to predict the observed hydrograph, despite calibration, led to the implementation of a version of TOPMODEL that partitions the catchment into two distinct areas, each with a different *m* value (Kirkby, 1997).

Table A4.3: Rudimentary reclassification of the LCM2000 Level 2 subclasses in the Cynefail catchment to analogous land cover classifications examined by Holden *et al*. (2008). If land with an LCM2000 land classification of '121 Bog' existed in the Cynefail catchment it would be reclassified to the '*Sphagnum*' Holden *et al*. (2008) classification. In the Cynefail catchment '91 Bracken' was reclassified to 'Eripohorum' since its spatial coverage is minimal. Similarly, '131 Water (inland)' was reclassified to the 'Bare' Holden *et al*. (2008) classification. Heather poses the most significant problem since this land cover was not examined during the OLF velocity experiments of Holden *et al*. (2008). The mean OLF velocities quoted were determined at a range of discharges over a range of slopes characteristic of UK peat uplands (Holden *et al*., 2008).

LCM2000 Level 2 subclass	Cynefail catchment coverage (%)	Hollinsclough catchment coverage (%)	Tunstead House catchment coverage (%)	Analogous Holden *et al.* (2008) land cover classification	Mean OLF velocity ($m\ s^{-1}$)
61 Neutral grass	34.2%	33.6%	21.3%	*Eriophorum*	0.03376
81 Acid grass	37.9%	27.4%	47.3%	*Eriophorum-Sphagnum* mix	0.01798
91 Bracken	0.6%	15.8%	0.7%	?	?
101 Dwarf shrub heath	18.5%	0.1%	1.7%	Heather	0.04 ?
102 Dwarf shrub heath	7.3%	4.8%	6.6%	Heather	0.04 ?
131 Water (inland)	1.2%	0.2%	0.0%	?	?
161 Inland bare ground	0.3%	1.6%	1.5%	Bare	0.04959

Table A4.4: Rudimentary raster reclassification of additional LCM2000 Level 2 subclasses in the Hollinsclough and Tunstead House catchments to analogous land cover classifications examined by Holden *et al*. (2008).

LCM2000 Level 2 subclass	Hollinsclough catchment coverage (%)	Tunstead House catchment coverage (%)	Analogous Holden *et al*. (2008) land cover classification	Mean OLF velocity ($m\ s^{-1}$)
11 Broad-leaved woodland	0.1%	1.5%	? (faster than *Eriophorum*; slower than Bare)	0.04 ?
21 Coniferous woodland	0.2%	0.0%	? (faster than *Eriophorum*; slower than Bare)	0.04 ?
42 Arable horticulture	0.0%	0.2%	? (faster than *Eriophorum*; slower than Bare)	0.04 ?
51 Improved grassland	3.0%	14.9%	*Eriophorum*	0.03376
71 Calcareous grass	13.2%	0.0%	*Eriophorum*	0.03376
121 Bog	0.0%	3.8%	*Sphagnum*	0.01490
171 Suburban/rural development	0.0%	0.6%	Bare	0.04959

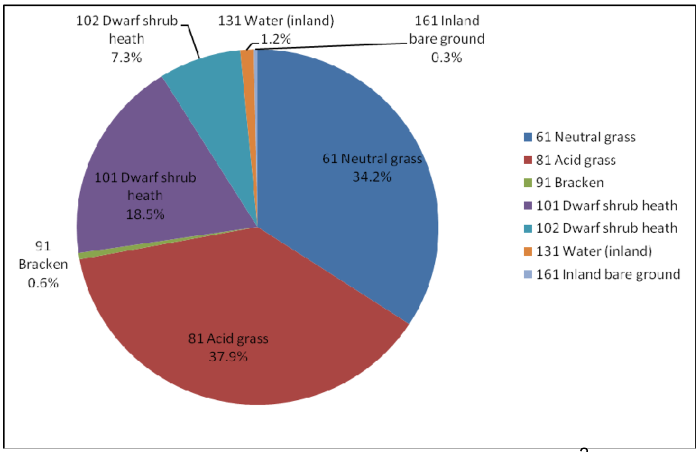


Figure A4.1: The LCM2000 Level 2 subclass composition of the 12.7 km^2 catchment of the Afon Gelyn that drains to the EA gauge at Cynefail (SH84254205).

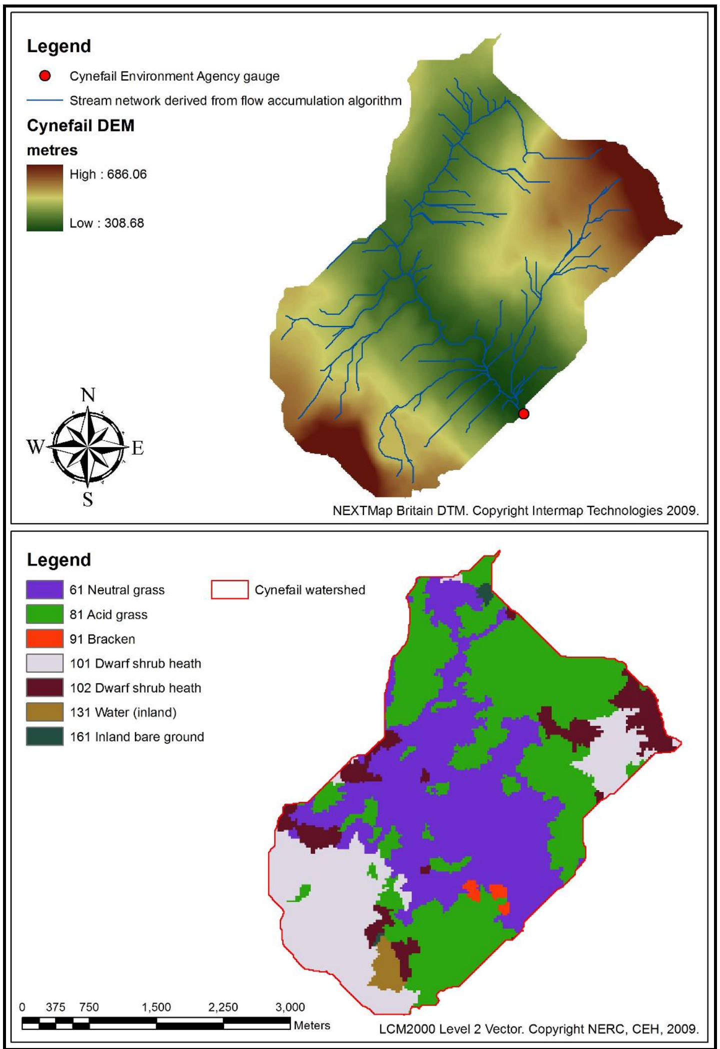


Figure A1.2: A DEM of the 12.7 km^2 delineated catchment of the Afon Gelyn that drains to the EA gauge at Cynefail (SH84254205). The DEM is overlaid with a stream network coverage derived from the ArcInfo FLOWACCUMULATION function using a conditional threshold of 350 upslope cells and the STREAMLINE function. The distribution of LCM2000 Level 2 subclasses in the catchment is shown.

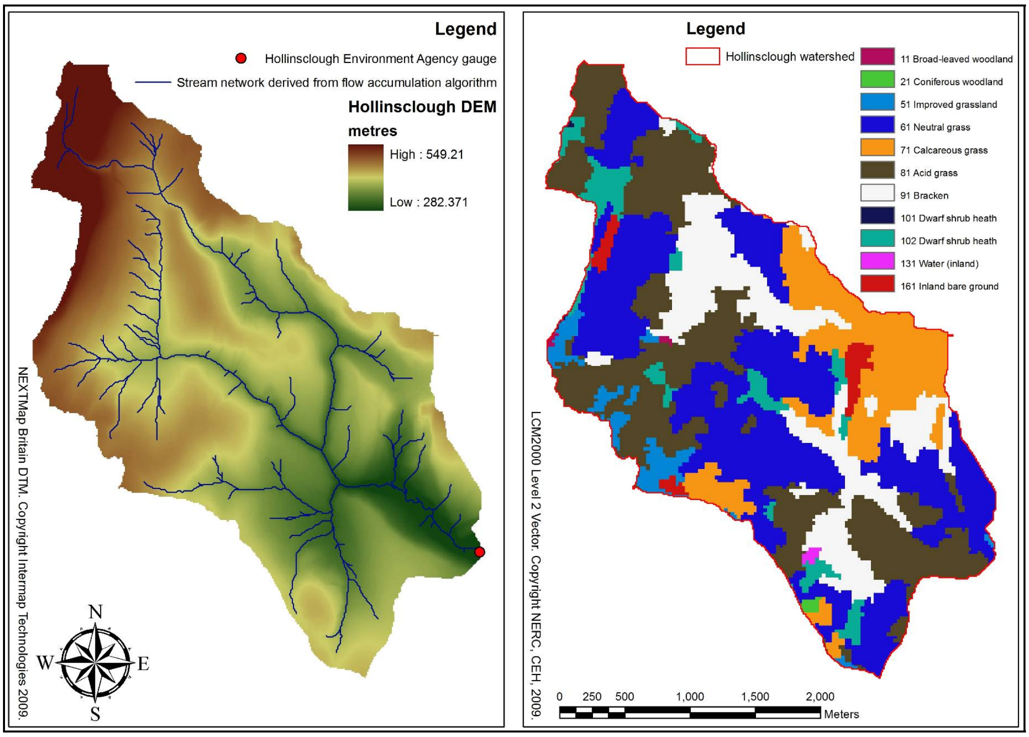


Figure A4.3: A DEM of the 8.1 km^2 delineated catchment of the River Dove that drains to the EA gauge at Hollinsclough (SK06326684). The DEM is overlaid with a stream network coverage derived from the ArcInfo FLOWACCUMULATION function using a conditional threshold of 350 upslope cells and the STREAMLINE function. The distribution of LCM2000 Level 2 subclasses in the catchment is shown.

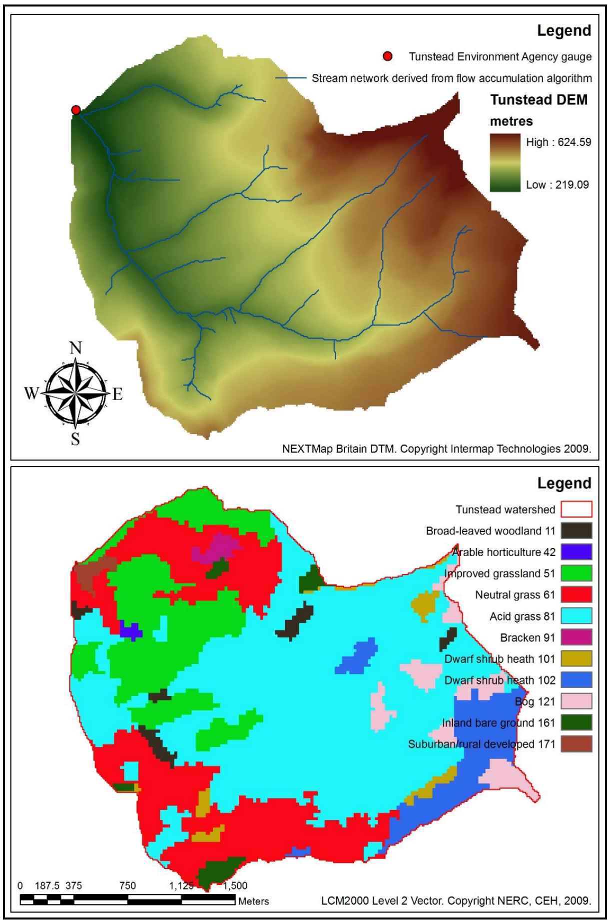


Figure A4.4: A DEM of the 5.9 km^2 delineated catchment of the River Sett that drains to the EA gauge at Tunstead House (SK05178678). The DEM is overlaid with a stream network coverage derived from the ArcInfo FLOWACCUMULATION function using a conditional threshold of 350 upslope cells and the STREAMLINE function. The distribution of LCM2000 Level 2 subclasses in the catchment is shown

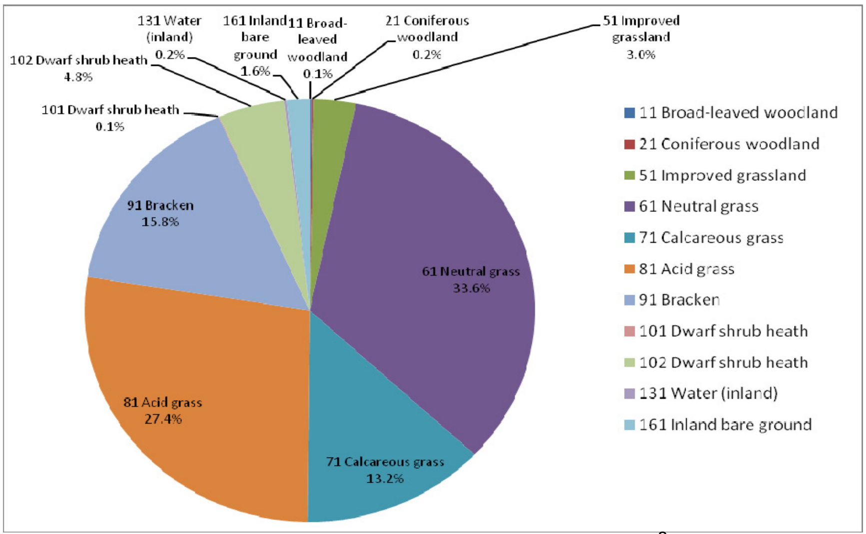


Figure A4.5: The LCM2000 Level 2 subclass composition of the 8.1 km^2 catchment of the River Dove that drains to the EA gauge at Hollinsclough (SK06326684).

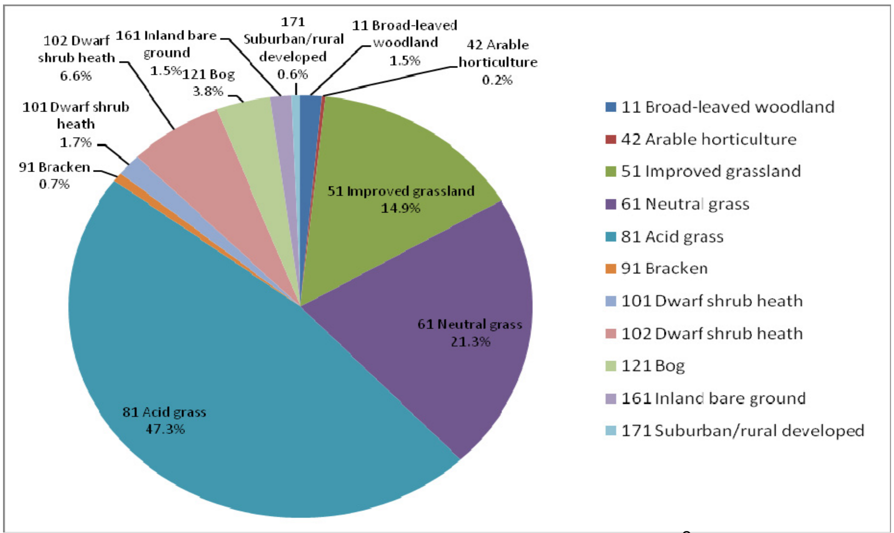


Figure A4.6: The LCM2000 Level 2 subclass composition of the 5.9 km^2 catchment of the River Sett that drains to the EA gauge at Tunstead House (SK05178678).

