MACRONUTRIENT CYCLES PROGRAMME

A CATCHMENT STRATEGY

Summary

The working group on 9 May 2011 and the workshop on 10 May 2011 concluded that the following 3 catchments should be selected for the MC Programme:-

Ribble (Lancashire)
Conwy (North Wales)
Avon (Hampshire)

It was agreed that whilst the proposals should have the majority of their research focussed in one or more of the 3 core catchments, we should welcome the inclusion of satellite sites, catchments, farmscapes /experimental units and national networks which enhance the research through the testing of models and provide information for upscaling, which cannot be efficiently carried out or are outside the scope of the core catchments selected.

As a result it has been decided that **the majority of the budget for proposals must be spent within at least one of the core catchments, though significant spending may be attributed to farmscapes, experimental units, additional satellite catchments, and upscaling.**

1. Introduction

The **overarching goal of the Macronutrients Cycles (MC) programme** is to quantify the scales (magnitude and spatial/temporal variation) of nitrogen and phosphorus fluxes and the nature of transformations through the catchment under a changing climate and perturbed carbon cycle**.** 'The catchment' is defined as covering exchanges between the atmospheric, terrestrial and aqueous environments, with the limit of the aqueous environment being marked by the seaward estuarine margin.

The Macronutrient Cycles (MC) programme was originally developed by NERC Theme Leaders based on consultation with the research community to address cutting edge science integrating key nutrient cycles. The Theme Leaders, and subsequently NERC's Science and Innovation Strategy Board (SISB), recommended to NERC Council that the research should be concentrated on more than one catchment but in a small number of catchments to stimulate the necessary cross-working between disciplines investigating both the processes of and inputs to the cycle interactions.

Subsequent capacity building (see 2010 workshop reports at http://macronutrient-cycles.ouce.ox.ac.uk/downloads) and consultation by the programme Director [Professor Paul Whitehead, University of Oxford] with researchers and users identified a number of potential catchments. At the workshop on 9 May 2011 a thorough review of catchments was undertaken and consensus reached about the selection of catchments. Details of the final recommendations of this working group are given at http://macronutrient-cycles.ouce.ox.ac.uk/downloads. The ranked selection of catchments was put to the workshop on 10 May 2011 with 120 representatives from the research community for approval and the selection was agreed.

2 Catchment Strategy

The working group on 9 May 2011 and the workshop on 10 May 2011 concluded that the following 3 catchments should be selected for the MC Programme:-

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Conwy (North Wales)
Avon (Hampshire)

It was agreed that whilst the proposals should have the majority of their research focussed in one or more of the 3 core catchments, we should welcome the inclusion of satellite sites, catchments, farmscapes /experimental units and national networks which enhance the research through the testing of models and provide information for upscaling, which cannot be efficiently carried out or are outside the scope of the core catchments selected.

As a result it has been decided that **the majority of the budget for proposals must be spent within at least one of the core catchments, though significant spending may be attributed to farmscapes, experimental units, additional satellite catchments, and upscaling.**

3 Details of the Selected Catchments

The catchments selected are the Ribble (Lancashire), the Conwy (North Wales) and the Hampshire Avon. The first two of these selected catchments are part of the Centre for Ecology and Hydrology source to sea catchment observatories programme, designed for landscape scale research from source to sea. They link with the Catchment to Coast

Initiative. Both catchments provide a good mix of urban and rural landscapes. The Conwy catchment is typical of non-industrialised areas of the north and west; it has few discrete agricultural and industrial sources, enabling easier attribution of large-scale drivers of change, e.g. climate and atmospheric pollution. In contrast the Ribble has a mixed urban and agricultural landscape with areas of upland and moor giving the opportunity to investigate the impacts of industry and agriculture as drivers of change. In addition, it has a good link to the estuary and to other initiatives, e.g. in the Irish Sea.

The last of the selected catchments is the Hampshire Avon, which is a case study site for the Demonstration Test Catchment (DTC) project recently launched by DEFRA, the Welsh Assembly Government and the Environment Agency (Figure 1). The aim of the DTC initiative is to provide a research platform from which a number of integrated ways of managing water and land across scales can develop. The Avon has been selected by DEFRA for its variable natural features, agricultural land use, and the existence of data from earlier research and monitoring studies. The DTC focuses on the headwaters of the catchment, is working at a $1km^2$ scales and centres on diffuse agricultural pollution. The Avon is an enhanced monitoring catchment under the England Catchment Sensitive Farming Delivery Initiative Programme, which is designed to reduce the level of surface water pollution caused by farming operations. This programme is a partnership between DEFRA, Natural England and the Environment Agency. The Hampshire Avon also has the advantage of a discrete estuary for research and drains into the south coast and the channel area. Further details of each catchment are given in Table 1 and in Appendix 2 to this note.

