CATCHMENT HYDROLOGY AND SUSTAINABLE MANAGEMENT (CHASM): GENERIC EXPERIMENTAL DESIGN

Paul Quinn, Enda O'Connell, Chris Kilsby, Geoff Parkin, James Bathurst, and Paul Younger

Water Resource Systems Research Laboratory, School of Civil Engineering and Geosciences, University of Newcastle upon Tyne, (Email: P.F.Quinn@ncl.ac.uk)

ABSTRACT

CHASM is a new UK long-term programme of research in which multi-scale catchment experiments, new theoretical developments and modelling will be used together to generate the scientific understanding needed to underpin sustainable catchment management. The first major project to be funded under CHASM is NICHE (National Infrastructure for Catchment Hydrology Experiments) which will provide £4M of funding to instrument a set of seven UK mesoscale catchments; three of these are the focus of a NERC-funded Thematic Programme of Lowland Catchment Research (LOCAR). The CHASM project goals are to create an unrivalled suite of static and dynamic hydrological and water quality parameters for the purposes of improved land classification and simulation across scale. Moreover, the generic instrumentation design allows the sampling strategy for measurements to evolve and change with time so that improved methods of creating robust water quantity and quality time series can be suggested. Also, new rapid data acquisition techniques based on hydro-geophysical methods and rapid, high-resolution surface mapping will be both validated using ground truth data and then evaluated as the basis of future rapid hydrological spatial and temporal site characterisation. Together, a vision for future large scale land characterisation, fluxes of water quantity and quality and new modelling techniques will be developed to underpin land use planning and decision-making made across scale.

Keywords: Catchment hydrology, sustainable management, multi-scale sampling

INTRODUCTION

The EC Water Framework Directive assumes that sustainable catchments can be created across Europe based on realistic catchment management plans. It is therefore imperative that robust multi-scale data sets are created that can assess the current scientific basis for catchment planning or seek to produce new methods that will inform and improve our future catchment management plans. In CHASM (www.ncl.ac.uk/chasm), measurements are made are key scales in order to maximise the information content of the data that is collected. Thus, robust hydrological time series and water quality data, that are representative of the location and scale, will be determined. If however, it is not possible to create such representative data sets then the implication of this uncertainty will be retained and evaluated in terms of setting up catchment sustainable plans.

The CHASM research programme will address the following Key Issues:

1. The vast majority of catchment experiments have been conducted at the microscale (<10km^2), only limited aspects of hydrological understanding can be transferred to larger scales (the scale issue).
2. The range and intensity of anthropogenic influences within catchments is increasing and impacts are not fully understood, particularly in relation to ecological diversity and biogeochemical cycling.
3. A better understanding is needed of how catchments are likely to behave under future climate conditions.
4. Sustainable management plans for catchments need to be underpinned by good scientific understanding, particularly of the influences of abstractions on the hydrological and ecological regimes of catchments.

Key elements of CHASM include the following:

- a new focus on mesoscale (~100km^2) catchment research to bridge the gap between the typical scale of past experimental catchment research (~10km^2) and the catchment scales which are the focus of sustainable management issues;
- a major assault on the scaling issue, with new scaling theories to be developed and tested using multi-scale experiments;
- a set of *n* mesoscale nested catchment experiments which will
  (a) sample heterogeneity in rainfall/topography/soils/vegetation/geology comprehensively, and
  (b) cover a range of anthropogenic impacts;
- a scientific platform for new developments in hydroecological research;
- an integrated monitoring and modelling approach in which modelling is used from the outset to design the catchment experiments and to steer field campaigns.

METHODS

Generic Experimental Design

A key set of elements have been chosen as the basis of the Generic Experimental Design.

- landscape classification;
- an adaptive, staged approach to instrumentation:
  - Mobile Instrumentation
  - Permanent Instrumentation
  - Staged Instrumentation
- a multi-scale approach with a nested structure;
- understand and resolve heterogeneity (through integrated monitoring and modelling);
- re-classify the landscape, and repeat the cycle.

The experimental design is seen as an iterative process in which the effects of heterogeneity in topography, soils vegetation and geology on catchment response are understood and resolved, leading ultimately to the classification of the landscape into hydrologically homogeneous domains.

Landscape Classification
It is envisaged that digital maps of topography, soils, vegetation and geology will, in the first instance, be used together with a priori knowledge and understanding of the dominant controls on hydrological response to produce a first attempt at landscape classification. It is recognised that any classification scheme must reflect a specific purpose, which, in the case of catchments, can be defined in terms of hydrological, geomorphological or ecological response. The Permanent, Staged and Mobile Instrumentation will be deployed in accordance with this initial classification. As data become available and models are developed, the understanding of the controls on hydrological response will be enhanced, leading to the reclassification of the landscape and the redeployment of instrumentation to sample unresolved hydrological variability.