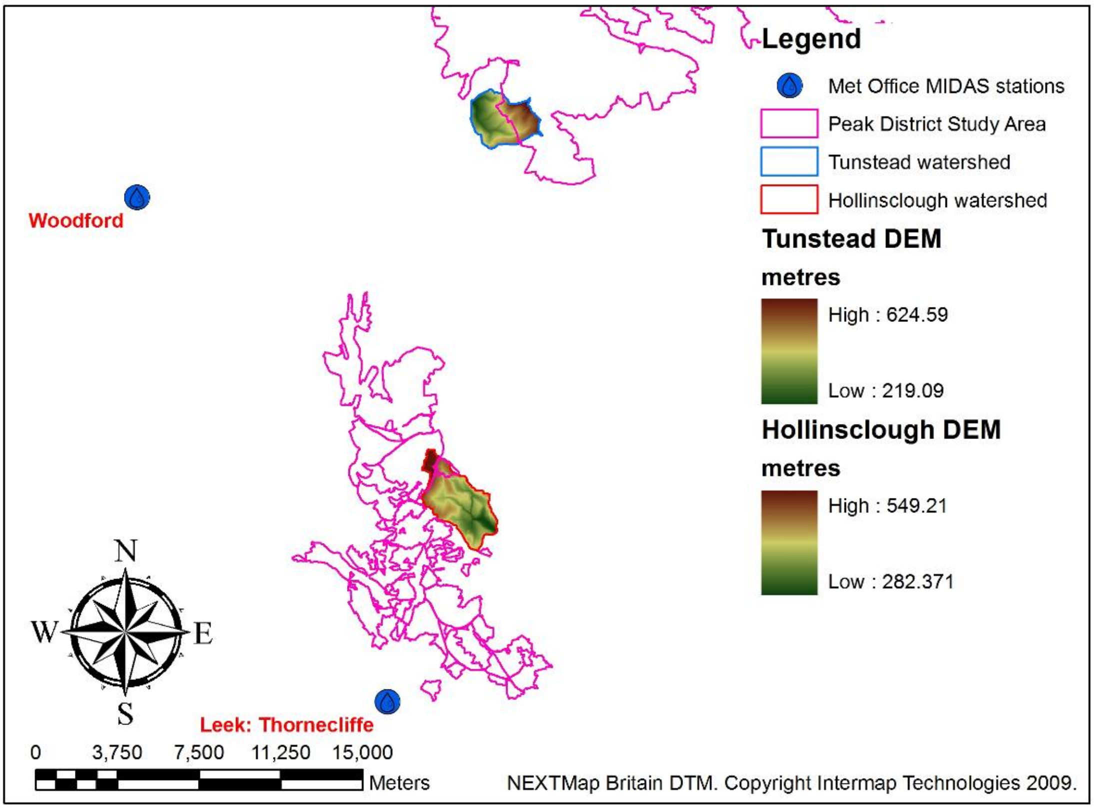
Table A4.5: Model parameters in the SAGA *TOPMODEL* module and the calibrated parameter values used to model the response of the Cynefail catchment during the period 19/12/2007 00:00:00 to 04/01/2008 00:00:00.

TOPMODEL module parameter	Units	Calibrated parameter values
Initial subsurface flow per unit area	m h^{-1}	0.000044
Areal average of *ln*(T$_0$)	m^2 h^{-1}	1.0
Model parameter *m*	m	0.003
SR$_{init}$ Initial root zone storage deficit	m	0
SR$_{max}$ Maximum root zone storage deficit	m	0.0001
Unsaturated zone time delay per unit storage deficit (h)	h	5
Main channel routing velocity	m h^{-1}	6000
Internal subcatchment routing velocity	m h^{-1}	106.7
Surface hydraulic conductivity	m h^{-1}	1
Wetting front suction	m	0.02
Water content change across the wetting front		0.1

Table A4.6: TOPMODEL parameters ordered by catchment area (adapted from Beven, 1997). The parameters used by Lane *et al*. (2004) are included because the Oughtershaw Beck study site is a peatland catchment of similar size and elevation to the Cynefail catchment. For references see Beven (1997).

Catchment	Area (km^2)	DTM Δx (m)	λ	m (m)	T_0 (m^2/h)	Reference	Comment
Gardsjön G1, Sweden	0·0063	5	5·1		1·8	Seibert *et al.*, 1997	$f = 13\ m^{-1}$, variable $\Delta\theta$
Saeternbekken MINIFELT, Norway	0·0075	2	5·0	0·0053	1·31	Lamb, 1996	
ECEREX B, French Guiana	0·015	2·5	5·62	0·0035	7	Molicova *et al.*, 1997	
Ringelbach, France	0·34	5	5·942	0·041	2·75	Ambroise *et al.*, 1996b	Parameters for exponential transmissivity function version
Alloux, Switzerland	0·036	10	6·9	0·022	2·18	Iorgulescu and Jordan, 1994	
Cal Parisa, Spain	0·36	15	6·21	0·0112	0·338	Gallart *et al.*, 1994	T_0 derived from $Q_0 = T_0 \exp(-\lambda)$
La Teula, Catalonia, Spain	0·385			0·1	78·94	Piñol *et al.*, 1997	Best of several different versions
L'Avic, Catalonia, Spain	0·516			0·099	78·76	Piñol *et al.*, 1997	Best of several different versions
Mahatango Creek WD38, PA, USA	0·64	30	4·37	0·016	1·39	Troch *et al.*, 1993	T_0 derived from effective conductivity and soil depth; m from effective porosity and f
Slapton Wood, UK	1	10	7·87	0·004–0·25	0·01–30	Fisher and Beven, 1996	Parameter ranges used in Monte Carlo experiments
Corbassière, Switzerland	1·85	10	7·4	0·031	0·64	Iorgulescu and Jordan, 1994	
Imnavit Creek, Alaska	2·1	20	6·74	0·003	6	Ostendorf, 1996; Ostendorf *et al.*, 1996	
Hafren, Wales	3·4	50	6·8	0·013–0·018	3–50†	Robson *et al.*, 1992;	Different parameter values for different calibration periods
Sleepers River, W3, VT, USA	3·9	30–90	6·56–8·41	0·05–0·060	0·0009–0·0038	Wolock and McCabe, 1995	Different parameters derived from different DTM grid sizes and analysis algorithms; T_0 derived from $Q_0 = T_0 \exp(-\lambda)$
Lehstenbach, Germany	4·2	10	8·29	0–0·01	0–2·0	Ostendorf and Mandershied, 1997	Parameter ranges used in Monte Carlo experiments
White Oak Run, VA, USA	5	*	5·32	0·0104	0·0012	Beven and Wood, 1983	T_0 derived from $Q_0 = T_0 \exp(-\lambda)$
White Oak Run, VA, USA	5	30	6·04–6·08	0·027	0·0007–0·0012	Wolock and McCabe, 1995	Different parameters derived from different DTM grid sizes and analysis algorithms; T_0 derived from $Q_0 = T_0 \exp(-\lambda)$
Kirkton, Balquhidder, UK	6·85	100	7·78	0·018 (0·020)	0·97 (0·97)	Robson *et al.*, 1993	$f = 5{\cdot}5\ (5{\cdot}5)\ m^{-1}$, values in brackets for calibration to different period
Monachyle, Balquhidder, UK	7·70	100	7·7	0·008 (0·021)	0·89 (0·42)	Robson *et al.*, 1993	$f = 12{\cdot}6(4{\cdot}86)\ m^{-1}$, values in brackets for calibration to different period after deforestation
Mahatango Creek WE38, USA	7·2	30	4·03	0·016	0·76	Troch *et al.*, 1993	T_0 derived from effective conductivity and soil depth; m from effective porosity and f
Crimple Beck, UK	8	*	6·9–8·1	0·00126–0·0033		Beven and Kirkby, 1979; Beven *et al.*, 1984	Using multiple subcatchment representation
Crimple Beck, UK	8	*	7·73	0·0067	1·197	Beven and Wood, 1983	T_0 derived from $Q_0 = T_0 \exp(-\lambda)$
Maurets, France	8·4	20–120	6·18–7·69	0·025–0·027	2·05–21·37	Saulnier *et al.*, 1997	For different DTM grid sizes including river pixels in $\ln(a/\tan/\beta)$ distribution
Maurets, France	8·4	20–120	6·40–6·96	0·025	1·05–1·5	Saulnier *et al.*, 1997	For different DTM grid sizes after excluding river pixels from $\ln(a/\tan\beta)$ distribution
Wye, UK	10·5	*	5·7–6·6	0·0114–0·0216		Beven *et al.*, 1984	Using multiple subcatchment representation
Wye, UK	10·5	50	7·6	0·0093	8·27	Quinn and Beven, 1993	
Wye, UK	10·5	10–100	5·0–9·8	0·0093	0·223–27·11	Quinn *et al.*, 1995	Different parameters derived from different DTM grid sizes
Coet Dan, France	12	30–100		0·027	400–2200	Bruneau *et al.*, 1995	Different parameters derived from different DTM grid sizes
Turbolo Creek, Italy		30	7·03	0·007	2·41	Mendicino and Sole, 1997	
Oughtershaw Beck, UK	13.8			0.003	1.0	Lane et al., 2004	
Jalovecky Creek, Slovakia	23·1			0·021	1·73	Holko and Lepisto, 1997	
Hodge Beck, UK	36	*	4·5–7·8	0·0095–0·0338		Beven *et al.*, 1984	Using multiple subcatchment representation
Réal Collobrier, France	70	60	7·31	0·017	1765	Obled *et al.*, 1994	Using constant velocity channel routing
Réal Collobrier, France	70	60	7·31	0·038	52·6	Obled *et al.*, 1994	Using calibrated gamma function channel routing
Davidson, NC, USA	105	*	6·58	0·0344	0·504	Beven and Wood, 1983	T_0 derived from $Q_0 = T_0 \exp(-\lambda)$
North Fork Rivanna, VA, USA	456	*	7·64	0·0092	11·75	Beven and Wood, 1983	T_0 derived from $Q_0 = T_0 \exp(-\lambda)$

* Manual terrain analysis from contour data
† Upper limit of range included



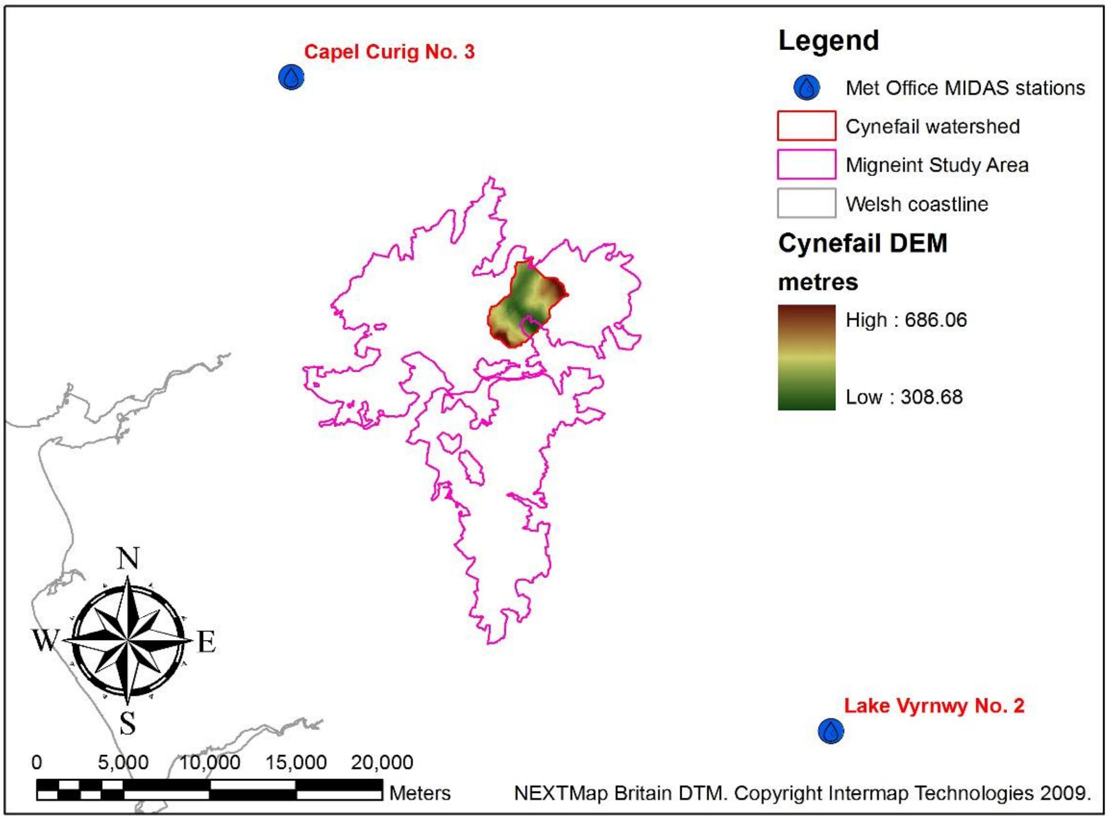


Figure A4.7: Location of the Lake Vyrnwy No. 2, Capel Curig No. 3, Woodford and Leek: Thornecliffe Met Office MIDAS station relative to the Cynefail, Hollinsclough and Tunstead House catchments.

Table A4.7: Catchment averaged overland flow velocities and catchment areas exhibiting a rapid response for each of the re-establishment and management scenarios. The nature by which the proportion of the catchment exhibiting a rapid response is established from reclassification of the LCM2000 Level 2 vector data dictates that Scenario 4 is identical to Scenario 3 in the Hollinsclough and Tunstead House catchments while in the Cynefail catchment both Scenarios 4 and 5 are identical to Scenario 3.

Scenario	Catchment averaged OLF velocity ($m\ s^{-1}$)			Area of catchment exhibiting a rapid response (%)		
	Hollinsclough	Tunstead House	Cynefail	Hollinsclough	Tunstead House	Cynefail
Present	0.03004	0.02655	0.02964	9.9	27.0	27.3
1	0.01490	0.01490	0.01490	0.0	0.0	0.0
2	0.04959	0.04959	0.04959	100.0	100.0	100.0
3	0.02942	0.02582	0.02910	8.1	24.9	25.8
4	0.02900	0.02509	0.02852			
5	0.02381	0.02218	0.02578	6.6	17.5	
6	0.02365	0.02187	0.02497	4.2	14.5	12.9
7	0.02372	0.02200	0.02529	5.2	15.7	18.1

7. Results from hydrograph calibration

The Nash-Sutcliffe (1970) coefficient (E) and the mean absolute error (MAE) were used to quantify model efficiencies. E can range from negative ∞ to 1. A Nash-Sutcliffe coefficient of 1 indicates a perfect model; a value of 0 indicates the model predictions are only as good as the mean observation. A negative value indicates that the simulation offers a worse prediction than the mean observation.

The calibrated hydrographs for Cynefail, Hollinsclough and Tunstead House catchments, using both the SAGA *TOPMODEL* module and the partitioned catchment approach, with and without the application of the meteorological adjustments, are shown in Figures A4.8, A4.9 and A4.10. Catchment information, model statistics and meteorological data adjustment factors are shown in Table A4.8.

In the Cynefail catchment (Figure A4.8), calibration of the TOPMODEL parameters in the SAGA module away from those used by Lane *et al*. (2004) commonly resulted in a reduction in model efficiency. The reasonable simulation provided by the parameter set can perhaps be attributed to the Oughtershaw Beck catchment also being composed of peat soils and having a similar area and elevation range to those at Cynefail; however, it has been identified that shrub species, such as *Calluna* (heather), are rare in the Oughtershaw Beck catchment (Holden *et al*., 2008). Although the modelled discharge peaks are similar in timing to the observed hydrograph, a systematic underestimation of the larger peaks is evident. The relatively low m parameter value of 3 mm is a reflection of attempts to generate a flashy runoff response to rainfall; however, there is a trade-off in that the recessional limbs fall away too steeply.