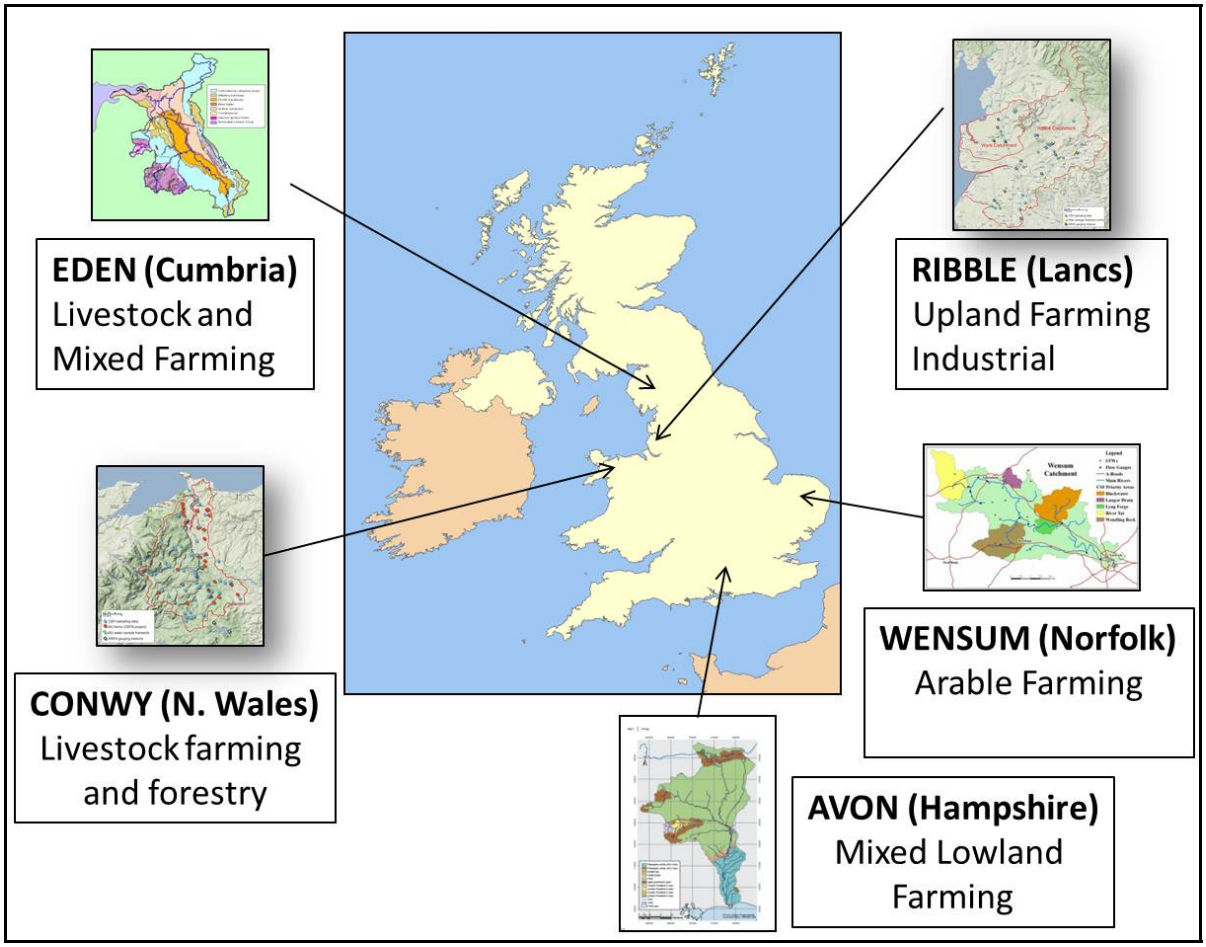

Figure 1 The DTC Catchments and the Selected MC Programme Catchments

Table 1. Characteristics of the selected catchments

	AVON (Hants)	**RIBBLE**	**CONWY**
Area (km^2)	1,750	2128	678
Main Channel Length (km)	96	100	55
Population	230,000	1,250,000	33,000
Elevation (m)	Min: 0 Max: 240	Min: 0 Max: 692	Min: 0 Max: 1064
Rainfall (mm)	700-800	850 -1700	900-3000
Dominant Geology	Chalk Tertiary sands/clays Jurassic Lst	Carboniferous: Lsts and sandstones Permo-Trias Sstns	Ordovician Silurian Cambrian: mixed igneous and sedimentary
Dominant soils	Brown redzinas, Brown earths	Stagnogleys	Brown podzolic; peats, gleys
Dominant land use	Agriculture: 75% Rural non agriculture: 23% Urban: 2%	Upland farming + Arable: 90%: Industrial: 10%	Upland Farming Mixed Livestock Arable Woodland
No. of NRFA flow gauges	12	12	2
Priority issues	-Soil structural degradation and nutrient management in greensand outcrops -Gateways as conduits for field for runoff carrying diffuse P -High Nitrate levels in sub-catchment	-Diffuse water pollution -Problems caused by limestone and sand extraction -Problems of low flow caused by excessive water abstraction	-Coastal pollution with pathogens and localised pollution with P, caused by downstream and rural wastewater discharges and upstream agricultural pressures, including sheep dips and unrestricted livestock access to water -Microbial pollution (point and diffuse) problems causing closure of shellfish beds leading to possible loss of sustainable fishery of Conwy -Acidification in headwaters, causing detrimental impact on the salmonid fishery

APPENDIX 1 RESEARCH AIMS AND KEY ISSUES

The overarching goal of the Macronutrients Cycles (MC) programme is to quantify the scales (magnitude and spatial/temporal variation) of N and P fluxes and the nature of transformations through the catchment under a changing climate and perturbed C cycle**.** 'The catchment' is defined as covering exchanges between the atmospheric, terrestrial and aqueous environments, with the limit of the aqueous environment being marked by the seaward estuarine margin.

Delivery of the overarching goal is through three secondary goals linking different science areas and a fourth goal concerned with impacts. All of the science goals, shown below, have technology science challenges embedded in them, and must interface with one another to deliver the overarching science goal.

1. To evaluate the nature and scale of macronutrient (N, C) exchange between the airshed and terrestrial system and consequences for fluxes (N, P, C) to soil, freshwater and atmosphere systems (atmosphere-terrestrial-freshwater feedback system).

2. To determine the role and spatial and temporal variation of macronutrients (N, P, C) on key limiting processes and ecosystem functions (i.e. decomposition, productivity, carbon sequestration) and consequent export at the catchment scale (terrestrial-freshwater systems).

3. To advance understanding of the co-limitation of N/P for eutrophication control in terrestrial systems and along the entire freshwater system to the estuarine boundary (freshwater system).

4. To determine the implications of nutrient enrichment on the fate and effects of other non-nutrient contaminants, including impacts on human health (i.e. pathogens, ozone) and biodiversity.

User issues:

1. Interaction and fate of N, P, and C within the aquatic environment
2. Relevance of the N,P, and C cycles to social and economic development: agriculture, industry, urban development, amenity resource
3. How changing N and P affects carbon footprint and food security.
4. Impacts of social, economic and climatic drivers of change on N,P,C functioning and the consequences to aquatic health
5. Production of a reliable ecosystem functioning model to predict physical, chemical and climate based changes

National Issues:

1. Climate change
2. Agricultural change in relation to the WFD and CAP reforms
3. Urban development and population growth
4. Improving our carbon footprint
5. Improving the aquatic ecosystem
6. Restoration of rivers to a better functioning ecosystem
7. A European dimension to legislation and environmental policy, Economic climate – reduced resources and the need for focus on critical issues

The user community is critical in linking 1,2,3, 4, 5, 6 within the context of the MC programme

APPENDIX 2 SUMMARY OF CATCHMENT SITES

THE RIBBLE CATCHMENT

Introduction

The Ribble catchment covers some 2128km^2 and comprises four major headwater tributaries: the Upper Ribble, the Hodder, the Calder and the Darwen (Figure A1). The river rises at an elevation of 692m in the Pennines, and flows east for 100km before running into the Irish Sea; it is one of the longest rivers in the North West.

The Ribble is an important site for nature conservation. There are a number of nationally and internationally protected sites within the area. These range from the Bowland Fell Special Protection Area (SPA) and Long Preston Site of Special Scientific Interest (SSSI) in the upper catchment, to the Ribble Estuary SPA where the Ribble enters the Irish Sea. The catchment is a priority site for the England Catchment Sensitive Farming Delivery Initiative (ECSFDI) run jointly by DEFRA, Natural England and The Environment Agency.

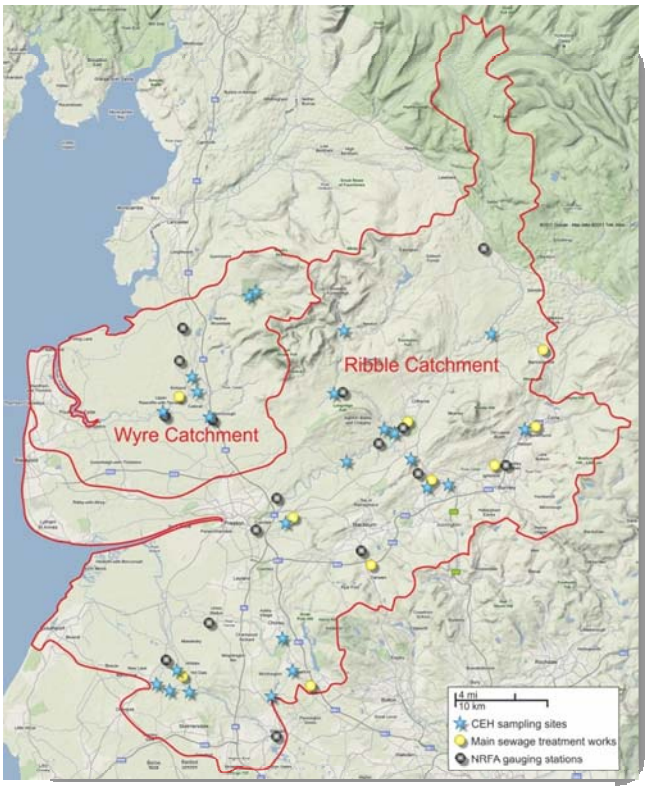

Figure A1 The Ribble Catchment

Geology

The oldest formations in the catchment are Silurian and Ordovician siltstones and mudstones which crop out in the Upper Ribble Valley around Settle. But most of the basin is underlain by rocks of Carboniferous age. These include the Millstone Grit, which underlies the Bowland Fells and Pendle Hill and further toward the coast the coal measures, a series of carbonaceous

mudstones and sandstones. The lower lying parts of the drainage basin toward the coast are for the most part underlain by Permian and Triassic sandstones.