Mobile Instrumentation- The Green Machine
'The Green Machine' (see fig. 1) is an all-terrain vehicle that will be adapted to carry out rapid surveys in the field. The Green Machine is to be fitted with a high resolution, real time, Global Positioning System and a set of geophysical surveying equipment (including a ground conductivity meter and a seismic refraction kit). A number of geophysical experiments are envisaged that will work in tandem with the staged and permanent instrumentation. The Green Machine will be used in the initial land classification scheme to survey prospective instrumentation sites to guarantee that those sites meet with the generic experimental design criteria of the CHASM project. The vehicle will also be used for the installation of field equipment (that includes a drilling rig) and for downloading data loggers directly onto an onboard computer.

Figure 1. The Green Machine.
- Rapid Surveys
- Real time, accurate mapping and navigation capability
- A lightweight all-terrain vehicle
- Fitted with a drilling rig, GPS and geophysical equipment

PERMANENT INSTRUMENTATION AND A MULTI-SCALE APPROACH WITH A NESTED STRUCTURE

Permanent instrumentation will be positioned within each catchment to follow a multi-scale nested structure consisting of microscale (1 km^2) and miniscale (10 km^2) catchments (see fig. 2). A major objective of CHASM is to scale-up process representation and catchment variability to the mesoscale (100-200 km^2). Miniscale catchments are seen as a key scale for observing the effect of local variability but also to study mixing and attenuation processes. The microscale catchments will help to resolve spatial variability in responses, by monitoring processes within distinct land units as defined from the basic landscape classification scheme.

Instrumentation includes

- River gauging stations with nested structure
- Observation boreholes and river aquifer experiments
- Hydrometeorological stations and raingauges
- Hillslope instrumentation (runoff troughs, lysimeters)
- Suspended sediment and water quality monitors

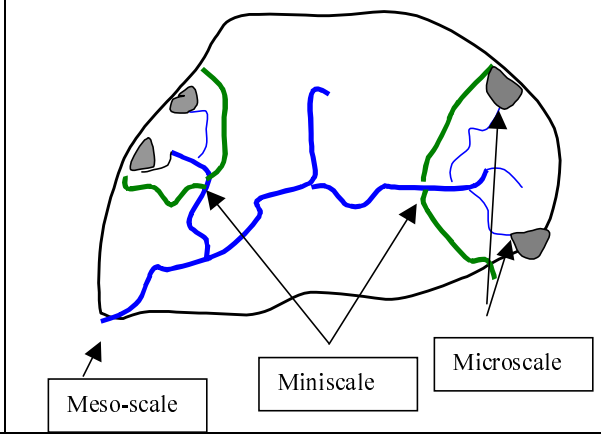

Figure 2. Permanent Instrumentation and a multi-scale approach with nested structure

Staged Instrumentation

Initially a series of detailed point scale measurements will be made within the microscale catchments (see fig. 3). A dense network of logged instrumentation will generate the basic data needed to establish the mean and distribution of key hydrological variables, such as the water table dynamics, the soil moisture regime and the evaporative dynamics, for a patch of land approximately 50m * 50m in extent. Patch instrumentation will improve the representation of catchment variability by targeting the heterogeneity seen at the hillslope scale. Two to three patches will be implemented on hillslopes within a microscale catchment to capture this heterogeneity. As this will require a large number of instruments, a staged instrumentation approach has been designed. Firstly, a full set of instruments are installed, which are left to record data whilst other patches are implemented. The data from the instruments will be analysed frequently, until it is agreed that the mean hydrological behaviour of the patch has been established. At this stage, several instruments that represent the mean behaviour of the patch will be left in situ, but the remaining instruments are removed and used in new patches. This process will allow the first goal of establishing patches in all micro-catchments to be fulfilled, but also offers the opportunity for other patches to be set up elsewhere in the mini or mesoscale catchments.

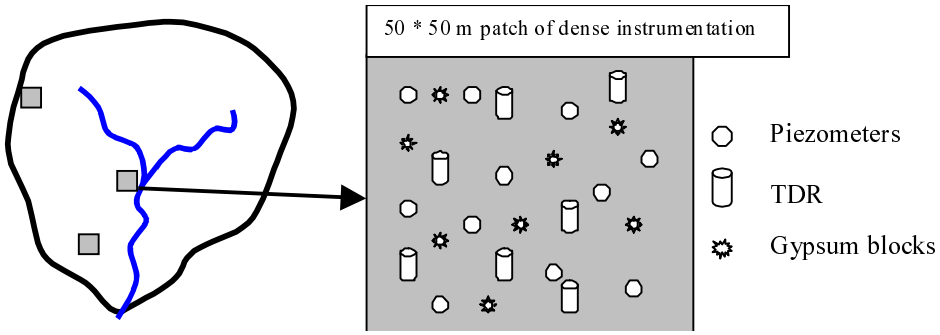

Figure 3. Staged instrumentation within a microscale catchment and the use of patches to capture hillslope scale variability.