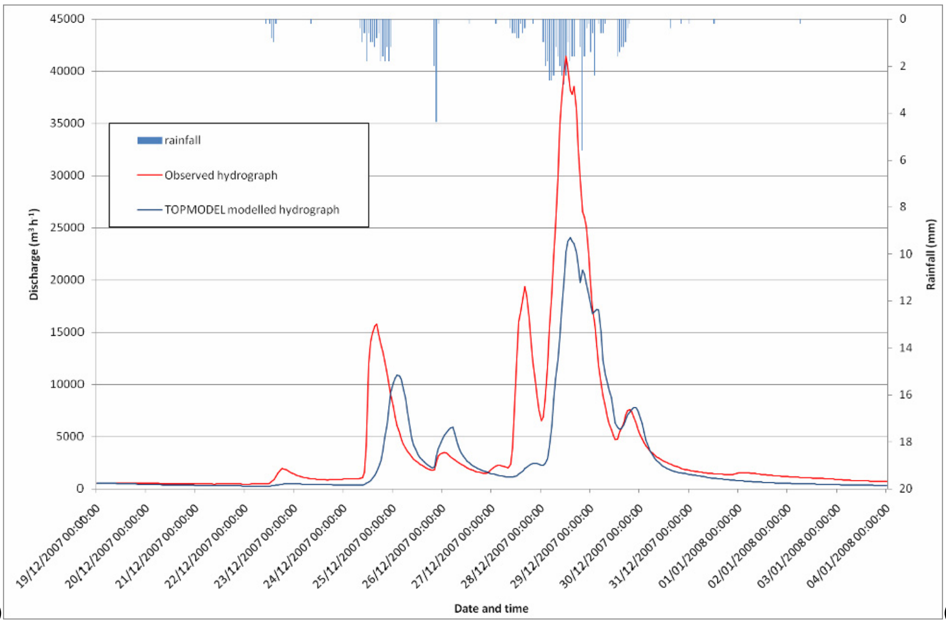
It was in response to this issue that the partitioned catchment approach described above was explored. The efficiency of the simulation achieved using the partitioned catchment approach without adjusting the meteorological data (Figure A4.8b) is lower than the initial SAGA module approach according to the Nash-Sutcliffe coefficients (Table A4.8); however, the technique allows the fit of the recessional limbs to be tuned more effectively. The adjustments made to the meteorological data, a reflection of the distant rain gauge and its elevation in the lower bounds of the catchment's elevation range, were designed to simulate peak discharges closer to those observed while improving the modelled efficiency of the receding limbs by decreasing the rate of evapotranspiration (Figure A4.8c). The adjustments increased model efficiency to 0.78. When the adjustments were applied to the initial SAGA calibration improvements were also seen (Figure A4.8d); however, issues relating to the steepness of recessional limbs endured.

The calibration procedure progressed in much the same way for the Hollinsclough catchment (Figure A4.9) with the exception that parameterisation away from the preliminary parameter set of Lane *et al*. (2004) resulted in significant model efficiency improvements. The model statistics (Table A4.8) show that the initial SAGA module calibration produced an efficient simulation (Figure A4.9a). Despite the Nash-Sutcliffe coefficients depicting an improved efficiency using the partitioned catchment approach (Figure A4.9b), the initial SAGA module calibration offers a closer simulation of the observed peak discharge. Application of the adjusted meteorological data to the calibrated SAGA module results in a simulation with a lower efficiency than the original SAGA calibration but provides a marginally improved estimate of the peak discharge (Figure A4.9d).

The parameter set that provided the best simulation in the Tunstead House catchment also differed significantly from that of Lane *et al*. (2004) used in the preliminary model run. Once again the simulation produced by the SAGA *TOPMODEL* module has a tendency to underestimate the observed discharge, with the notable exception of the peak discharge recorded in the calibration period (Figure A.4.10a). Adjustment of the meteorological data saw a marked improvement of the model efficiency achieved using the partitioned catchment approach (Figure A4.10b and c); however, input of the adjusted data into the calibrated SAGA module produced a much less efficient simulation that that originally achieved (Figure A4.10d). Both simulations using the adjusted meteorological data are a trade-off between simulating the flow for the majority of the time and simulating the peak flow. In achieving the quoted efficiency statistics the baseflow and subsidiary peaks are suitably simulated at the expense of significant overestimation of peak flow.

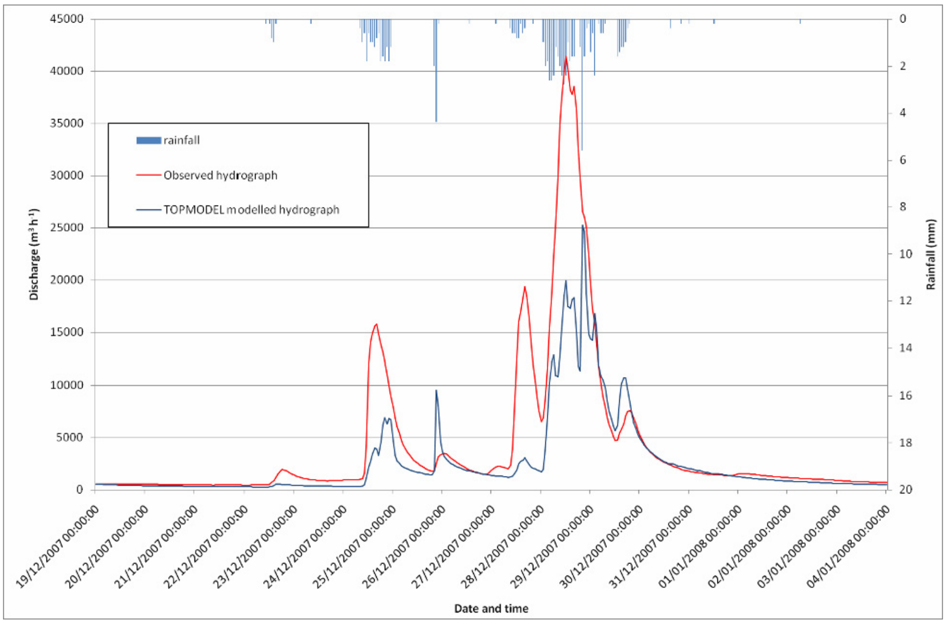
The simulated hydrographs generated for the test storms in each catchment are shown in Figures A4.11, A4.12 and A4.13. There is a systematic underestimation of the observed runoff with the exception of the simulations that apply the meteorological data adjustments in the Tunstead House catchment (Figure A4.13b and d). The model statistics (Table A4.8 iv) reflect the poor model efficiency evident in the hydrographs. Nevertheless, the models offer a suitable simulation of the timing of flows in the catchment. Due to the poor performance of the calibrated parameter sets in simulating the runoff during the test storm periods, the vegetation re-establishment and management scenario exploration was performed using the calibration period data. Although some improvements in model efficiency were observed when adjusted meteorological model inputs were applied, unadjusted data were used in scenario modelling since the adjustment factors did not reflect any quantifiable gauge-catchment differences. Furthermore, since the scenario modelling seeks only to identify changes in runoff regulation relative to the current situation, it is acceptable that a definitive model for each catchment, capable of simulating absolute observed values, has not been achieved.

(a)

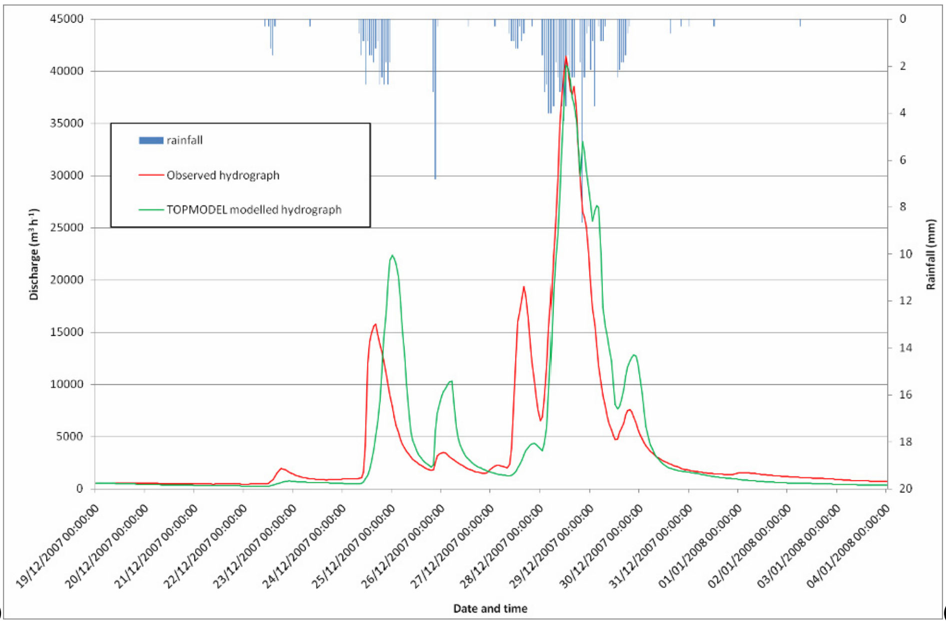


rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
Discharge (m³ h⁻¹)
Rainfall (mm)
Date and time

(b)



rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
Discharge (m³ h⁻¹)
Rainfall (mm)
Date and time



(d) (c)

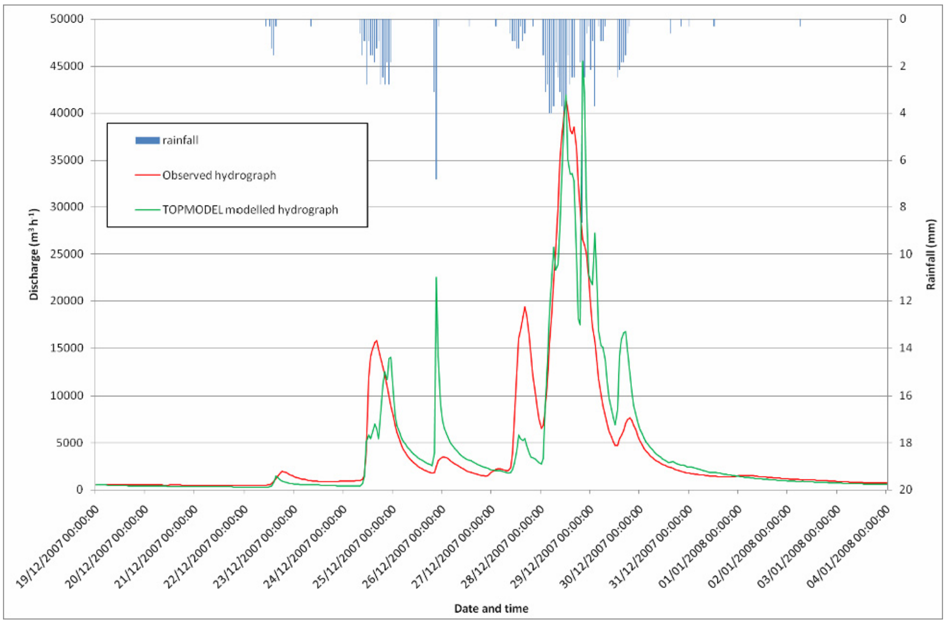
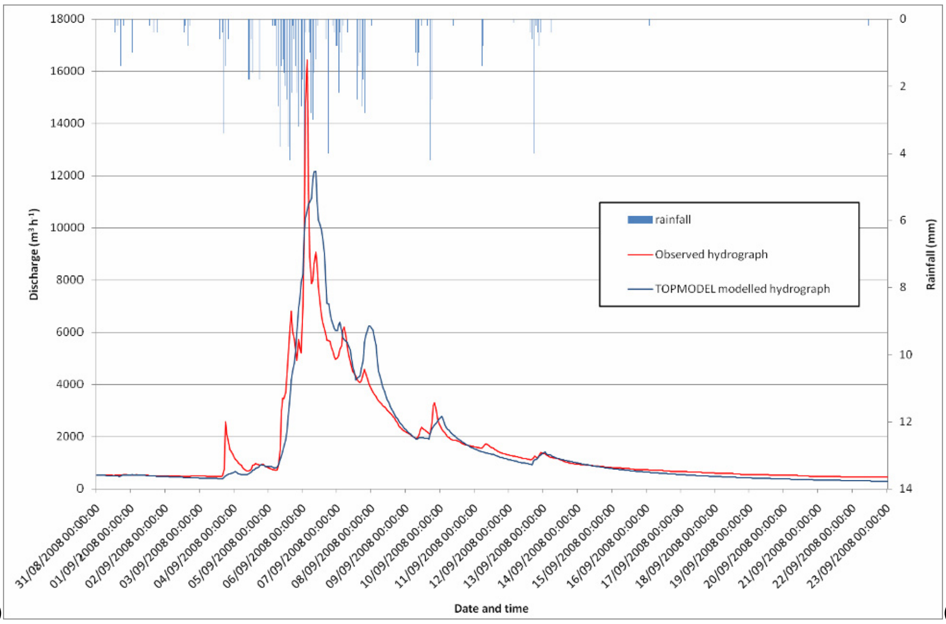
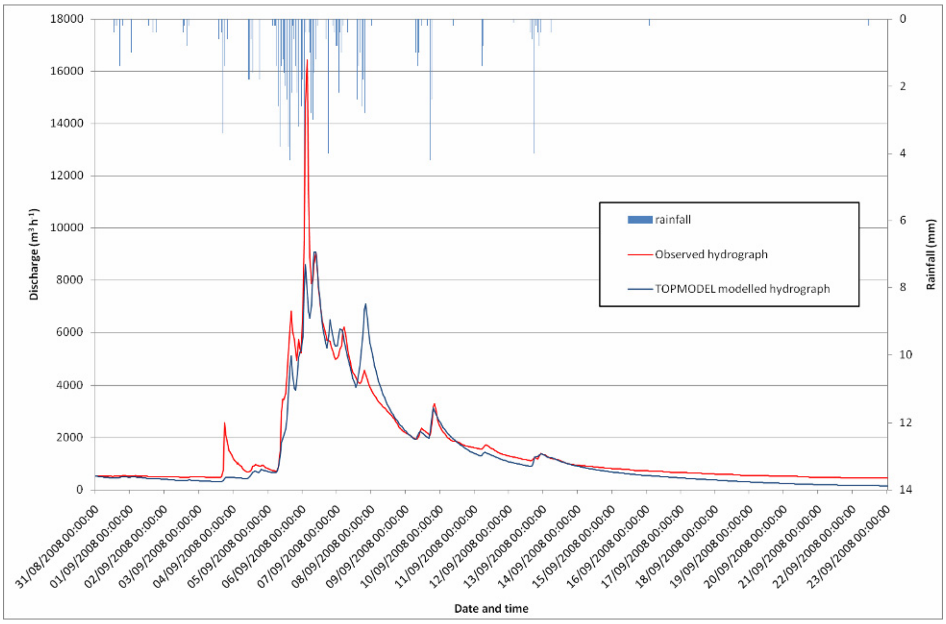


Figure A4.8: Calibrated TOPMODEL modelled hydrographs for the Cynefail catchment for the period 19/12/07 00:00 to 04/01/08 00:00. Clockwise from top-left the modelled hydrographs are generated using (a) the SAGA *TOPMODEL* module, (b) the partitioned catchment approach advocated by Kirkby (1997), (c) the partitioned catchment approach but with adjusted meteorological data, and (d) the SAGA *TOPMODEL* module with adjusted meteorological data.