Hydrology
South of Clitheroe the upper Ribble is joined by its two principal tributaries, the Rivers Hodder and Calder. The 'Big Ribble' continues through fertile pastoral land with a large amount of dairy farming and becomes tidal in Preston, Lancashire's administrative centre. The Ribble Estuary flows past the fertile Fylde plain on its way to the Irish Sea, where the coastline becomes increasingly urbanised from Lytham St Annes northwards towards the popular holiday destination of Blackpool.

The Standard Average Annual Rainfall (SAAR) for the Ribble catchment is 1350mm, but totals vary from over 1700mm on the higher ground of the headwaters to 800mm along the coast.

Land Use
The catchment has a population of 1.25 million, concentrated in a few urban areas including Preston, Blackburn, Wigan, and Blackpool, with the rest of the catchment (90%) predominantly rural. Agricultural activity is extensive throughout the area. The uplands above Settle and the Trough of Bowland are largely sheep farming areas with dairy predominating on the lower river. In the upland catchment, the farming is based around small villages. However, some upland farms are located on permeable limestone so spillages and other releases of pollutants can enter groundwater quickly, and re-emerge in surface waters deteriorating water quality. The problem is compounded by the soil of the Ribble area being predominantly clay, which increases the diffuse pollution from agricultural run-off.

The key urban areas within the catchment lie in the industrialised areas of East Lancashire adjacent to the River Calder and Darwen, such as Burnley, Nelson and Blackburn; and also in the lower reaches of the River Ribble at Preston and Walton-le-Dale. There are also numerous dispersed villages in the upper catchment, with some larger towns such as Settle, Clitheroe and Ribchester located in the middle to upper catchment. The industrial legacy of the Ribble catchment is evident in areas of East Lancashire where industrial buildings such as mills and factories were built over rivers, creating numerous culverted watercourses.

Current management issues
Both urban and rural activities have all had an impact upon the water quality and quantity of the Ribble. Historically, the landscape has also been modified as watercourses and wetlands were altered to improve land drainage. The general pressures on land and water include:

1. development and growth of urban areas which has led to increased pressures on water supply and the potential for point source pollution of surface and ground water sources;
2. transport networks criss-crossing the catchment—run off from road surfaces is a growing problem;
3. changing agricultural markets and the intensification of agriculture, especially in the context of diffuse water pollution;
4. the use of land by extractive industries across the river basin from limestone in the head-waters to sand extraction in the estuary;
5. water abstraction in parts of the catchment, leading to low flow problems.

Current activities
The Ribble catchment is one of the Centre for Ecology and Hydrology source to sea catchment observatories. As part of this initiative 26 sampling sites, ranging from rural to industrial catchments, have been established, including:

- full chemical analysis of at least monthly frequency for rivers,
- rapid deployment monitoring for hourly storm sampling,
- continuous discharge at most river sites and Environment Agency water quality data,
- monthly nitrate and chloride sampling at 26 sites,
- full nutrient and mass spectroscopic survey of particulate and dissolved material.

The catchment has also been used by the Environment Agency as a prototype for the development of a River Basin Management Plan incorporating all the requirements of the Water Framework Directive, Catchment Abstraction Management Strategies (CAMS), Catchment Flood Management Plans (CFMP), Shoreline Management Plans (SMP) and Fisheries Actions Plans (FAP).

Rules of engagement and points of contact
CEH data collected through National Capability funding will be made available to all parties via the CEH Gateway https://gateway.ceh.ac.uk/ in the coming months.

*Groups coming to work in the catchments should contact the local EA officer, Jackie Monk (Jackie.Monk@environment-agency.gov.uk**);** supported by Paul Simmons and Stuart Mounsey.*

Further details of the CEH data sets for the Ribble and CEH contacts are given in Table 2

Table 2 A summary of the CEH Ribble Data Sets

Project/dataset in addition to that provided by EA	Details	Duration	Frequency	Owner(s)	Contact and data type
Ribble Wyre Source to Sea	**National capability research**				**Paul Scholefield**, paul1@ceh.ac.uk
Bi-monthly/Monthly water quality	Stream sampling of major ions, metals, DOC, total N, pH, alkalinity (dissolved and particulate),chlorophyll. For 26 sites covering a range of landscapes and scales. Headwater streams, locations on the main river and estuary sites. Reduced to 6 sites from 2010.	2007-2011	Monthly	CEH	National Capability
Continuous discharge	Flow data for 26 sites, coincident with sampling points.	2010-2011	15 minute	EA	National Capability
Estuarine spot sampling	Phosphorus, salinity, sediment. 2 sites.	2009-2010	Monthly, Hourly	CEH	Available for research, subject to discussion with CEH
Historic water quality	Stream sampling of (mainly) major ions, DOC, total N, pH, alkalinity for sites covering a range of landscapes. Headwater streams, locations on the main river collected for a variety of historic projects.	1978-2006	Mixed, <Monthly	Mixed	National Capability
Spatial data	Analysis of catchment specific land use, and related data, e.g septic tanks, river centrelines.	1978-2011	Mixed	Mixed	National Capability
Pathogens(Wyre/Ribble)	**Ribble Wyre Source to Sea**				
Microbial pollution in the Ribble and Wyre	Spot sampling	2010-11	Single Survey	CEH	Ongoing research project, Glen Rhodes (CEH)
Topographic data	**Land Cover and Topographic data**				
Lidar survey	0.5m, 1.0, 2.0 resolution survey of majority of the Ribble and Wyre Basins.	2009	Single survey	EA	Available for research, subject to discussion with EA
Land Cover Map	Land cover map of the UK	1990, 2000, 2007	Single survey	CEH	Available for research, subject to discussion with CEH
Biological Data					
Ribble saltmarshes livestock grazing (CEH)	Plant, invertebrate, nematode, small mammal, soil processes and greenhouse gas emissions.	2008-2010	Single survey	CEH	Available for research, subject to discussion with CEH
River Habitat Survey, Aquatic macrophyte database, Shellfish data	Sampled along stretches of the Ribble	1978 - 2000	Annual, single surveys	Mixed	National Capability

THE CONWY CATCHMENT

Introduction

The River Conwy is the third largest river discharging into the Irish Sea along the North Wales coast. It drains a catchment of 678 km^2, the main drainage channel covering a distance of 55 km (Figure A2). The river rises in the Snowdonia National Park, in the Migneint range, at an elevation of 460 m AOD. The upper reaches of the river cross upland blanket bog and moorland, passing through improved grazing land and conifer plantations via steep gorges to the town of Betws y Coed. The lower Conwy, which flows through extensive flood plains and by several larger towns, meets the tidal limit at Llanrwst, around 20 km inland from the estuary mouthy. Three major tributaries (the Machno, Lledr and Llugwy) join the upper Conwy from the west, and drain many of the high mountains of Snowdonia. The tidal Conwy receives further inflows from a number of smaller tributaries.