THE NICHE CATCHMENTS

The NICHE project is being implemented by two consortia (Table 1 and fig 4). The NICHE-CHASM consortium will focus on four predominantly upland catchments (Oona, Feshie, Eden and Upper Severn) while the NICHE-LOCAR consortium will focus on three lowland catchments which overly major UK aquifers (Tern, Pang/Lambourn and Frome). It is intended that the Generic Experimental Design should, as far as possible, be implemented across all seven catchments. NICHE task forces have now been set up by both consortia to develop specific experimental designs for implementation on the two groups of catchments, and to ensure that the designs for individual catchments conform as far as possible with the Generic Experimental Design.

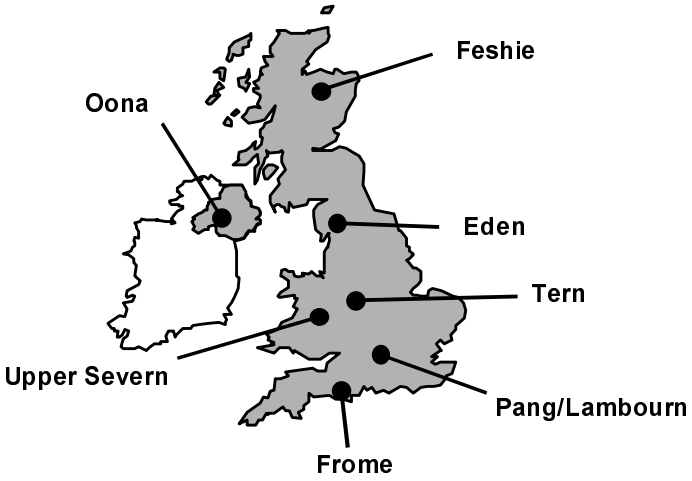

Figure 4. The location of the CHASM and LOCAR catchments

Table 1 a list of all partners involved in the NICHE project.

NICHE Project	
NICHE-CHASM	**NICHE-LOCAR**
Uni. Of Newcastle	Imperial College London
Uni. Of Aberdeen	University of Birmingham
Uni. Of Dundee	University of Exeter
Uni. Of Durham	NERC British Geological Survey
Uni. Of Lancaster	NERC Centre for Hydrology and Ecology
Uni. Of Leeds	CEH Wallingford
Uni. Of Ulster	
CEH Wallingford	

RESULTS AND DISCUSSION

As time progresses a vast amount of time series and existing GIS data sources and newly created maps will be accrued for general usage by the scientific community. In the early phases of the project it is worth presenting just a few of the results reflecting the CHASM project goals of acquiring a wide range of spatial and temporal time data at many scales

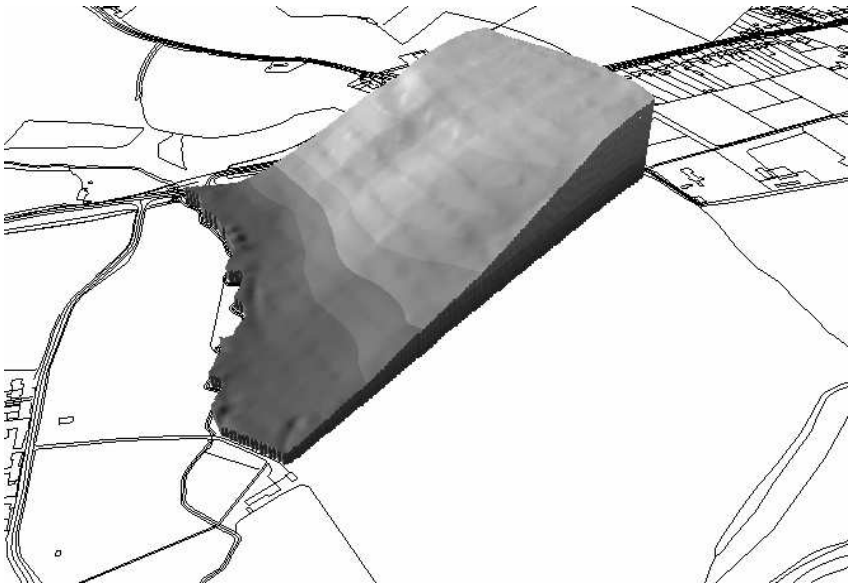

Fig 5 A 2m resolution map created with the GPS mounted on the Green Machine.