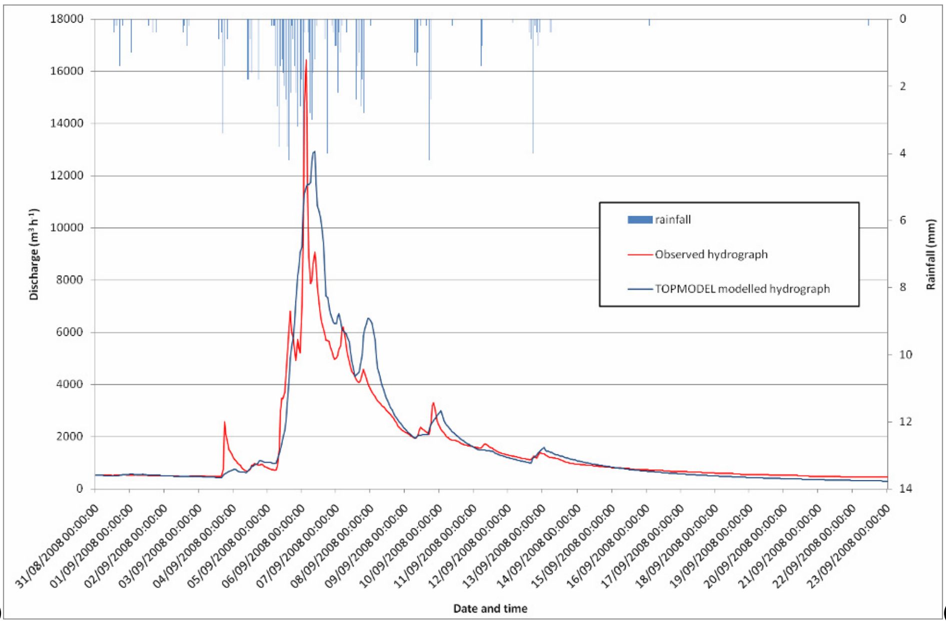


Discharge (m³ h⁻¹)
Rainfall (mm)
rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
Date and time

(a) (b)



Discharge (m³ h⁻¹)
Rainfall (mm)
rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
Date and time



(d) (c)

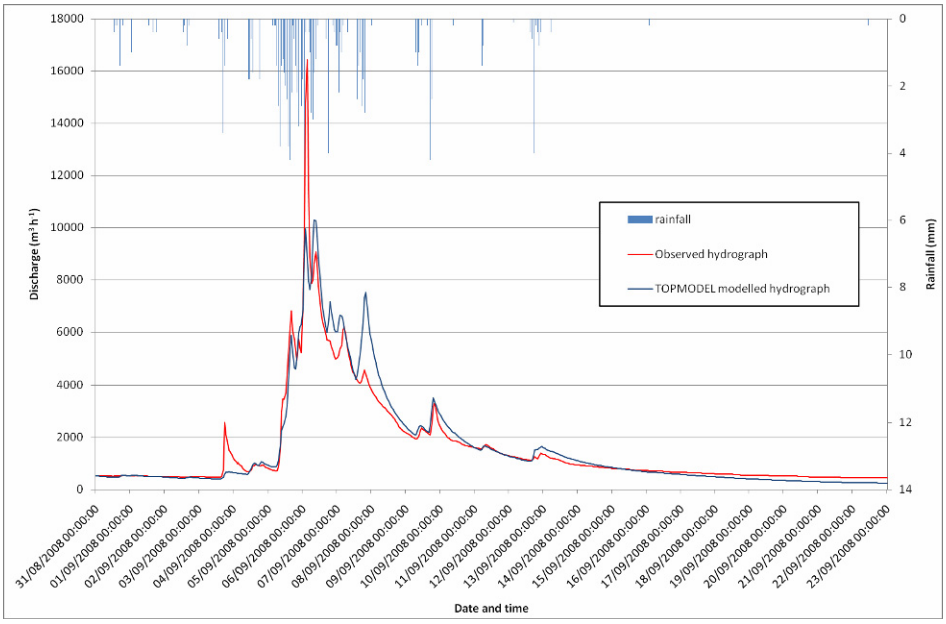
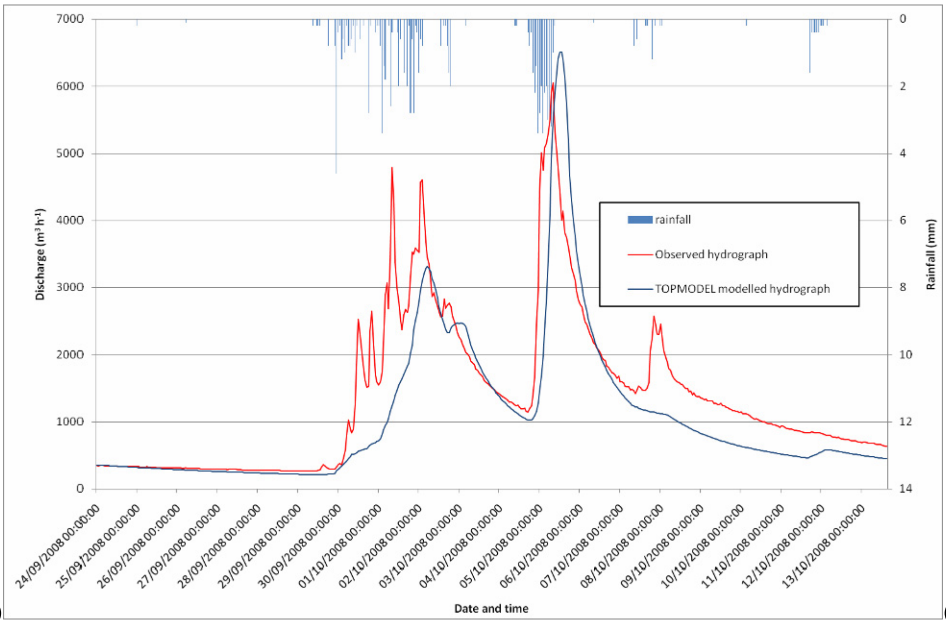
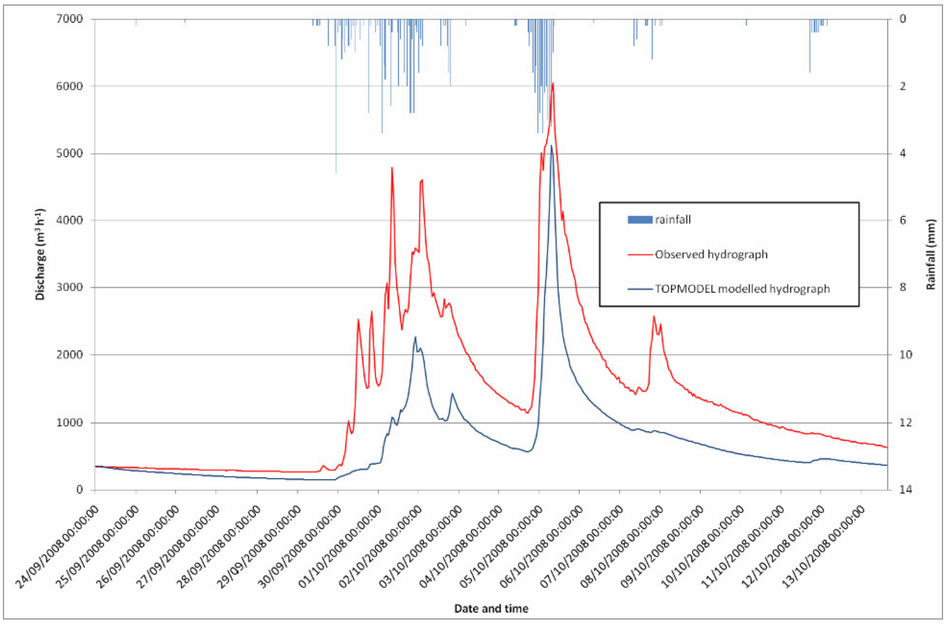


Figure A4.9: Calibrated TOPMODEL modelled hydrographs for the Hollinsclough catchment for the period 31/08/2008 00:00:00 to 23/09/2008 00:00:00. Clockwise from top-left the modelled hydrographs are generated using (a) the SAGA *TOPMODEL* module, (b) the partitioned catchment approach advocated by Kirkby (1997), (c) the partitioned catchment approach but with adjusted meteorological data, and (d) the SAGA *TOPMODEL* module with adjusted meteorological data.



7000
6000
5000
4000
3000
2000
1000
0
Discharge (m³ h⁻¹)
0
2
4
6
8
10
12
14
Rainfall (mm)
rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
24/09/2008 00:00:00
25/09/2008 00:00:00
26/09/2008 00:00:00
27/09/2008 00:00:00
28/09/2008 00:00:00
29/09/2008 00:00:00
30/09/2008 00:00:00
01/10/2008 00:00:00
02/10/2008 00:00:00
03/10/2008 00:00:00
04/10/2008 00:00:00
05/10/2008 00:00:00
06/10/2008 00:00:00
07/10/2008 00:00:00
08/10/2008 00:00:00
09/10/2008 00:00:00
10/10/2008 00:00:00
11/10/2008 00:00:00
12/10/2008 00:00:00
13/10/2008 00:00:00
Date and time

(a) (b)



7000
6000
5000
4000
3000
2000
1000
0
Discharge (m³ h⁻¹)
0
2
4
6
8
10
12
14
Rainfall (mm)
rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
24/09/2008 00:00:00
25/09/2008 00:00:00
26/09/2008 00:00:00
27/09/2008 00:00:00
28/09/2008 00:00:00
29/09/2008 00:00:00
30/09/2008 00:00:00
01/10/2008 00:00:00
02/10/2008 00:00:00
03/10/2008 00:00:00
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09/10/2008 00:00:00
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13/10/2008 00:00:00
Date and time

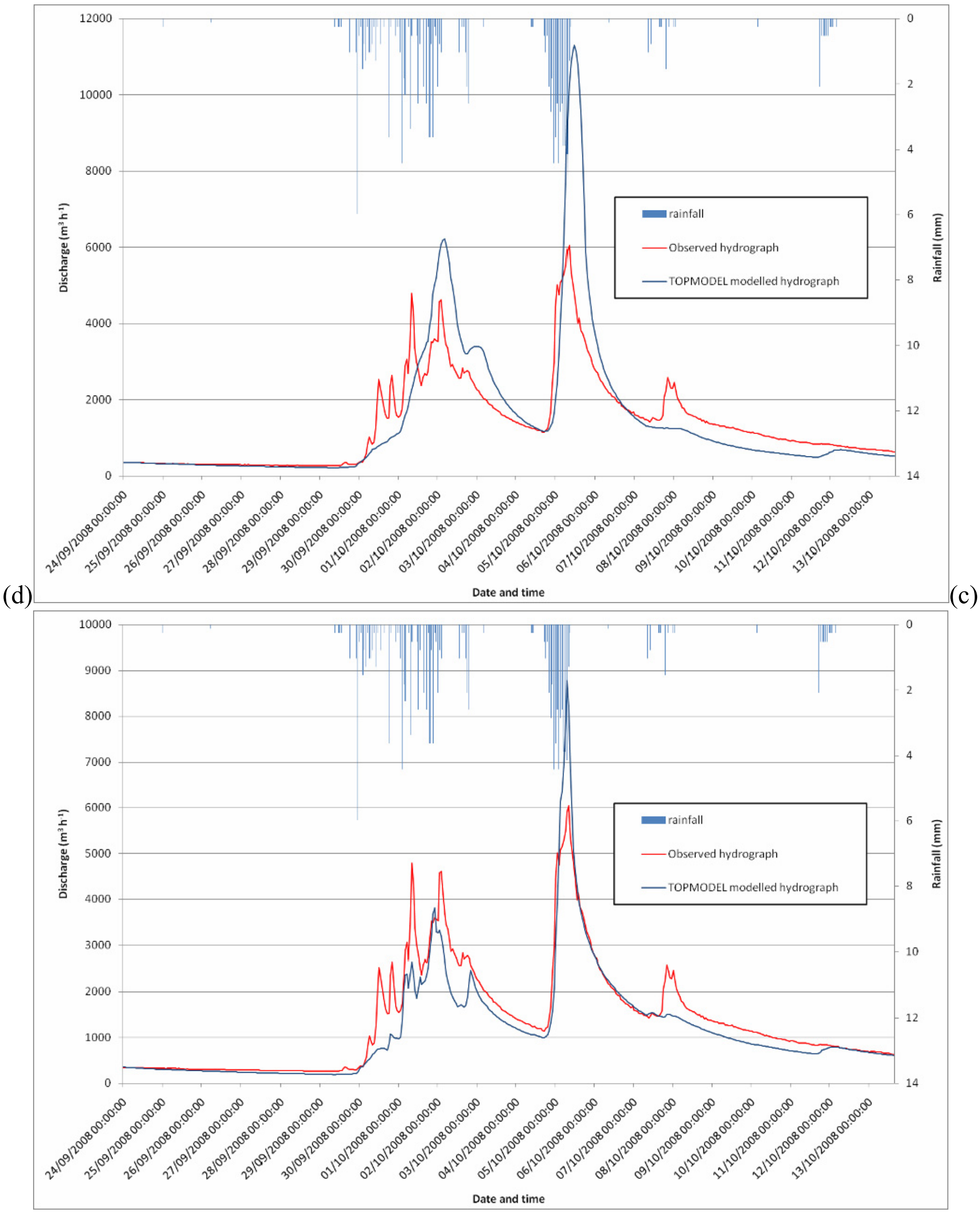
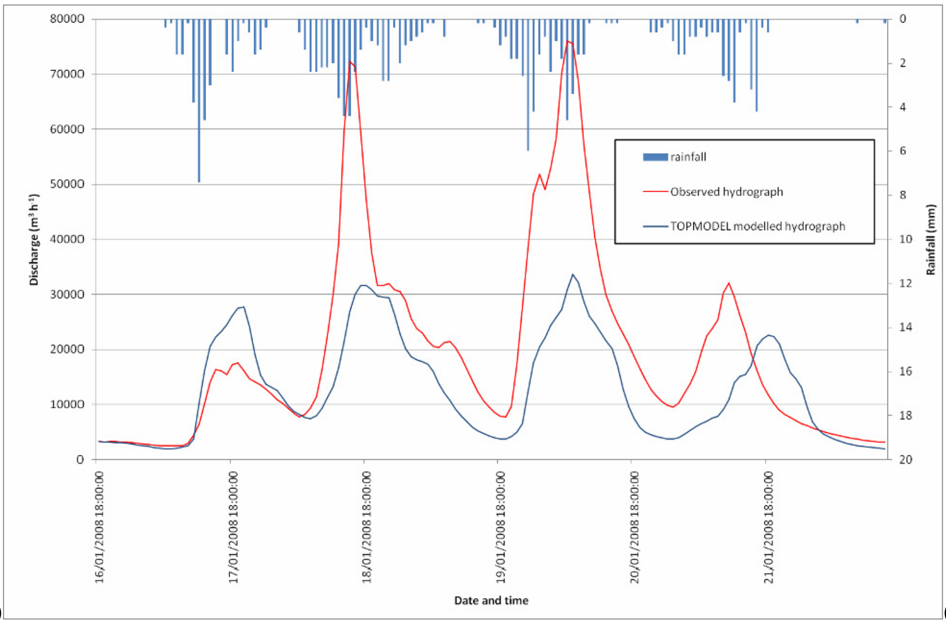
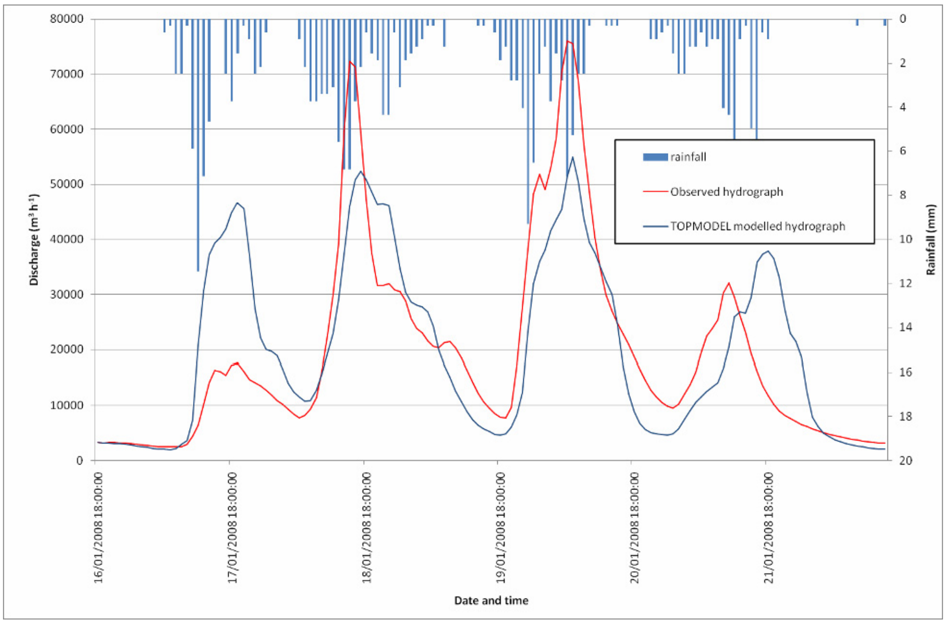