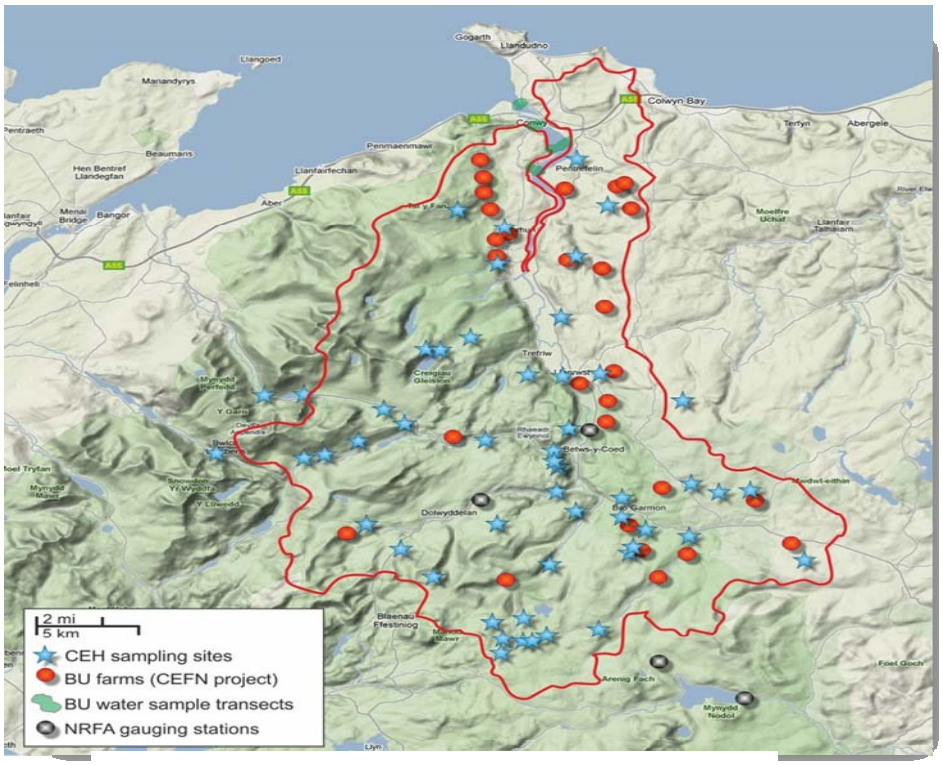

Figure A2 The Conwy Catchment

Overall proportions of major soil and land use classes are close to the Welsh national average, and the catchment therefore provides a good representation of the wider Welsh landscape.

The catchment contains many important conservation sites. The western and southern parts of the catchment fall within the Snowdonia National Park. There are 5 candidate sites for designation as Special Areas of Conservation (cSAC) under the Habitats Directive and 46 Sites of Special Scientific Interest (SSSIs), 25 of which are water dependent.

Important stakeholders in the catchment include the Conwy Rural Partnership, the Clwyd and Conwy Rivers Trust, Dŵr Cymru/Welsh Water, the National Trust, the Forestry Commission

Geology

The spectacular upland features to the west of the river within the Snowdonia National Park have resulted from glacial action on the resistant Ordovician and Cambrian rocks of the region. The softer more homogenous Silurian deposits to the east eroded more readily, resulting in the rounded moorland summits of the Denbighshire Moors. In post-glacial times, as sea levels rose

and fell, the valley floor has been filled in with muds and silts from below and by alluvium carried down from the fast flowing rivers above.

The Ordovician and Silurian rocks do not make good aquifers. For this reason groundwater abstraction in Gwynedd and Conwy at the present time is exempt from licensing.

Hydrology

Thin soils, steep topographic gradients, impermeable rock and high rainfall lead to a rapid hydrological response. Mean annual runoff at the Cwm Llanerch gauging station, above the tidal limit, is 19 $m^3 s^{-1}$ (1.74 m yr^{-1}), with a mean annual flood of 376 $m^3 s^{-1}$. Historically this has caused frequent inundation of the floodplain and its villages and towns, such as Llanrwst and Trefriw. Flood protection measures have been implemented over the years, and are under continuing development. Several large reservoirs used for water supply and hydroelectric power generation with an extensive network of leats are located in the northwest of the catchment, draining the Carneddau mountains. These affect the catchment hydrology to the extent that some tributaries are classified as "heavily modified" under the EU Water Framework Directive.

Land Use

The catchment is predominantly rural, with sheep farming as the main land-use to the west and mixed dairy, beef and sheep farming to the east. The lowland flood plain area, downstream of Betws-y-Coed, has some arable farming which requires improved drainage. To the west of Betws-y-Coed there is a large afforested area, the Gwydir Forest, containing numerous abandoned mine adits which leach metal-bearing mine waters into several tributaries of the main river. The upper catchment is given over mainly to sheep farming. There is extensive semi-natural woodland cover in most sub-catchments including important areas of wet woodland. The Conwy estuary is in part managed by the Royal Society for the Protection of Birds. It has important salt marshes which have been landscaped into several ponds for observation purposes. There is also an historic mussel fishery in the estuary.

The catchment landscape is of exceptionally high aesthetic quality, and tourism is the main contributor to the local economy. Livestock farming and forestry management maintain the landscape quality as well as being productive in their own right.

Current management issues

There are a range of water quality and flow issues in the catchment requiring management including:

- coastal pollution with microbial and viral pathogens, affecting shellfish Consistent production of a good quality product is essential for a successful shellfish business. In the Conwy catchment the problem of increased microbial loadings on shellfish beds affects the production of a consistently high quality product. Microbial pollution has also forced the failure of blue flag bathing beaches. The closure of the fishery along with the loss of tourist income due to the closure of the blue flag beaches would cause not only a direct loss to the local economy, but also large indirect economic losses.
- localised pollution with phosphorus, caused by downstream and rural wastewater discharges
- upstream agricultural pressures, including sheep dips and contamination caused by unrestricted livestock access to water,
- persistent acidification in the headwaters, which is having a detrimental impact on the salmonid fishery.
- major flooding in the lower valley. During 2004/2005 a £5m flood alleviation scheme was implemented to alleviate this problem.

- the upper Conwy blanket bog was heavily drained during the mid-20th century, and was previously managed as a shooting estate. The National Trust, who now own much of the area, undertake conservation management and have recently initiated a major programme of blanket bog restoration through blocking of drainage grips, with the aims of enhancing carbon storage, improving biodiversity and reducing downstream flooding and water quality problems. Traditional summer grazing of the blanket bog has declined significantly during the last decade. Dissolved organic carbon (DOC) concentrations have been rising in surface waters since the 1980s, and have affected water supplies including Llyn Conwy, a high-DOC headwater lake used for supply.