Firstly, figure 5 is a high resolution map of one of the research farms as created by the CHASM Green Machine. This site has been instrumented with a series of soil moisture patches and a local flow gauges. These high-resolution maps are the

basis upon which many further maps of soil moisture and water dynamics will be superimposed. Equally, it important to address land use and management and cause and effect issues as seen at this scale (Quinn et al., 2003, Hewett et al., 2003). Whilst installing a number of piezometers a number of soil cores were extracted for nutrient analysis using the Green Machine coring facility. Figure 6 is thus a profile of the variation of the nitrate level in the soil. Once high-resolution terrain data has been acquired, it is the possible to simulate the role of natural topographic gradients and man made features on flow accumulation and thus assess the likely risk of nutrient pollution from these sites as well as suggest possible mitigation strategies. Finally, figure 6 also shows the time series results of the soil moisture patches and the local CHASM flow sampling sites. This type of data will be combined with time series of nutrient pollution data that is currently being gathered. The CHASM project will attempt to simulate nutrient sources, transport and their impact downstream. Moreover, the project will then recommend strategies for better underpinning the decision making process required to create realist catchment management plans.

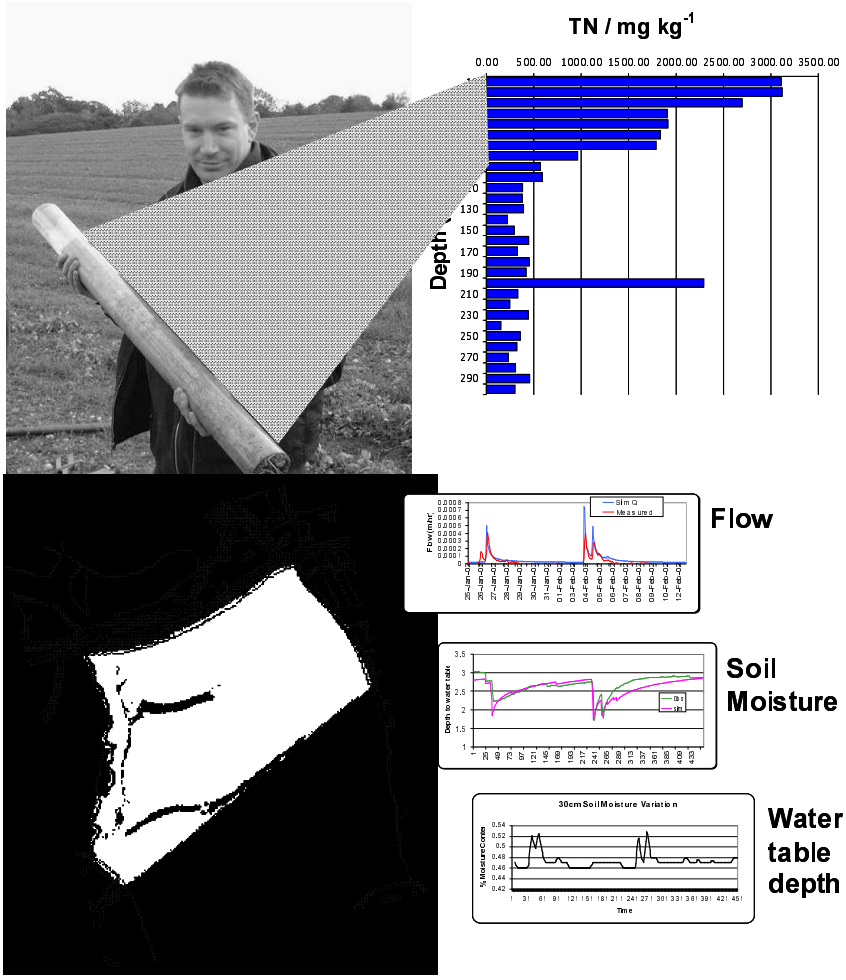

Fig 6 A typical soil core, the variability of nitrate level with depth, a derived flow accumulation map based on figure 5 and a selection of hydrological times series derived at one micro scale site.

CONCLUSION

The CHASM project is currently ongoing, it seeks to produce the kind of multi-scale data that is needed for understanding land classification, simulation and land management. New rapid data acquisition and sampling regimes are being tested and ground truthed, so that future landscape characterisation and evaluation can be established. It is a key requirement of catchment management and the EC Water Framework Directive that scientist and policy makers can access, evaluate and create the evidence needed to improve environmental standards.

REFERENCES

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