Figure A4.10: Calibrated TOPMODEL modelled hydrographs for the Tunstead House catchment for the period 24/09/2008 00:00:00 to 13/10/2008 15:00:00. Clockwise from top-left the modelled hydrographs are generated using (a) the SAGA *TOPMODEL* module, (b) the partitioned catchment approach advocated by Kirkby (1997), (c) the partitioned catchment approach but with adjusted meteorological data, and (d) the SAGA *TOPMODEL* module with adjusted meteorological data.

(a)


Discharge (m³ h⁻¹)
Rainfall (mm)
rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
16/01/2008 18:00:00
17/01/2008 18:00:00
18/01/2008 18:00:00
19/01/2008 18:00:00
20/01/2008 18:00:00
21/01/2008 18:00:00
Date and time

(b)


Discharge (m³ h⁻¹)
Rainfall (mm)
rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
16/01/2008 18:00:00
17/01/2008 18:00:00
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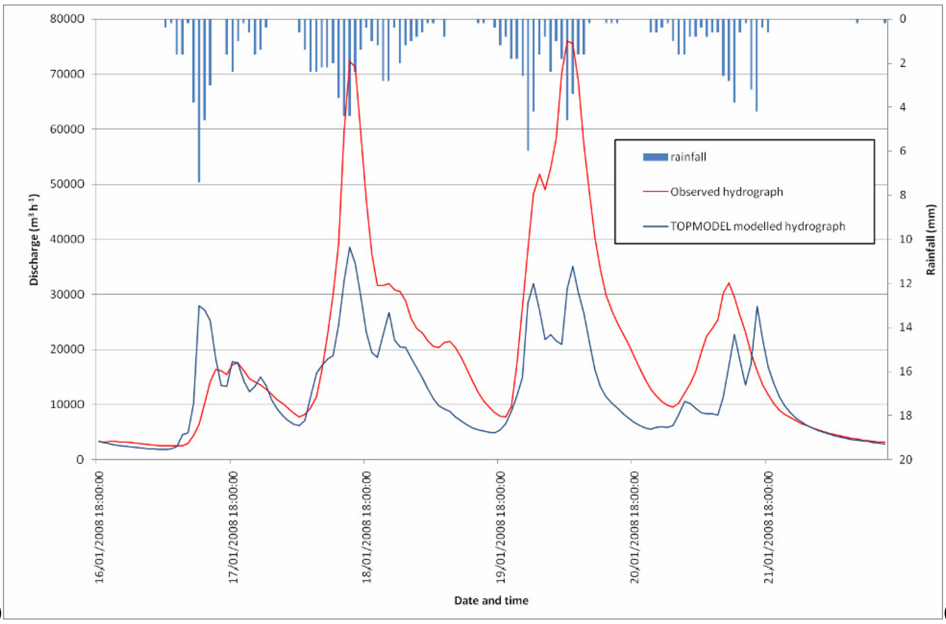
19/01/2008 18:00:00
20/01/2008 18:00:00
21/01/2008 18:00:00
Date and time



(c) (d)

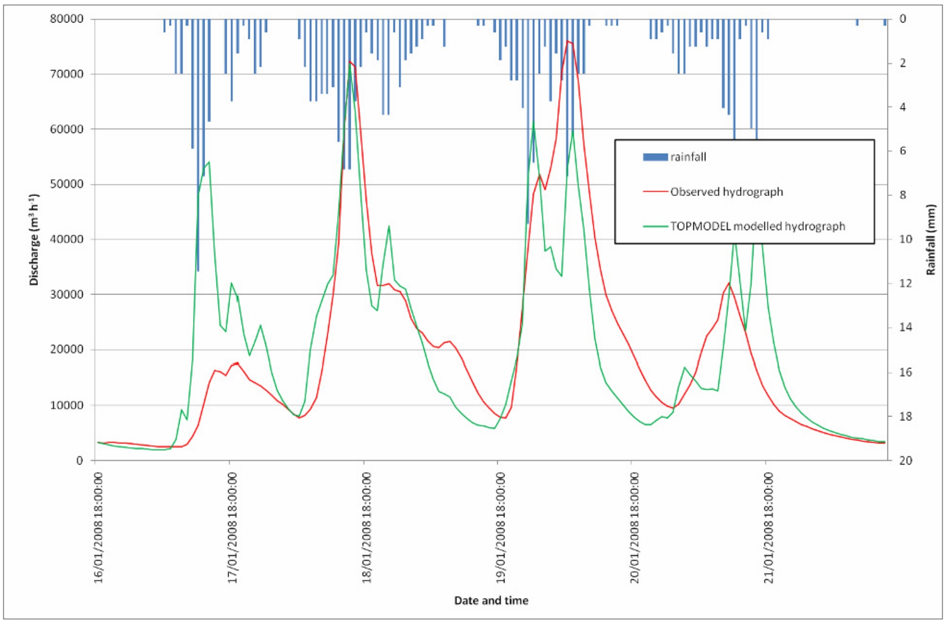
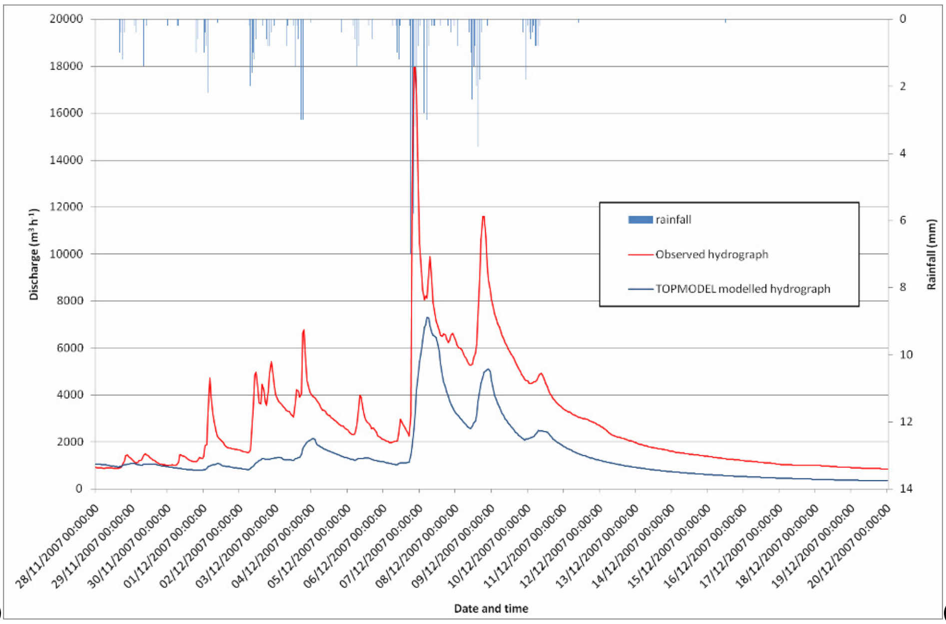
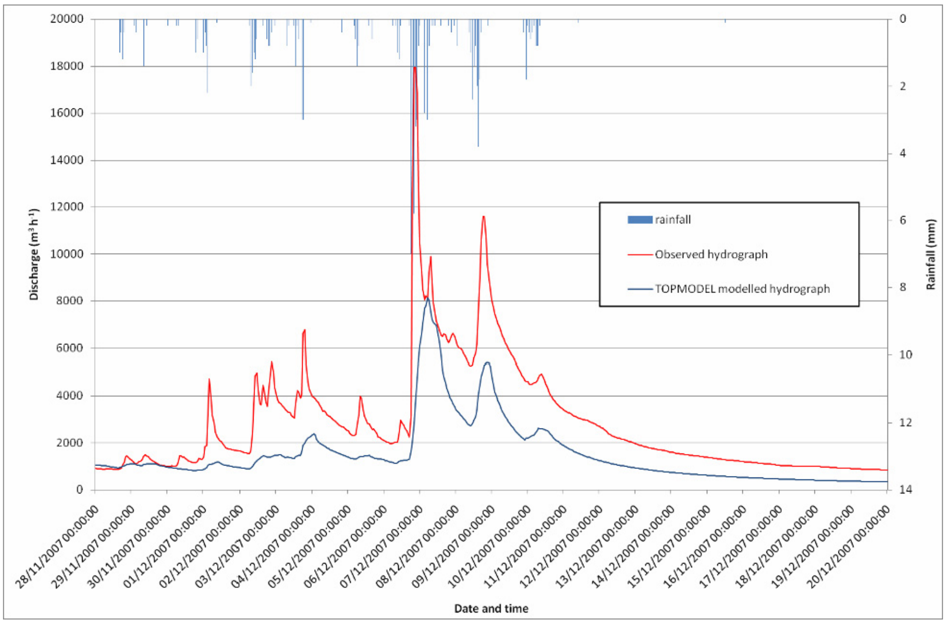


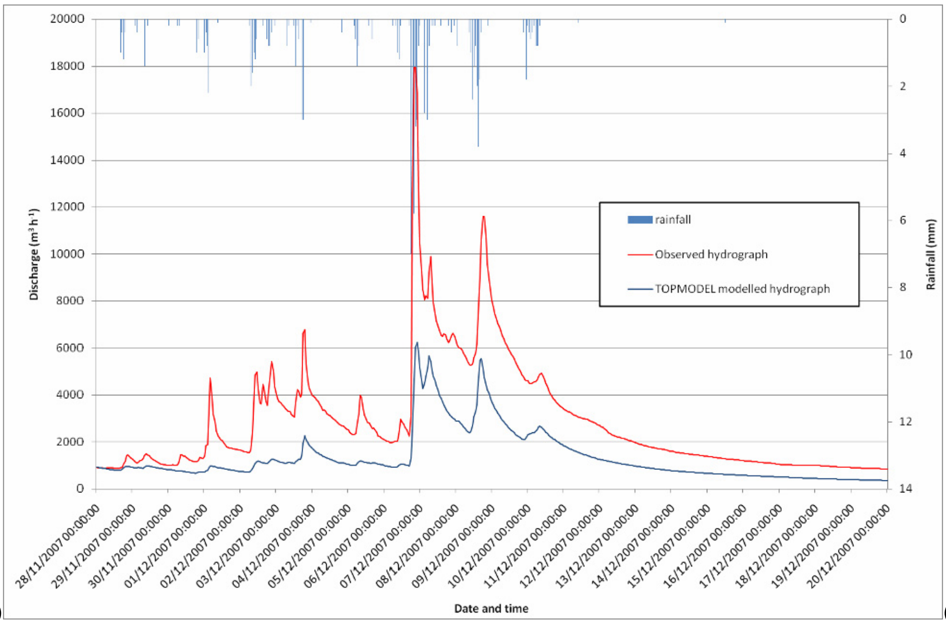
Figure A4.11: Testing the efficiency of the calibrated parameter sets on a test period which includes the highest discharge recorded in the flow record held for the Cynefail catchment. The modelled hydrographs are generated using (a) the SAGA *TOPMODEL* module, (b) the SAGA module with meteorological data adjustments applied, (c) the partitioned catchment approach, and (d) the partitioned catchment approach with meteorological data adjustments applied.


rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
Discharge (m³ h⁻¹)
Rainfall (mm)
Date and time

(a) (b)


rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
Discharge (m³ h⁻¹)
Rainfall (mm)
Date and time

(c)



(d)

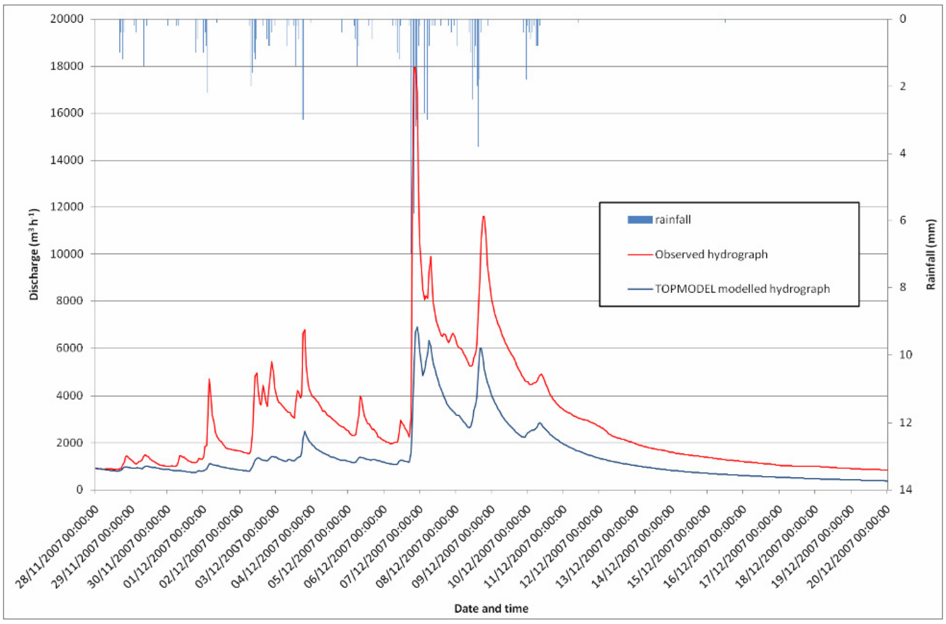
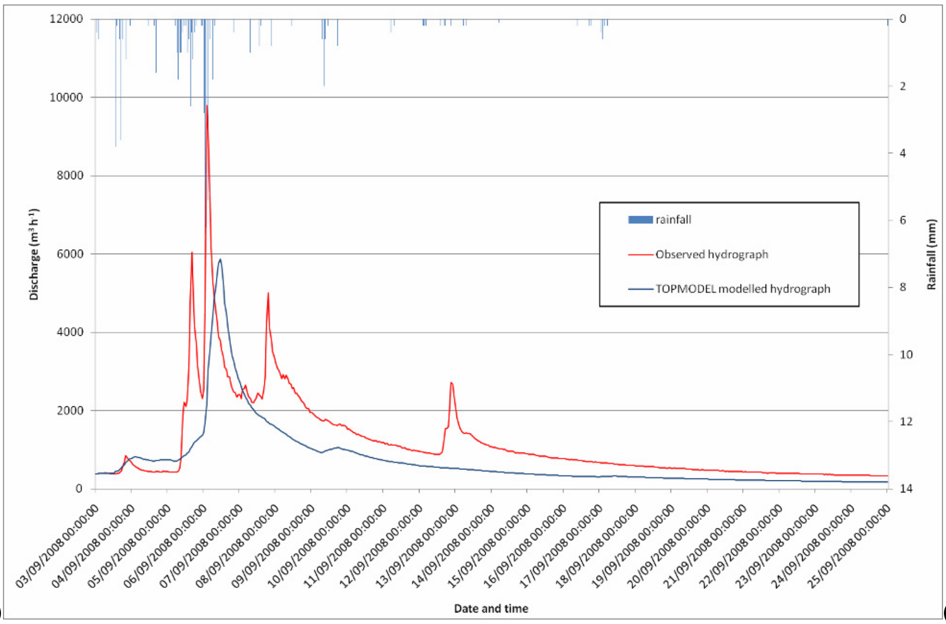