Current activities

There are a number of initiatives currently underway in the catchment, many of them operating under the auspices of the CEH Source to Sea and Carbon Catchment research platforms, including.:

- detecting environment change and identifying key processes of environmental change in terrestrial and freshwater habitats, including those at the interface with marine systems, using a combination of long-term monitoring, designed surveys and experiments (e.g. Countryside Survey, ECN, AWMN, EU projects);
- quantifying peatland carbon and greenhouse gas balances through a combination of gaseous greenhouse gas flux measurement (eddy covariance, static chambers) and fluvial carbon flux monitoring (CEH Carbon catchments)
- quantifying and modelling carbon, nutrient and pollutant fluxes from terrestrial to freshwater and inter-tidal areas (CEH Source to Sea observatory)
- characterising the physical and chemical behaviour of a peatland headwater lake, Llyn Conwy (part of the NERC lake buoy sensor network)
- improving catchment environmental quality by better management of diffuse pollutants through farmer liaison, improved nutrient and stock management on farms (CEFN-Conwy project funded through the Rural Development Programme by EU and WAG)
- monitoring of forest stand dynamics in coniferous and semi-natural woodlands funded by FC and CCW

A number of other major experiments are also being conducted in the catchment, including:

- long-term climate change and deposition manipulation experiments on peatlands to determine controls on soil carbon sequestration and feedbacks to the climate system (CEH, Bangor University);
- a five-year Defra- and EU-funded field experiment on the impacts of grip-blocking on the carbon and greenhouse gas balance of the blanket bog (CEH, Leeds and Bangor Universities)
- a Defra-funded study of the processing and fate of peat-derived organic carbon within the river network, from headwaters and lakes to the estuary (CEH, Bangor, Durham, Leeds and Manchester Universities).
- a NERC-led study of the drivers of rising DOC in surface waters, and their implications for water treatment, including human health impacts (Bangor University, CEH).
- developing response functions describing current invertebrate and plant biodiversity in terrestrial, freshwater and coastal environments in relation to key environmental variables/drivers to predict future changes in biodiversity (CEH)

More studies are being undertaken at coastal sites. This Coastal Research covers a number of topics:

- CEH work focuses on nutrient pollution and climate change in two key coastal habitats – saltmarsh and sand dunes.
- impacts of atmospheric nitrogen deposition on stabilisation and species loss in sand dunes
- how changes in water table dynamics affect plant species composition
- adaptive management options to mitigate adverse effects of large-scale environmental drivers such as climate change and nitrogen
- impacts of flow, nutrients and contaminants on inter-tidal communities
- options for adaptive management including managed retreat in response to increased storminess and sea level rise.

Previous work within the Conwy catchment includes a Defra-funded assessment of the ecosystem services provision of the Migneint SAC. This work, led by Moors for the Future, included quantification and modelling of the effects of land-management on climate regulation, water quality regulation, flooding, provisioning services, recreation and biodiversity.

Studies by Bangor University in conjunction with Conwy County Borough Council are focusing on the river estuary continuum. These studies are elucidating pathogen dynamics in the Conwy with field observations and experiments ranging from river samples collected at Betws y Coed to seawater samples collected over the mussels beds and bathing beaches. The mussel beds and bathing beaches are also being extensively studied in terms of microbial and viral pollution. Currently funded projects include:

- Microbial pollution in the Conwy estuary: Assessing microbial pollution dynamics in the Conwy river and estuary. This project includes recommendations for remedial actions and potential climate change alterations.

- Microbial pollution in shellfish: Assessing microbial pollution dynamics in the mussel beds and bathing beaches in the Conwy.

- Viral pollution in shellfish: Assessing viral pollution dynamics in the mussels beds and bathing beaches in the Conwy. Tracing of contaminant in the Conwy.

Rules of engagement and points of contact

CEH in partnership with Bangor University and the National Trust has established an array of research and monitoring activities in the Conwy. CEH data collected through National Capability funding will be made available to all parties via the CEH Gateway https://gateway.ceh.ac.uk/ in the coming months.

Groups coming to work in the catchments may find information on the Conwy Rural Partnership http://www.ruralconwy.org.uk/ website of value. All groups should contact the local EA officer, Wendy Price (wendy.price@environment-agency.wales.gov.uk) at the EA to establish contact with local landowners.

Further details of the CEH data sets for the Conwy and CEH contacts are given in Table 3

Table 3 A summary of the CEH Conwy Data Sets and Contacts

Project/dataset in addition to that provided by EA	**Details**	**Duration**	**Frequency**	**Owner(s)**	**Contact and data type** *(National capability indicates data will be made available; other data info provided to prevent duplication)*
Conwy Source to Sea				CEH	**David Cooper**, cooper@ceh.ac.uk
Monthly water quality	Stream sampling of major ions, DOC, total N, pH, alkalinity for ~20 sites covering a range of landscapes. Headwater streams, locations on the main river and estuary sites.	2007-2011	Monthly	CEH	National Capability
Quarterly water quality	Stream sampling of major ions, DOC, total N, pH, alkalinity for 60-70 sites covering a range of landscapes. Headwater streams, locations on the main river and estuary sites.	2008-2010	Quarterly	CEH	National Capability
Continuous water quality	Continuous water quality sensors measuring temperature, pH, conductivity	2010-2011	Hourly	CEH	National Capability
Historic water quality	Stream sampling of (mainly) major ions, DOC, total N, pH, alkalinity for sites covering a range of landscapes. Headwater streams, locations on the main river collected for a variety of historic projects.	1994-2006	Mixed, <Monthly	Mixed	
River invertebrates	Sampled at 25 locations coincident with headwater water quality sampling sites	2008-2010	Annual	CEH	National Capability
Carbon catchment	**CEH and linked Defra and PhD research projects, Upper Conwy (Migneint)**				**Chris Evans**, cev@ceh.ac.uk
Eddy covariance CO_2, CH_4	Flux tower on blanket bog – CO_2 since 2010, CH_4 sensor added in 2011.	2010-2011	30 minute	CEH	National Capability
Static chamber CO_2, CH_4	Multiple sites on blanket bog (intact, drained and restored, and for a range of vegetation types), acid grassland for PhD, NERC and Defra projects	2007-2011	Monthly	CEH, Bangor University, Leeds University	Ongoing research projects, PhD research
Water table	Dipwells with water table loggers co-located with static chambers		Hourly	CEH	National Capability
Stream stage, temperature, discharge	Gauged section on peatland stream	2008-2011	Hourly	CEH	National Capability
Meteorology	Automatic weather station	2009-2011	30 minute	CEH	National Capability

Two-weekly water quality	Monthly/two weekly stream sampling of major ions, DOC, total N, pH, alkalinity for peat stream, subsidiary monthly data from other sites (linked to Source to Sea project)	2006-2011	Two-weekly	CEH	National Capability
Continuous water quality	Continuous water quality sensors measuring temperature, pH, conductivity	2007-2011 (discontinuous)	Hourly	CEH	National Capability
Llyn Conwy monitoring	**CEH project, now part of NERC lake buoy sensor network**				**Chris Evans**, cev@ceh.ac.uk
Meteorology	Automatic weather station on lake buoy	2006-2007, 2011	Hourly	CEH	National Capability
Water temperature	Thermistor chain on lake buoy, 2 m intervals from 1 m to 19 m	2006-2007, 2011	Hourly	CEH	National Capability
Monthly water quality	Lake outflow major ions, DOC, total N, pH, alkalinity. EA/Welsh Water data since 1980.	2006-2011	Monthly	CEH, EA, Welsh Water	National Capability
Continuous water quality	Continuous water quality sensors measuring temperature, pH, conductivity on lake outflow	2010-2011	Hourly	CEH	National Capability
Freshwater dissolved organic carbon research	**Defra- and NERC-funded research projects**				**Chris Evans**, cev@ceh.ac.uk
Fate of fluvial carbon	Synoptic surveys of DOM processing at multiple locations through the lake and river system, field and laboratory studies of DOM degradation under ambient and changed pH, nutrient concentrations, solar radiation and climate	2010-2011	Quarterly	CEH, Bangor Leeds and Durham universities	Ongoing research project
DOC health impacts	Episode sampling and characterisation of peat-derived DOC in water supplies	2010-11	Episodic	Bangor University, CEH	Ongoing research project
Estuarine DOC processing	Transect studies of DOC and POC through the freshwater-marine interface	2010-11	Quarterly	CEH	Ongoing research project
Agricultural nutrients	**Rural Development Programme (EU and WAG)-funded research project**				**Julie.williamson@bangor.ac.uk**
Farm nutrient management	On-farm questionnaire survey of nutrient management practices, field soil sampling and slurry sampling (no river monitoring)	2009-2011	Survey sampling only	Bangor University	Ongoing research project
Pathogen research in the Conwy Estuary	**KTP, Convergence and industrial funded projects. All projects involve a large stakeholder group**				**Shelagh Malham,** S.Malham@bangor.ac.uk.
Microbial pollution in the	KTP between BU and Conwy County Borough Council.	2010-11	Episodic	BU and CCBC	Ongoing research project