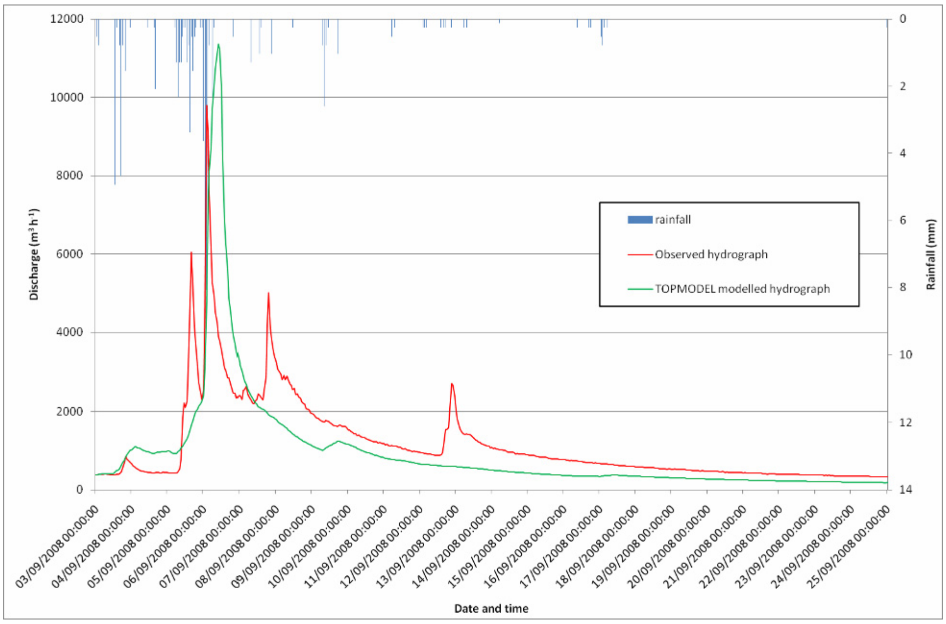
Figure A4.12: Testing the efficiency of the calibrated parameter sets on a test period which includes the highest discharge recorded in the flow record held for the Hollinsclough catchment. The modelled hydrographs are generated using (a) the SAGA *TOPMODEL* module, (b) the SAGA module with meteorological data adjustments applied, (c) the partitioned catchment approach, and (d) the partitioned catchment approach with meteorological data adjustments applied.

(a)



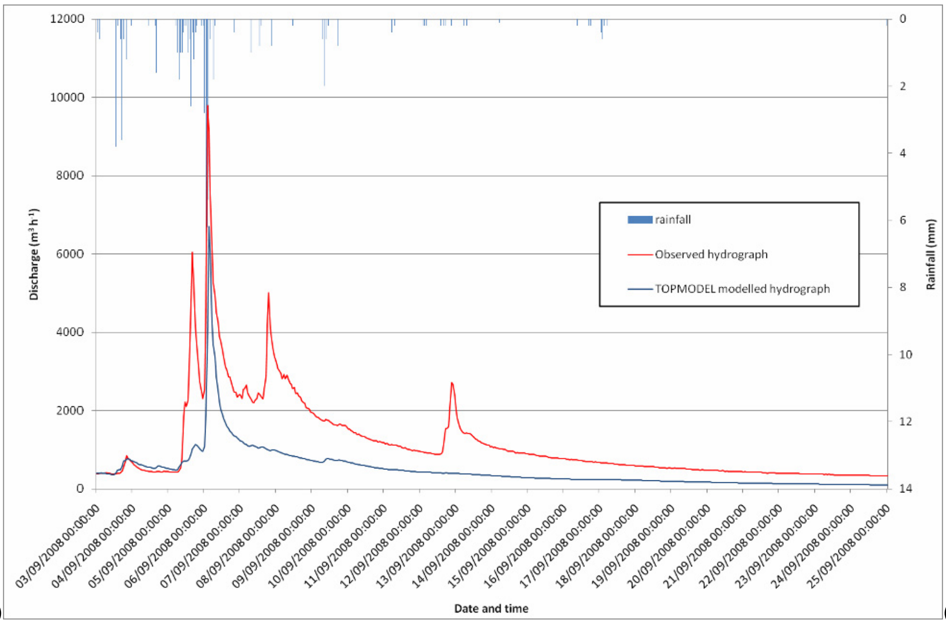
Discharge (m³ h⁻¹)
12000
10000
8000
6000
4000
2000
0
Rainfall (mm)
0
2
4
6
8
10
12
14
rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
03/09/2008 00:00:00
04/09/2008 00:00:00
05/09/2008 00:00:00
06/09/2008 00:00:00
07/09/2008 00:00:00
08/09/2008 00:00:00
09/09/2008 00:00:00
10/09/2008 00:00:00
11/09/2008 00:00:00
12/09/2008 00:00:00
13/09/2008 00:00:00
14/09/2008 00:00:00
15/09/2008 00:00:00
16/09/2008 00:00:00
17/09/2008 00:00:00
18/09/2008 00:00:00
19/09/2008 00:00:00
20/09/2008 00:00:00
21/09/2008 00:00:00
22/09/2008 00:00:00
23/09/2008 00:00:00
24/09/2008 00:00:00
25/09/2008 00:00:00
Date and time

(b)



Discharge (m³ h⁻¹)
12000
10000
8000
6000
4000
2000
0
Rainfall (mm)
0
2
4
6
8
10
12
14
rainfall
Observed hydrograph
TOPMODEL modelled hydrograph
03/09/2008 00:00:00
04/09/2008 00:00:00
05/09/2008 00:00:00
06/09/2008 00:00:00
07/09/2008 00:00:00
08/09/2008 00:00:00
09/09/2008 00:00:00
10/09/2008 00:00:00
11/09/2008 00:00:00
12/09/2008 00:00:00
13/09/2008 00:00:00
14/09/2008 00:00:00
15/09/2008 00:00:00
16/09/2008 00:00:00
17/09/2008 00:00:00
18/09/2008 00:00:00
19/09/2008 00:00:00
20/09/2008 00:00:00
21/09/2008 00:00:00
22/09/2008 00:00:00
23/09/2008 00:00:00
24/09/2008 00:00:00
25/09/2008 00:00:00
Date and time

(c)



(d)

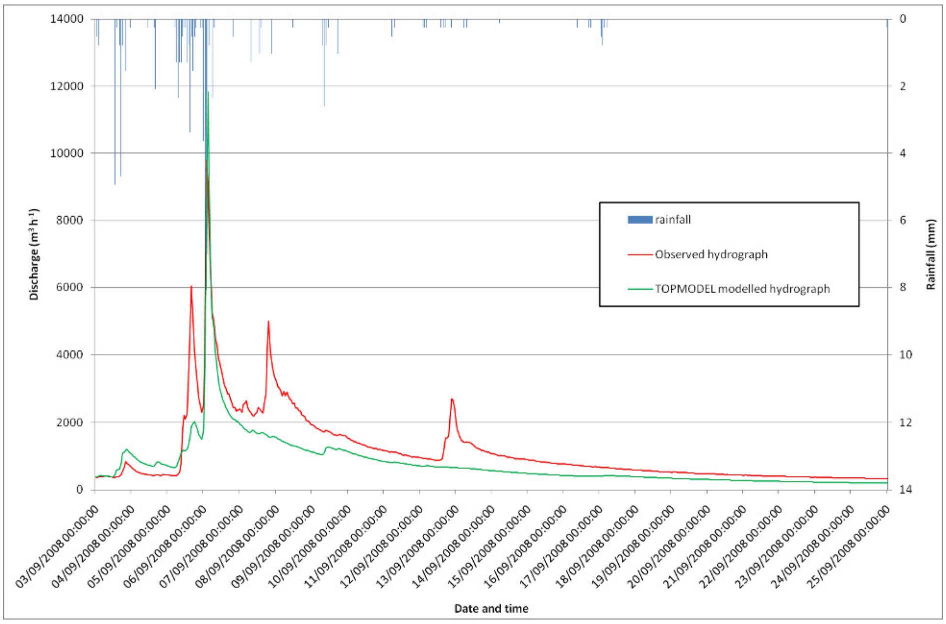


Figure A4.13: Testing the efficiency of the calibrated parameter sets on a test period which includes the highest discharge recorded in the flow record held for the Tunstead House catchment. The modelled hydrographs are generated using (a) the SAGA *TOPMODEL* module, (b) the SAGA module with meteorological data adjustments applied, (c) the partitioned catchment approach, and (d) the partitioned catchment approach with meteorological data adjustments applied.

Table A4.8 (next page): TOPMODEL performance during (i) initial SAGA module calibration, (ii) initial partitioned catchment approach calibration, (iii) partitioned catchment approach and SAGA module modelling both using existing calibrated parameter sets and adjusted meteorological model inputs, and (iv) testing model performance on test storms that encompass the highest recorded discharges in the flow series data holdings. In assessing the performance of the calibrated SAGA module on test storms parameter sets were held at their calibrated values with the exception of the initial subsurface flow per unit area which was adjusted to produce favourable start-up conditions. The quoted catchment elevations are based on the resampled 10 m DEMs.

(i) Catchment	Area (km^2)	Closest Met Office MIDAS station recording hourly precipitation	Approximate distance from catchment watershed to Met Office MIDAS station (km)	Catchment elevation range (m above Ordnance Datum)	Met Office MIDAS station elevation (m above Ordnance Datum)	SAGA *TOPMODEL* module calibrated *m* model parameter (m)	SAGA *TOPMODEL* module calibrated T_0 model parameter (m^2 h^{-1})	SAGA calibrated TOPMODEL Nash-Sutcliffe Coefficient	SAGA calibrated TOPMODEL mean absolute error (m^3 h^{-1})
Cynefail	12.66	Lake Vyrnwy No. 2	28.7	309 - 686	360	0.003	1.0000	0.63	2077.4
Hollinsclough	8.08	Leek: Thornecliffe	8.5	282 - 549	298	0.011	0.0100	0.85	319.1
Tunstead House	5.95	Woodford	15.8	216 - 625	88	0.011	0.0008	0.64	400.2

(ii) Catchment	Storm period under calibration	Area of catchment exhibiting a rapid response (%)	Calibrated *m* parameter for rapidly responding area (mm)	Calibrated time delay for rapidly responding area (h)	Calibrated *m* parameter for area of more moderate response (mm)	Calibrated time delay for area of more moderate response (h)	Partitioned catchment Nash-Sutcliffe Coefficient	Partitioned catchment mean absolute error (m^3 h^{-1})
Cynefail	19/12/07 00:00 – 04/01/08 00:00	27	0.8	1.0	8.0	2.0	0.58	1591.0
Hollinsclough	31/08/08 00:00 – 23/09/08 00:00	10	3.1	3.0	15.0	4.0	0.87	308.9
Tunstead House	24/09/08 00:00 – 13/10/08 15:00	27	5.0	0.3	26.1	15.0	0.35	685.8

(iii) Catchment	Precipitation adjustment factor (%)	Evapotranspiration adjustment factor (%)	Partitioned catchment Nash-Sutcliffe Coefficient	Partitioned catchment mean absolute error (m^3 h^{-1})	SAGA calibrated TOPMODEL Nash-Sutcliffe Coefficient	SAGA calibrated TOPMODEL mean absolute error (m^3 h^{-1})
Cynefail	+55%	-50%	0.78	1654.3	0.70	2053.3
Hollinsclough	0%	-50%	0.89	271.5	0.82	340.6
Tunstead House	+30%	-55%	0.83	271.0	0.15	509.6

(iv) Catchment	Date and time of largest recorded discharge in flow data holdings	TOPMODEL test period	SAGA		SAGA (adjusted meteorological inputs)		Partitioned		Partitioned (adjusted meteorological inputs)	
			N-S Coef	MAE (m^3 h^{-1})	N-S Coef	MAE (m^3 h^{-1})	N-S Coef	MAE (m^3 h^{-1})	N-S Coef	MAE (m^3 h^{-1})
Cynefail	20/01/08 06:00	16/01/08 18:00 – 22/01/08 15:00	0.36	9346.8	0.57	8327.4	0.40	8811.4	0.59	7509.7
Hollinsclough	06/12/07 21:00	28/11/07 00:00 – 20/12/07 00:00	0.26	1440.2	0.33	1354.6	0.24	1531.7	0.35	1407.0
Tunstead House	06/09/08 02:00	03/09/08 00:00 – 25/09/08 00:00	0.40	547.8	0.12	569.7	0.28	696.3	0.67	447.9

8. Results from TWI and Land cover 2000 comparison

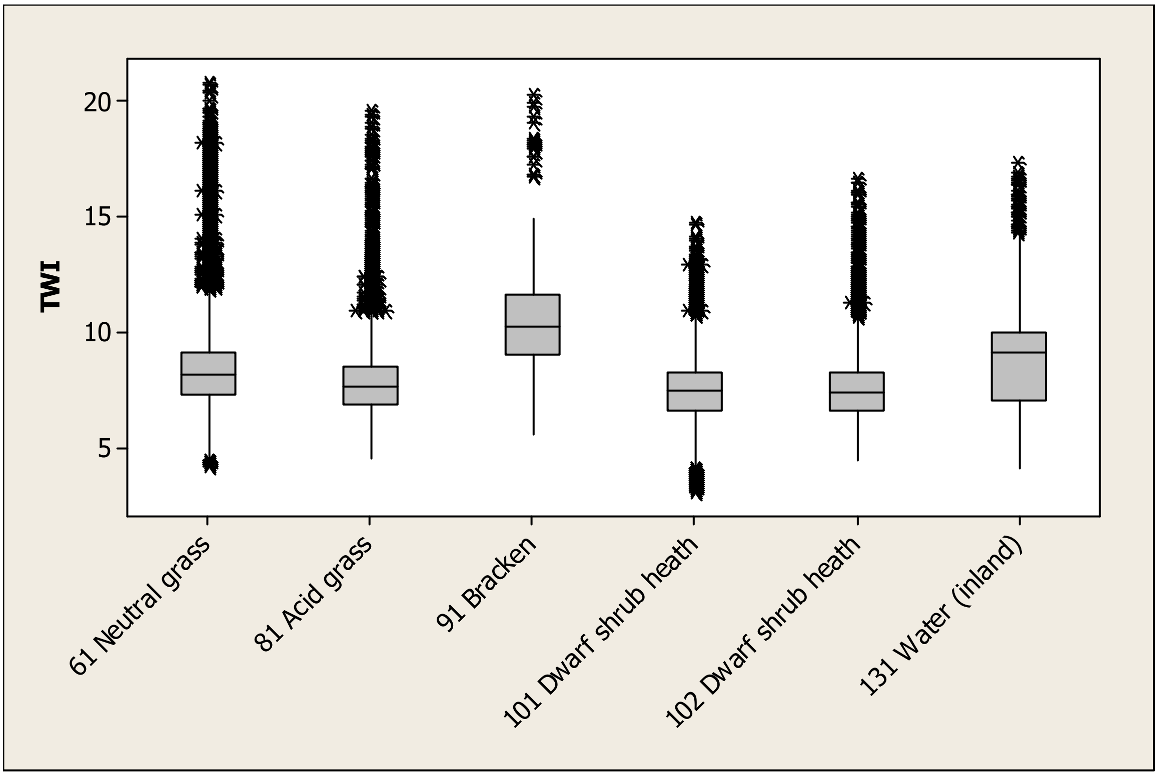


Figure A4.14: The distribution of TWI values associated with the LCM2000 subclasses in the Cynefail catchment. The median, inter-quartile range, upper and lower 25% of the distribution and outliers are shown by the horizontal line, box, whiskers and asterisks respectively.

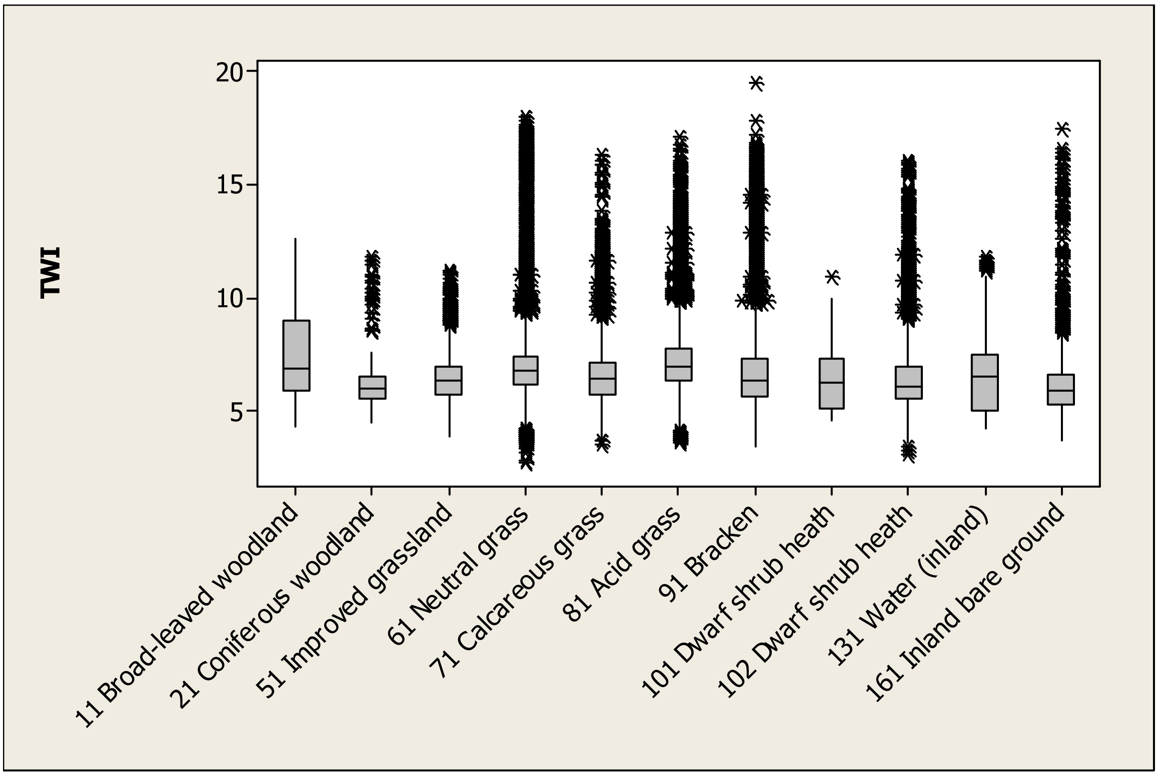


Figure A4.15: The distribution of TWI values associated with the LCM2000 subclasses in the Hollinsclough catchment.

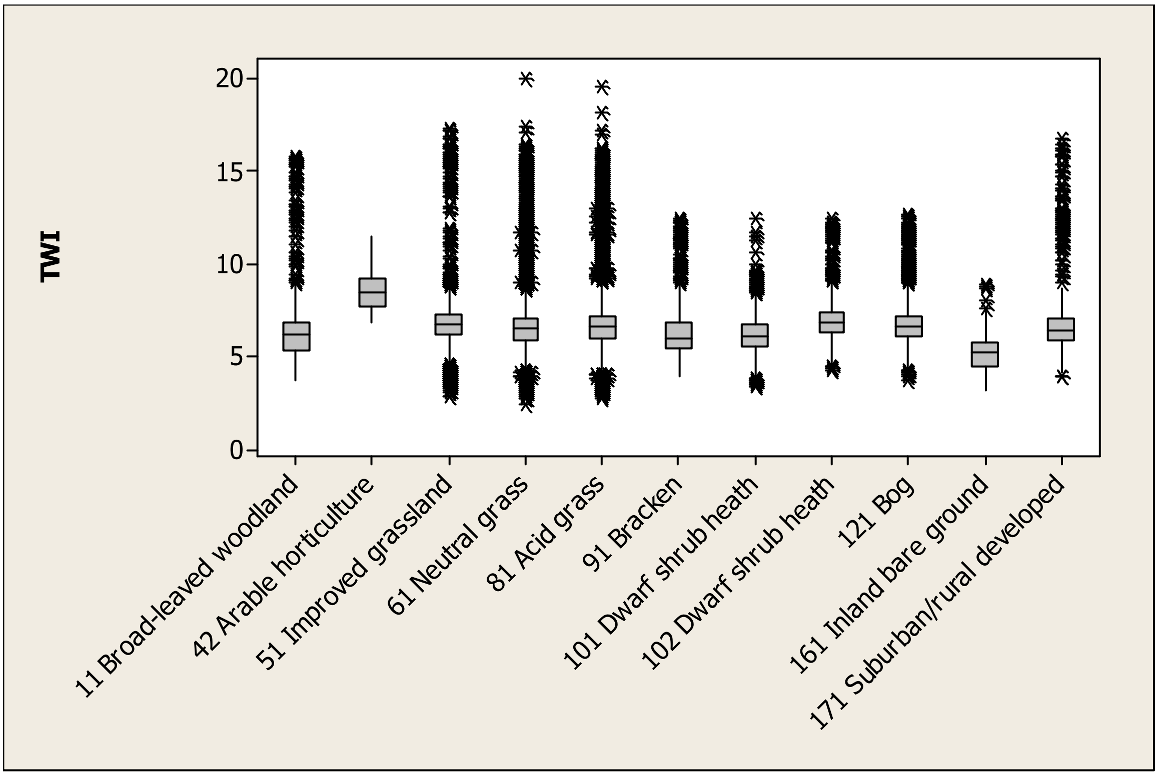


Figure A4.16: The distribution of TWI values associated with the LCM2000 subclasses in the Tunstead House catchment.

9. Additional discussion of results and limitations

There are marked differences between the vegetation change scenario simulations using the two TOPMODEL approaches. Each catchment partition in the partitioned catchment approach is associated with a different calibrated TOPMODEL *m* and time delay. Adjusting the proportionate split of the catchment to reflect the vegetation change scenarios alters the relative weighting of the partitioned parameter sets; the equivalent TOPMODEL parameters are held constant when the scenarios are simulated using the SAGA *TOPMODEL* module. To determine which simulation approach provides the most realistic representation it must be established whether or not a change in vegetation cover is likely to be associated with a change in TOPMODEL parameters.

The overland flow data collected by Holden *et al*. (2008) was re-plotted to provide an estimate of TOPMODEL *m* (Figure 28; Kirkby, 2009). The curves for OLF velocity plotted against depth for each surface can be described by a rough exponential relationship of the form $v = Ke^{\left(\frac{z}{m}\right)}$ (Kirkby, 2009). From these relationships TOPMODEL *m* can be estimated as 1000/93.372 = 10.7 mm for Bare surfaces, 1000/120.54 = 8.3 mm for *Eriophorum* surfaces, and 1000/114.05 = 8.8 mm for *Sphagnum* surfaces. The similarity of the gradients of the exponential relationships results in similar estimates for TOPMODEL *m*. *K* differs more substantially between surfaces. Since TOPMODEL *m* is similar for each surface, the runoff generated will be of the same magnitude and timing; however, the depth of overland flow will be greatest over *Sphagnum* surfaces and least on Bare surfaces (Kirkby, 2009). Conversely, the velocity of flow will be fastest over Bare surfaces and slowest over *Sphagnum* surfaces. The consistent estimates of TOPMODEL *m* across the range of surfaces lends support to the SAGA *TOPMODEL* module approach, where TOPMODEL *m* is maintained from one scenario to another, and calls the simulations obtained

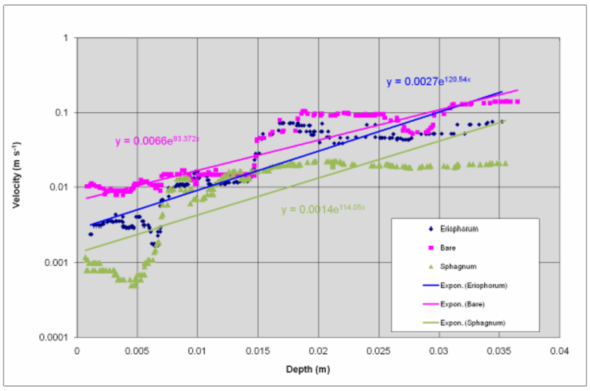


Figure A4.17: Holden *et al*. (2008) overland flow data re-plotted to provide an estimate of TOPMODEL *m* for each surface.

using the partitioned catchment approach into question. Furthermore, the values of TOPMODEL *m* calibrated using the SAGA module for the Hollinsclough and Tunstead House catchments (Table A4.8) are favourably comparable with the estimates provided in Figure A4.17.

However, the simulations provided are not definitive. In particular, the locations of the rain gauges some distance from the catchments inhibit the development of robust rainfall-runoff models. The reliance on a single gauge, even when located within the catchment, has been identified as problematic in catchments of comparable area to those simulated (Evans *et al*., 1999). It is likely that localised rainfall events occur that generate storm runoff without any precipitation being recorded, and vice versa, particularly considering the elevation of the gauges relative to the elevation ranges of the catchments. Furthermore, since the location of the Lake Vyrnwy No. 2 gauge is to the east of the Migneint upland in which the Cynefail catchment is located there is a possibility that a rain shadow effect results in further underestimation of rainfall here. Fundamentally, the magnitude, duration and timing of the rainfall events experienced in the catchment are likely to be different to those recorded by the gauges. Estimates of daily evapotranspiration rates were calculated using data from the same stations so similar issues of spatial applicability exist, particularly at the highest elevations in the catchments. Additionally, since only daily maximum and minimum temperatures were available, it was not possible to calculate estimates at a finer temporal resolution and the daily rate was simply divided by 24 to provide the hourly rate required. Adjustments were made to the meteorological data in an attempt to improve the situation but the adjustments had no quantifiable grounding beyond the catchment water balance. Despite these limitations the simulations achieved are of a sufficient standard to allow the relative comparison of vegetation re-establishment and management scenarios.

Holden *et al*. (2008) identified that successful application of their empirically based overland flow velocity forecasting equations is reliant on the availability of suitable vegetation maps. Although interpretation of the descriptions of certain LCM2000 categories allowed them to be easily reclassified into the peatland surface categories addressed by Holden *et al*. (2008), the similar reclassification of other LCM2000 categories was incredibly subjective. A requirement for more detailed, peatland specific, vegetation maps dovetails with a need for the Holden *et al*. (2008) overland flow velocity observations to be performed for other vegetation types that occur above peat soils, notably *Calluna*, bracken and improved grassland. The rudimentary reclassification of broad-leaved woodland, coniferous woodland, arable horticulture and suburban land covers has little impact on this study due to their restricted coverage; however, a reliance on the location of EA flow gauges may mean that this is more of a problem as catchment size increases. Catchments must be modelled in their entirety; therefore, the definitive quantification of the hydrological ecosystem services specifically provided by peatlands requires careful experimental design and is unlikely to be achieved using off-the-shelf datasets. **There is a need for the flow gauging of peatland subcatchments and the careful location of a network of rain gauges combined with comprehensive vegetation mapping and observations of overland flow velocities on further peatland surfaces.**

Upland drains have been excluded from the analysis since debate continues regarding their impact on catchment hydrology (Holden *et al*., 2004). The hydrological implications of upland drainage are complex; elevated (e.g. Conway and Millar, 1960) and reduced (e.g. Burke, 1967) flood peaks have been observed. These observations have been attributed, in turn, to rapid flow in grips enhancing slope-channel connectivity (Holden, 2005a; Holden 2005c), and to a reduction in overland flow as a result of an increase in storage capacity associated with the lower water tables characteristic of drained peats (Holden *et al*., 2004; 2007b). The size and spacing of drains, and the characteristics of the peatlands which they drain, have also been identified as crucial factors in determining the catchment-scale hydrological response to drainage (Holden *et al*., 2004) which adds further uncertainty as to how drains should be incorporated into hydrological models. Furthermore, increases in soil pipe density associated with upland drainage have also been observed (Holden, 2005c; 2006). Soil pipes are also often associated with areas dominated by woody *Calluna* species (Holden, 2005b) and desiccation of bare areas results in the opening of macropores (Holden and Burt, 2002). Since TOPMODEL assumes that the saturated zone's hydraulic gradient is proportional to the topographic slope, which is equivalent to Darcy's law, it may not provide a good approximation of flow in catchments with significant soil pipe and macropore flow (Kirkby, 1997). Nevertheless, saturation excess OLF remains an important hydrological process even over peat soils with significant macropore networks (Holden, 2009).

The version of TOPMODEL available from Lancaster University (HFDG, 2005) includes functionality to produce maps of saturation similar to those presented by Lane *et al*. (2004); however, since the size of the catchment that can be modelled using this freeware is limited to 100 × 100 pixels (Beven, 1998), the resolution of the Cynefail, Hollinsclough and Tunstead House DEMs would be required to be reduced to 53, 48 and 33 m respectively. This introduces further resampling error and results in a loss of boundary information (Quinn *et al*., 1995). In addition, a decrease in resolution results in a shift in bias toward higher TWI values resulting in the prediction of an unrepresentatively large saturated extent (Quinn *et al*., 1995;

Lane *et al*., 2004). The assessment of ecosystem service would benefit from a coding effort to combine the functionality of the SAGA *TOPMODEL* module, particularly the 'Internal subcatchment routing velocity' parameter which is crucial to this study, with the saturated extent mapping functionality of the Lancaster University version. This approach would facilitate the use of elevation data of a suitable resolution (Zhang and Montgomery, 1994) and allow the mapping of the impact of re-establishment scenarios on saturation as a means of quantifying the ecosystem service. Additionally, the Lancaster University version has the capability to undertake multiple Monte Carlo runs of TOPMODEL, applying a random sample of parameters within a specified range, the results of which are compatible with the Generalised Likelihood Uncertainty Estimation (GLUE; Beven and Binley, 2002; HFDG, 2005) technique which is used to explore uncertainty in model calibration and the concept of equifinality.