Conwy	Transect studies of water and sediment in the Conwy				
Shellfish microbial pollution	PhD funded by Convergence and Bangor mussel producers. Investigation microbial pollution in shellfish	2010-2013	Episodic	BU	Ongoing PhD research project
Viral pollution in Shellfish	PhD funded by Convergence and Bangor mussel producers. Investigation viral pollution in shellfish	2010-2013	Episodic	BU	Ongoing PhD research project
Pathogens dynamics in the Conwy	PhD funded by Convergence and Welsh Water. Investigating pathogen dynamics in the Conwy	2011-2014	Episodic	BU	To be appointed
Contaminants in the Conwy	A4B funded. Investigation sources and sinks in the Conwy	2010-2012	Episodic	BU	Ongoing project
Topographic data	**National Trust survey of the Ysbyty Estate**				**Trystan Edwards,** trystan.edwards@nationaltrust.org.uk
Lidar survey	0.5m resolution Lidar survey of 8000 ha Ysbyty Estate, includes the part of the Migneint blanket bog which drains to the Conwy, and 51 hill farms in the upper Conwy and Machno valleys	2009	Single survey	National Trust	Available for research, subject to discussion with National Trust

HAMPSHIRE AVON CATCHMENT

Introduction

The Hampshire Avon lies within the counties of Dorset, Hampshire and Wiltshire and has a catchment area of approximately 1,750 km^2 (Figure A4). It is largely a spring fed, groundwater dominated river giving relatively stable base flow throughout the year.

The majority of the river is designated as a Site of Special Scientific Interest (SSSI); it has also been declared a Special Area of Conservation (SAC) under the EU Habitats directive. By and large the SAC and SSSI cover almost the same geographical area. Parts of the catchment lie within Areas of Outstanding Natural Beauty (AONB), areas of high scenic quality that have statutory protection in order to conserve and enhance

Many of the SSSI units are currently judged to be in an unfavourable condition mainly due to adverse nutrient levels, particularly phosphates, and reduced flows either from abstraction or historic land drainage and channel modifications. Currently only 30% of water bodies in the catchment are considered to be in a good ecological condition.

There is a long history of farmer engagement in the catchment. The Landcare Partnership was set up by the Environment Agency in 1997 to educate and influence farmers to adopt best practice to reduce soil and nutrient loss, make best use of farm wastes and save money.

Geology

The Hampshire Avon, although predominantly a Chalk catchment, has a varied geology (Figure A2). Much of the upper catchment is underlain by the Chalk of Salisbury Plain. But elsewhere older formations such as the Upper Greensand, Gault, Lower Greensand, Wealdon clay and the Purbeck and Portland Limestones are exposed. In other places Tertiary deposits such as the London Clay, Poole Formation, Branksome Sand and Barton Group all overly the Chalk. Also present are important river terrace deposits and alluvium, which are present in the Avon valley south of Salisbury.

Except for some areas in the New Forest, the river is largely spring-fed with the Chalk strata providing a large storage capacity and relatively stable base flow throughout the year. The Chalk and Upper Greensand are classified under the EA Policy and Practice for the Protection of Groundwater as highly vulnerable major aquifers, providing an important resource for potable, industrial and agricultural supply.

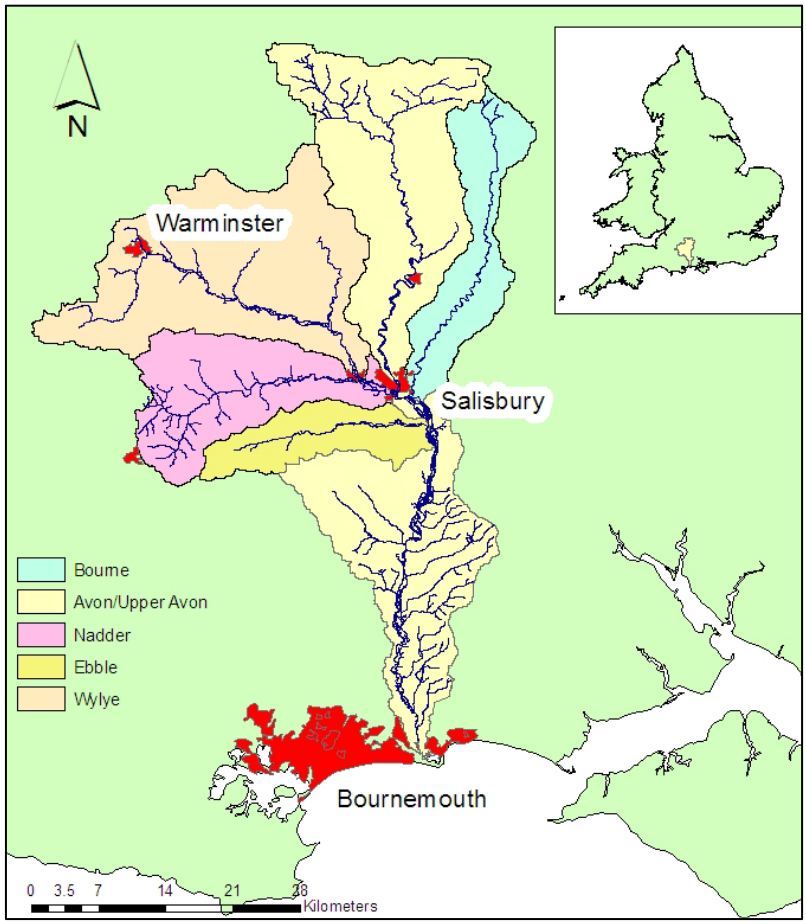

Figure A4: River Avon, Hampshire

Hydrology

Annual average rainfall in the catchment varies from 700-800 mm on the coast to more than 900mm over the western tributaries of the Nadder and Wylye. The 1961-1990 annual average rainfall for the Avon catchment as a whole was 810mm. This compares to the average for England and Wales of 920mm.

Hydrological differences are observed across the catchment, reflecting the different geologies. The proportion of infiltration which discharges as quick flow is highest in the Nadder catchment, headwaters of the Wylye and East Avon catchments, and the streams draining the New Forest. The Baseflow Indices (BFI) at gauging stations in the catchment range from 0.70 on the Nadder at Wardour, which drains predominantly Upper Greensand with Chalk and Gault, to 0.92 on the Bourne at Laverstock which drains a permeable Chalk catchment. There are 12 Environment Agency flow gauging stations along the length of the river.