The MCE analyses were performed in response to the TOPMODEL methodology used being unable to provide a means of quantifying ecosystem service beyond the simulated hydrographs. The original composition of the catchments is reflected in the analyses since vegetation categories are shifted en mass. The use of categorical data to define the overland flow velocity factor is not ideal. Furthermore, areas of inland water were classified as 'Bare' which may contribute to these areas being identified as having a high potential to rapidly produce runoff. This assumption is acceptable if reservoirs and lakes are at capacity and can offer no further storage but is inappropriate if this is not the case. To compound the situation, areas of inland water are also associated with high TWI values. In comparison to the simulations of the SAGA *TOPMODEL* module, the impact of vegetation re-establishment and management upon ecosystem service provision is exaggerated by the MCE analyses.

Appendix 5 Cost Surface Model Parameters for Peatland Access

Table A5.1: Cost surface model coefficients for determining walking speed across different habitats, i.e. 100% walking speed on bare ground and diminished walking speed due to friction across e.g. fens.

Code	LCM_class	Friction
221	Sea / Estuary	0
131	Water (inland)	25
201	Littoral Rock	25
211	Littoral Sediment	25
212	Saltmarsh	25
181	Supr-littoral rock	25
191	Supra-littoral sediment	25
121	Bog	50
101	Dwarf shrub heath	50
102	Open shrub heath	80
151	Montane habitats	80
11	Broad-leaved / mixed woodland	10
21	Coniferous woodland	10
41	Cereals	0
42	Horticulture / not cereal	0
43	Not annual crop	0
51	Improved grassland	0
52	Setaside grass	0
61	Managed neutral grass	0
62	Calcareous grass	0
71	Acid grass	90
81	Bracken	80
91	Fen, marsh, swamp	50
111	Suburban / rural developed	100
171	Continuous urban	100
172	Inland bare ground	100

Appendix 6 Expert Recreation mapping survey

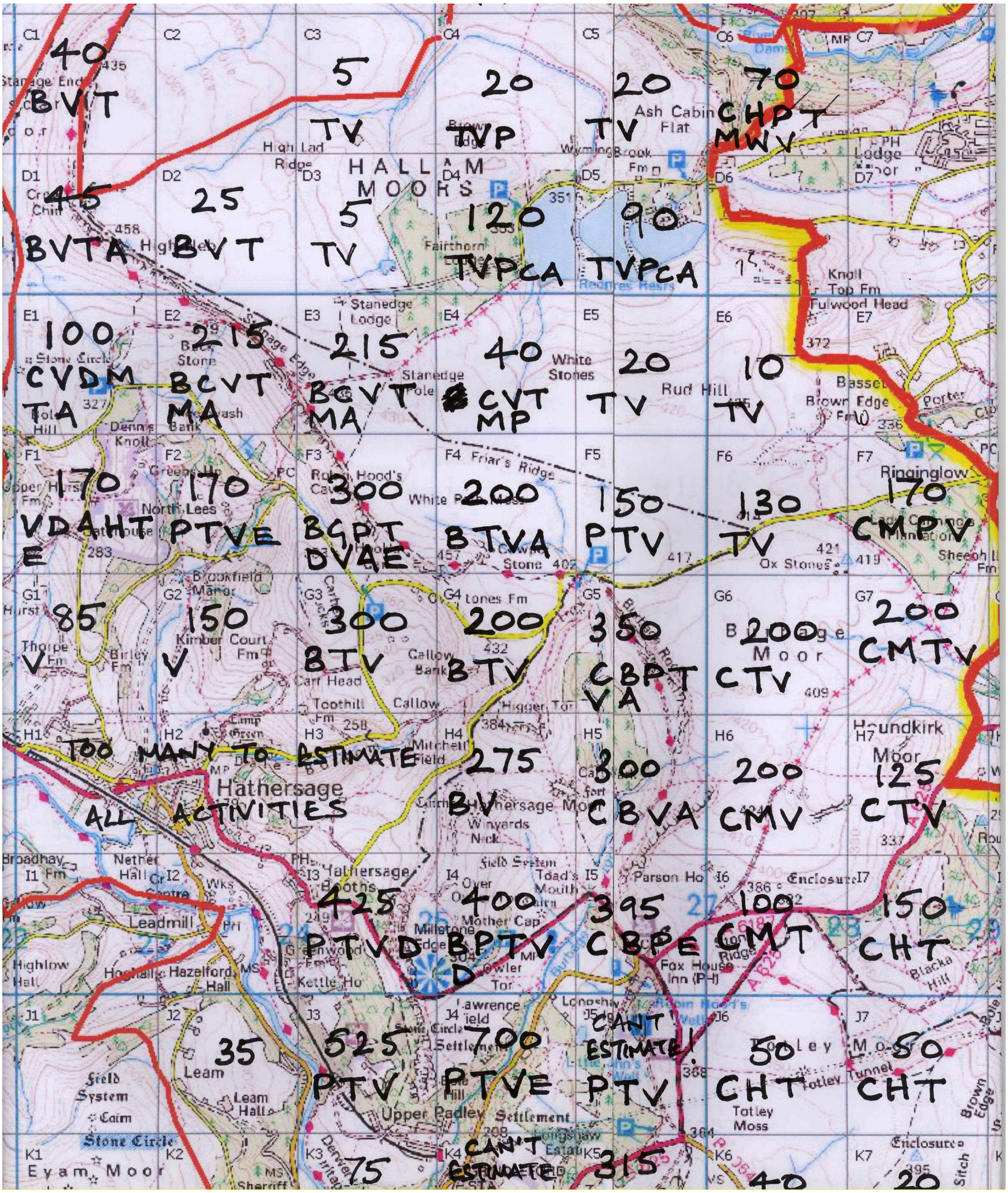


Figure A6.1: Sample map for expert survey estimates of visitor numbers and activities in part of the Peak District. Area wardens were asked to estimate numbers on a peak day (Saturday in July) and to use letter codes to indicate the activities that took place in the relevant grid squares (see survey questionnaire Figure A6.3).The first maps to be returned were used to inform the creation of cohorts to aid visitor number estimation (see Table A6.1)

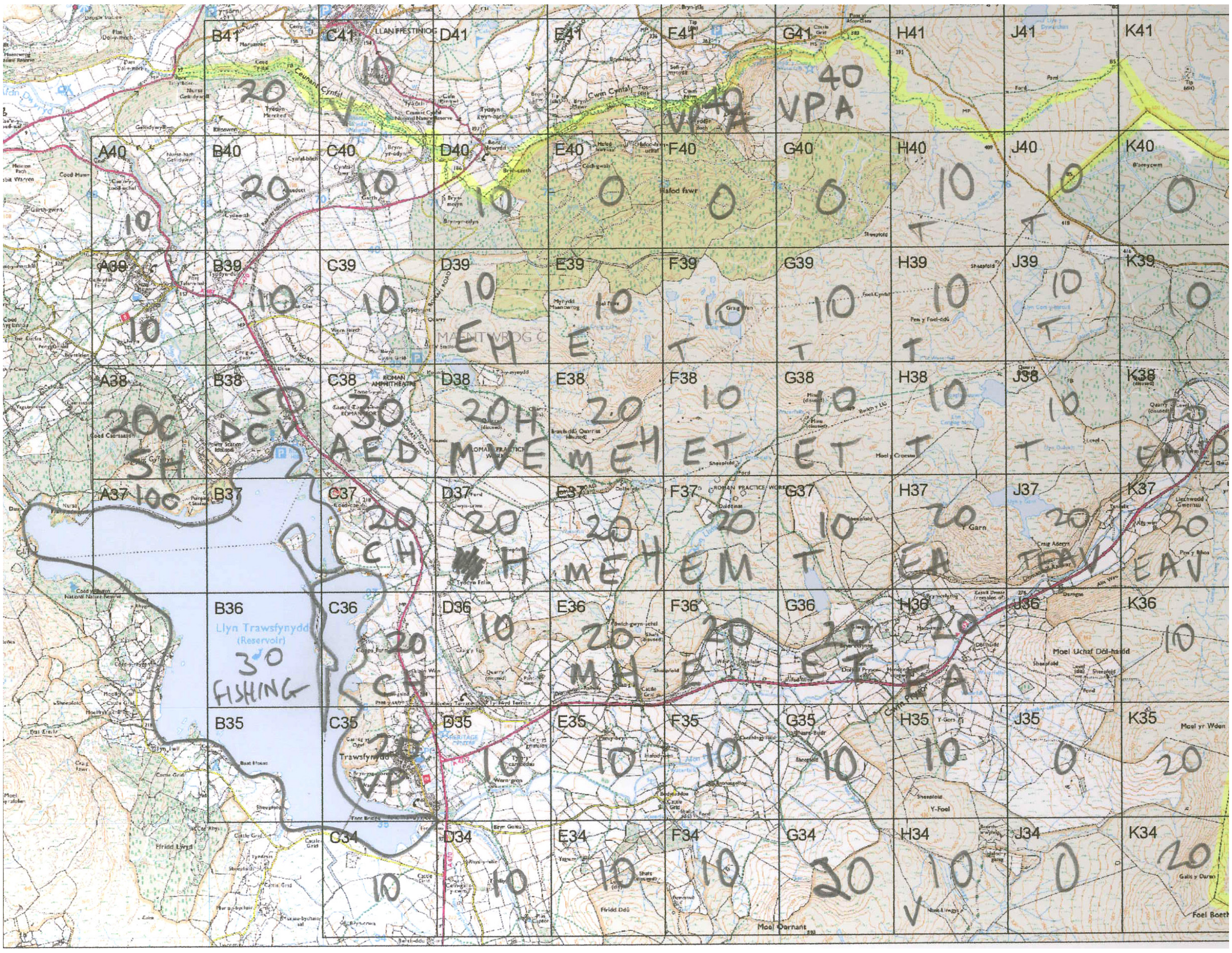


Figure A6.2: Sample map for expert survey estimates of visitor numbers and activities in part of the Migneint. Area wardens were asked to estimate numbers on a peak day (Saturday in July) and to use letter codes to indicate the activities that took place in the relevant grid squares (see survey questionnaire Figure A6.3).

Table A6.1 Cohorts for estimated visitor use. The range cohorts were created after initial data analysis of first 'absolute' data collected from Thorne & Hatfield, Migneint and Peak District rangers and area wardens.

Cohorts	**Range of estimated visitor numbers**
0	0
1	1 – 5
2	6 – 10
3	11 – 25
4	26 – 50
5	51 – 100
6	101 – 250
7	251 – 500
8	501 – 1000
9	1001 – 2500

The following questionnaire was used to inform and aid the expert visitor survey in Thorne & Hatfield, Migneint and Peak District. After speaking with site managers and explaining aim and goals of the survey, rangers and area wardens were identified and maps and questionnaires we sent out. This was followed up by phone calls and emails and in some cases personal visits to clarify any queries,

Figure A6.3: Experts survey questionnaire (here with specific introduction for the Peak District)

RANGER QUESTIONNAIRE - VISITOR PATTERNS ON PEATLANDS

BACKGROUND

The Moors for the Future (MFF) Partnership are currently working on a project for Defra looking at the 'Ecosystem Services of Peat'. One of the chapters is looking at the provision of recreation, for which we will be investigating estimates of visitor usage within the Peak District National Park with a view to developing a GIS database of information on recreation. As you are aware, the last official survey of visitors was conducted by MFF in 2004 and 2005 with the help of rangers and volunteer rangers and a comparative map of visitor usage pre Crow (which was collated by Mike Rhodes and Andy Jones with the area rangers). As no other figures are available for today, the expert knowledge held by the PDNPA Rangers is the best source of information available. Many of the responses will be informed guesstimates based on your observations - information which is vital to build up the bigger picture of visitor usage in the peatland areas.

We are grateful for your assistance and hope that this will not take up too much of your time. Any other comments that you think will be useful to this research will be gladly received. If you need more space please continue on another sheet.

VISITOR NUMBERS

Visitor Totals:

	Estimated visitor totals* for your whole area	**Estimated number that are on educational visits**
Peak Weekday		
Peak Weekend day		
Shoulder Weekday		
Shoulder Weekend day		
Off-peak Weekday		
Off-peak Weekend day		

Peak - July or August; Shoulder - October; Off-Peak December to February.

* Visitor totals should include all visitors including educational groups.

VISITOR PROFILES

Visitor Age:
What percentage of the total visitors in your area would you estimate to be:

Age (years)	% of Moorland Visitors
0 -15	
16 - 24	
25 - 44	
45 - 59	
60+	

Visitor Gender:
What % of total visitors would you estimate to be male? ....

Visitor Ethnicity:
What % of total visitors would you estimate to be from black and ethnic minority (BME) backgrounds? ....

Visitor Mobility:
What % of total visitors would you estimate to have mobility problems? ....

Mode of transport used:
What % of total visitors would you estimate used the following mode of transport to visit the area?

Mode of Transport	% of Visitors
Car/van	
Coach/minibus	
Motorbike	
Bus/train	
Bicycle only	
Walk only	
Other (please specify)	

Partners and groups:
What recreational groups and/or partnership forums are active in your area? eg British Mountaineering Club, 'Ride the Peak' etc

Group Name	*Contact name*	*Tel no and/or email*
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

VISITOR BEHAVIOURS AND ATTITUDES

Behaviour:
% of visitors walking dogs? ....
% of dogs not on leads? ....
% of dogs out of control (ranging more than 25m from the owner) ....

Attitudes:
% of visitors who you discuss environmental issues with? ....
% of those visitors who ensure their behaviour minimises their impact on the peatlands? ....

VISITOR MONITORING

Do you undertake any formal or informal collection of visitor data such as:
- visitor numbers eg total usage, usage distribution by area or activity? YES/NO
- visitor profiling eg demographic and socio-economic backgrounds of visitors? YES/NO
- visitor opinions eg assessing the attitudes, behaviours and motivations of visitors' choices of recreation? YES/NO

If yes to any of the above, what information do you collect? If it is easy to copy please attach, if not please describe type of information you hold...
....
....
....
....
....
....
....
....

MAP - PATTERNS OF VISITOR USE

The attached A2 map needs to be completed to show:

1. Distribution of visitor usage, and
2. Type of visitor activity.

The map is subjective and will show your perception of how these areas are used at their peak times. *The map should be completed as if all recreational activities are being carried out at their highest usage rate* (even if two activities would not be happening on the same day eg sledging and climbing).

How to complete the map: Please fill in each grid to show two different pieces of information:

1. Distribution.

Please put a figure showing the (estimated) maximum number of people who would use this area during an *average peak day for each 1 km grid.*

2. Type of activity.

Using the following codes please mark the main visitor activities. Please draw a boundary around the activity area as exact as possible. We will assume walking is an activity in each grid.

ACTIVITY	CODE
CYCLING	C
HORSE RIDING	H
CLIMBING/BOULDERING	B
PICNIC	P
ART/PHOTOGRAPHY	A
BIRD WATCHING	T
MOTORISED SPORTS	M
WATER SPORTS	W
PARAGLIDING OR SIMILAR	G
ENJOY ARCHAEOLOGY/CULTURAL HERITAGE	E
ENJOY THE VIEW	V
EDUCATIONAL ACTIVITIES	D

Please indicate on the back of the map which activities you think impact on other purposes of peatlands e.g. biodiversity conservation, carbon storage/erosion, water quality, flood risk, cultural heritage conservation?

THANK YOU VERY MUCH FOR YOUR TIME!