Land use

The catchment is predominantly rural in character, with approximately 75% of the land farmed or used for agriculture. The area supports a population of over 200,000 people, approximately 60% of which live in the larger towns of Amesbury, Christchurch, Fordingbridge, Pewsey, Ringwood, Salisbury and Warminster. The area is heavily influenced by military activities, with several large military bases mainly concentrated on and around Salisbury Plain. Other industrial activity is mostly light and located within the towns. Agriculture in the catchment is diverse with cereal, cattle and sheep farming identified as the predominant activities. Arable land is predominantly located in the upper catchment and grassland in the valleys and lower catchment. The upper catchment is farmed more intensively than the Lower Avon, large parts of which are

still managed on an extensive grazing system. The catchment retains a relatively high proportion of semi-natural habitats in the form of woodland, scrub and marsh.

Current management issues

There are a number of management pressures on the catchment both in terms of water quality and quantity.

1. Abstractions for public water supplies are from both ground and surface waters in the Hampshire Avon catchment. In some areas, particularly in the upper reaches of the catchment, groundwater abstraction contributes to the risk of unacceptably low flows in rivers during the summer months.
2. Agricultural land and farming activities contribute significant loads of nitrate, phosphorus and sediment to surface and ground waters in the river.
3. Rivers in the catchment receive treated domestic effluent from 12 large municipal sewage works. There are also a significant number of single dwelling or small community discharges within the area, some of which are consented. Such input poses a potential threat to activities such as fish farming and the cultivation of water cress.

Current activities

A number of activities and research projects are currently being undertaken in the catchment. These include:

1. The catchment is a DEFRA Demonstration Test Catchments (DTC) set up to assess the effectiveness of on-farm mitigation measures for reducing diffuse pollution from agriculture to water.
2. It also forms part of the 'The England Catchment Sensitive Farming Delivery Initiative' (ECSFDI) which aims to identify ways to reduce Diffuse Water Pollution from Agriculture
3. Currently 13 water- quality and - flow related scientific studies are being conducted in the catchment; these are all documented in Annex 3 of the Avon catchment appraisal study produced by DEFRA.

Rules of engagement and points of contact

Initial enquiries and approaches with respect to undertaking research in the Hampshire Avon should be directed towards the DTC manager at DEFRA (daniel.mcgonigle@DEFRA.GSI.GOV.UK) and the Avon DTC consortium leader Professor Adrian Collins (adrian.collins@adas.co.uk) or Fiona Grant whio is the principal local contact; fiona.grant@adas.co.uk). The Avon Data Manager for the DTC is Hafedh Benamor (hafedh.benamor@adas.co.uk) and further information is available at the Avon DTC website at http://www.avondtc.org.uk/. See APPENDIX 3 for 'research groups coming to work in the Demonstration Test Catchments".

Groups coming to work in the catchments should also contact the local EA officer, Julian Wardlaw (Julian.Wardlaw@environment-agency.gov.uk) at the EA to establish contact with local landowners.

APPENDIX 3

PROTOCOLS FOR RESEARCH GROUPS COMING TO WORK IN THE DEMONSTRATION TEST CATCHMENTS

A major objective of the Demonstration Test Catchments (DTC) project is to establish a platform or "outdoor laboratory" to host collaborative land management research, consisting of:

- **A national network of catchment-scale study sites.** DTC water monitoring will collect temporal and spatial data on ground/surface water, flow and ecology.

- **Data infrastructure** to allow others to freely use data and information generated in the DTCs and to promote collaboration in research and analysis.

- **Co-ordinated catchment-science research activities.** The DTC catchments will host future research projects on agriculture and other aspects of land management. These will interact to develop an understanding of the interactions of multiple factors (e.g. food production, biodiversity, flood protection, air quality, greenhouse gas emissions, farm economics etc). There will be a co-ordinated approach to the development and calibration of modelling approaches to assess the expected outcomes of policy interventions for achieving multiple objectives.

- **A community of researchers, policy makers, delivery bodies and other stakeholder groups** who are developing a shared understanding of the policy challenges, evidence gaps and practical implications of addressing diffuse agricultural pollution in the context of wider objectives and ecosystem services which land management is expected to provide.

Establishment of the platform: A consortium has been established in each of the three DTC study catchments through a project to provide underpinning research, from farm to catchment scale, that informs both policy and practical approaches for the reduction of agricultural diffuse pollution and the improvement of ecological status in freshwaters, whilst maintaining economically viable food production. In establishing this, consortia have built up working relationships with land owners, land agents, estate managers, farmers and a range of other stakeholders including fishery organisations.

Long-term persistence of platform: In order to maintain the catchment-scale water quality research that is being established through DTC beyond the initial 5-year timeframe, it is important to bring new projects and groups into the DTC catchments to undertake catchment research.

Developing integrated approaches to land management to achieve multiple outcomes: Whilst the core DTC project focuses on water quality in relation to land management, it is recognised that the platform could be used to host research on other areas related to agricultural land management.

General guiding principles:

DTC has established a series of guiding principles for groups wishing to undertake work on the research platform:

1. New groups are welcomed into the DTC to undertake research.

2. Data from projects hosted in the DTC catchments will be made available to all parties via the DTC data hub.

3. New collaborations and partnerships are welcomed by all of the DTC consortia with a view to build upon the research platform infrastructure that is currently under construction and to expand research through a coordinated strategy.

4. Groups coming to work in the DTC catchments

    a. Are invited to join the growing DTC land management community of interest and take part in knowledge exchange activities with policy makers and other stakeholders. This will be achieved by joining the local stakeholder group for each catchment.

    b. Are asked to make data available via the DTC data hub

    c. Must negotiate access to field sites via established points of liaison as detailed in the table below. This must be strictly adhered to in order to manage relationships with local landowners, to ensure that farmers are not contacted by multiple organisations. New collaborators must work closely with the local DTCs to manage this.

    d. Are asked to consider interactions with existing research activities in their design of experiments through early liaison with the DTC consortia.

Avon	Eden	Wensum
Points of contact:		
Initial enquiries and approaches with respect to undertaking research in the Hampshire Avon DTC should be directed towards the Avon consortium leader Professor Adrian Collins (adrian.collins@adas.co.uk) or Fiona Grant (principal local contact; fiona.grant@adas.co.uk).	Contacts regarding local knowledge on the sites and sub catchments: Dr Sean Burke (sean.burke@newcastle.ac.uk) and Dr Will Cleasby (will@edenriverstrust.org.uk). For more general enquires on the contact the DTC manager Prof Phil Haygarth (p.haygarth@lancaster.ac.uk) Potential partners are strongly requested not to approach farmers or landowners without first approaching EdenDTC.	In order that farmers are not contacted by multiple organisations, prospective new research partners are requested to contact either of the project leaders: Dr Kevin Hiscock (k.hiscock@uea.ac.uk), Prof. Andrew Lovett (a.lovett@uea.ac.uk) or to contact Dr Trudie Dockerty via the Wensum Alliance (wensumalliance@uea.ac.uk) to discuss farm liaison.
Stakeholder groups:		
All collaborators and partners are required to join the local stakeholder group which acts as the forum for leading the programme of work. This local stakeholder group meets at least four times per year (typically at the Game and Wildlife Conservation Trust HQs at Fordingbridge).	All partners are required to sit on the Eden DTC consortium management group, which meets four times a year. This is particularly important with regard to working with local farming communities and landowners. This is particularly important with regard to working with local farming communities and landowners.	To encourage the development of a 'community of practice', research partners are expected to engage with the Wensum Alliance through knowledge exchange activities, including attendance at annual stakeholder meetings. In addition, in the spirit of a participatory approach, researchers are requested to deposit copies of reports and datasets with the Wensum Alliance for dissemination to stakeholders through its website and newsletters.
Data format and delivery		
Where appropriate, datasets will be incorporated into WISKI and GIS database systems held on secure servers prior to forwarding to the Freshwater Biological Association that is tasked with both archiving data from the DTC consortia and in developing web portals for knowledge dissemination. Queries regarding data format and delivery can be made to:		
Avon Data Manager: Hafedh Benamor (hafedh.benamor@adas.co.uk)	Eden Data Manager: Mark Wilkinson (m.e.wilkinson@newcastle.ac.uk)	Wensum Data Manager, Dr Tobias Krueger (t.krueger@uea.ac.uk)
Websites:		
http://www.avondtc.org.uk/.	http://www.edendtc.org.uk/.	http://www.wensumalliance.org.uk/ mailto:wensumalliance@uea.ac.uk

Experimental plans for testing diffuse pollution mitigation at the catchment scale:

Each DTC consortium is establishing a catchment-scale experiment to test combinations of measures for mitigating diffuse water pollution from agriculture.

Additional R&D projects, hosted on the DTC platform, may include research to:

- Test individual measures at the field scale
- Monitor additional environmental variables in relation to farm practices (e.g. pesticides, flooding, biodiversity, air quality, greenhouse gas emissions etc).
- Develop and test integrated approaches to farm management
- Understand biogeochemical processing and catchment processes

Groups undertaking these future projects will work closely with DTC consortia to ensure that research is well coordinated, projects build on each other and that catchment-scale measure testing is not compromised. The approaches for measure testing in each of the DTC catchments are summarised below:

Hampshire Avon

The Hampshire Avon catchment comprises mixed agriculture and the DTC platform is focusing on using target sub-catchments on clay (River Sem), greensand (River Nadder) and chalk (Rivers Ebble and Wylye). The Avon DTC platform has recently been expanded into the River Tamar catchment in SW England, working on the River Ottery tributary. Both study areas are England Catchment Sensitive Farming Delivery Initiative (ECSFDI) priority catchments. Investigations into the efficacy of diffuse pollution mitigation measures are examining a spectrum of intervention intensity, including the use of a constructed wetland at the outlet of one target sub-catchment (low intensity), agri-environment measures in ELS together with some carefully targeted additional options (medium intensity) and water company-funded payment for ecosystem services (high intensity). The planning of mitigation measures is mindful of the source-mobilisation-delivery-impact diffuse pollution continuum and the need to support the agricultural sector with respect to critical business considerations. Experiments examining the efficacy of interventions are based on a comparison of control and manipulated sub-catchments (Before-After, Control-Impact version 1) or upstream and downstream datasets (Before-After, Control-Impact version 2). The monitoring of conventional water quality determinants at the target sub-catchment outlets is being synthesised with repeat source apportionment (pre- and post- mitigation) and a range of additional metrics (e.g. engagement, attitudes, implementation and behaviour data; pollutant mobilisation; soil surveys) in an integrated toolkit for catchment appraisals as a means of maximising the opportunity for reporting positive outcomes within the lifespan of the current DTC project. The integrated toolkit will be tested and revised using 'communities of practice' focused on helping to develop bottom-up river catchment management as part of the 'big society' initiative launched by the coalition government.

Wensum

The Wensum is an intensive arable catchment in northern East Anglia. The Wensum DTC is concentrating its monitoring activities in the Blackwater Drain sub-catchment in the area north of Reepham. The Blackwater Drain is an ECSFDI priority area in which four mini-catchments (A, B, C and D) have been identified for monitoring with a nested sampling approach. The table below shows a simplified land cover profile (in hectares) for the four mini-catchments. The planning of mitigation measures embraces the source-mobilisation-delivery diffuse pollution paradigm and recognises the need to respect the practicalities of farm business operations.

Almost all of the area is already in agri-environmental schemes, with ELS predominating in mini-catchments A and B, while much of C and D are in Countryside Stewardship. The Broads & Norfolk River Valleys HLS Target Area covers mini-catchment C and smaller parts of B and D. Current measures include 6 m margins around most cultivated areas and some wider headlands (e.g. in field corners). In mini-catchment areas A and B, an ELS agreement is expected to result in 6 m buffers alongside all water course margins, to extend 6 m margins to fields where they are presently not included and to allow natural regeneration of redundant field corners. There is a willingness among local farmers to employ minimum tillage methods or measures such as over-wintered stubble prior to sugar beet planting. More generally, there is a preference for planting autumn-sown crops. A target for minimum tillage would be several large arable fields that border some of the stream courses. Precision farming methods are also a possibility. There are some existing no- or low-input grassland areas in riparian zones with the possibility of extending areas of wet woodland and in developing scrapes and constructed wetlands with the aim of slowing hydrological flow paths. Hence, the Wensum DTC consortium is particularly interested in evaluating the effects of: (i) increased use of minimum tillage and/or precision agriculture techniques; (ii) the provision of sustainable drainage systems (SuDS) e.g. scrapes, in-ditch wetlands and associated vegetation at key points in the stream network; (iii) the management of field drains; and (iv) the creation of new areas of grassland or wet woodland.

Sub-Catchment	Woodland	Arable	Grassland	Other Land	Total
A	8.6	446.7	3.3	2.4	461.1
B	6.5	133.1	0.8	0.0	140.4
C	74.5	249.2	45.0	1.8	370.5
D	81.2	473.3	100.3	7.5	662.3
Total	170.8	1302.3	149.3	11.8	1634.2

Note: statistics calculated from LandCover Map 2000.

Eden

The Eden catchment is a mixed grassland catchment in the North West of England. Eden DTC is focussing activities on three sub catchments (Pow, Moreland, Dacre) and one demonstration farm (Newton Rigg). The general approach in the Eden is that mitigation should be approached through the source –mobilisation–delivery framework and that this needs to work closely with local farmers and landowners, with ownership and empowerment at the heart of the approach. Eden is eligible to ELS and HLS. The Eden is a priority catchment for CSFI and the mitigation strategy should also complement/work with existing initiatives particularly the NWDA livestock programme and CSFI. There are already some funded streams of activity in the Eden and the potential to expand the partnerships through Defra, EA , CSFOs, research councils and European funding is either already in place or is being pursued. The Eden DTC is already committed to 'cleaning' up 3, two km^2 catchments within the DTC sub catchments. 'Mobilisation' control will require all 'hotspots', e.g., farm standing local foul water drains and vulnerable fields, to be identified. A series of interventions including new guttering, drains, ponds, lagoons and soakaways will also be required. The evidence base for strategy can be largely determined by before–after, control-impact studies. 'Delivery' management will require a landscape scale assessment of flow pathways, including edge of fields, roads, tracks, land drains, riparian areas and both small and larger scale wetlands. Dr Paul Quinn

(p.f.quinn@newcastle.ac.uk) and Prof John Quinton (j.quinton@lancster.ac.uk) are the contacts for more information on the mitigation strategy Eden DTC.