NEWSLETTER OF THE COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

CATCHWORD

NO 82 APRIL 2000

A NOTE FROM THE DIRECTOR

Professor
Russell Mein

Inside...

Research program overview

In *Catchword* last month, I began a series of articles intended to give an overview of the CRC's integrated research program. The purpose is to show how each program contributes to the main goal - predictive capability for water, sediment, solute, and nutrient movement at catchment scale. (I note here, as I did last month, that the integration of programs extends to the Programs for Communication and Adoption, and Education and Training; they are just as important as the research programs in the overall goals of the CRC.)

The first program discussed was the Climate Variability Program; this month the series continues with Program 1 'Predicting Catchment Behaviour'.

Overview Part Two – Predicting Catchment Behaviour
The key objective of the CRC is given in its mission statement:

To deliver to water resource managers the capability to assess the hydrologic impact of land-use and management decisions at whole-of-catchment scale.

To achieve this mission, we have to develop predictive models that are applicable to a range of problems, spatial scales, and time scales. Our aim is to integrate hydrologic, meteorologic, geomorphic, ecologic, and socio-economic knowledge in such models. Quite a challenge, and a major change from what is currently available for water resource management.

Drivers of catchment response
Figure 1 depicts the catchment 'system', with climate an important 'driver' of hydrologic response. (The March *Catchword* "overview" provides some expanded discussion on the Climate Variability aspects.) Another important driver is land-use (or land cover). *Figure 1* also indicates the potential for better management of land-use (eg for sustainability) if suitable predictive tools are available to evaluate the impacts of different management strategies.

The tool kit (Project 1.1)
The heart of the predictive package will be the modelling tool kit, a suite of models able to cover a wide range of spatial and temporal scales. The tool-kit has to provide links between models and data (eg climate, catchment), between different component processes, between different disciplines (eg hydrology, economics), and to different output formats.

An important initial step for the project will include selection of a 'framework' which provides the linkage points to add new components as required.

Scaling Issues (Project 1.2)
Figure 1 also shows that scaling issues apply to the various elements of catchment modelling. Climate and catchment characteristics vary in location and timing, but the level of detail needed to represent this depends on the issue in question. For instance, the effect of a local thunderstorm on runoff may be large in the area affected, but negligible when considering regional scales. On the other hand, such thunderstorms can initiate sediment movement through erosion, so may need to be included for regional scale sediment modelling. Project 1.2 targets such issues to provide the knowledge base necessary to choose the appropriate degree of modelling detail for the task in hand.

Overall
The climate and modelling programs of the CRC are fundamental components of the capability we seek. The remaining research programs are more applied, enabling the 'impacts' to be specified; more details in coming editions.

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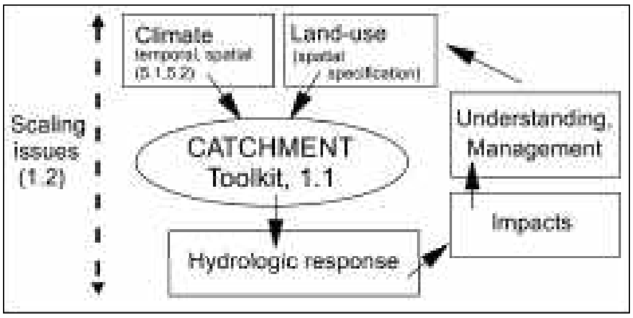

Figure 1 Modelling perspective of a catchment

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by Lionel Siriwardena, Erwin Weinmann

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95/1 A review of scale in hydrology
by Geoff Lacey

94/5 Regionalisation of hydrologic data – a review
by Bryson Bates

94/4 Loss modelling for flood estimation – a review
by Nanda Nandakumar, Russell Mein, Lionel Siriwardena

94/1 Development of regional prediction equations for the RORB runoff routing model
by Ben Dyer, Rory Nathan, Tom McMahon, Ian O'Neill

WORKING DOCUMENTS

Forest Hydrology

95/4 User manual for the Hillflow 3-D catchment modelling system (physically based and distributed modelling of runoff generation and soil moisture dynamics for micro-catchments)
by Alex Bronstert

Waterway Management

96/3 Lake Eppalock silt section survey report
by Jennifer Davis (Wilson)

Flood Hydrology

97/1 Development and testing of a variable proportional loss model
by Lionel Siriwardena, Peter Hill, Russell Mein

96/5 Empirical analysis of data to derive losses: methodology, programs and results
by Peter Hill, Upala Maheepala, Russell Mein

96/4 Development and testing of methodology to derive areal reduction factors for long duration rainfalls
by Lionel Siriwardena, Erwin Weinmann

96/2 Comparison of two adoptive unit hydrograph: methods for real-time flood forecasting
by Sri Srikanthan, Soori Sooriyakumaran, Jim Elliott, Peter Hill

96/1 The scaling of baseflow
by Geoff Lacey

95/6 Estimation of extreme rainfalls for Victoria – application of Schaeffer's method
by Fiona McConachy

95/2 Development and testing of a variable proportional loss model based on 'saturation curves' (a study on eight Victorian catchments)
by Lionel Siriwardena and Russell Mein

PROGRAM 1
PREDICTING CATCHMENT BEHAVIOUR

Program Leader
ROB VERTESSY

Report by Brad Houghton

Initial Tasks for Project 1.1

Throughout the months of January and February Project 1.1 (the catchment modelling toolkit) swung into action. As a summer student with the CRC for Catchment Hydrology, I have been working in close consultation with Robert Argent on starting some of the tasks for the project. Project 1.1 proposes a framework (including design, user involvement, documentation, production and delivery) for the integration of appropriate existing models and newly developed models (by the CRC and others) into a toolkit for predicting aspects of catchment behaviour. It is anticipated that the tasks undertaken in the project will result in the selection and implementation of a pilot framework that will support the long-term design and integration of a variety of models relevant to the prediction of catchment behaviour.

Modelling frameworks

In my work with Robert over the summer months I researched some of the modelling frameworks that are being used or developed by other groups, both for simulation systems and other applications. One of the major problems with all the frameworks encountered in my research was that they concentrated on the technical aspects of the software engineering. Only rarely were the following important aspects in the design and implementation of modelling frameworks included:

- documentation of model design;
- data and metadata;
- the ability (or otherwise) to examine, edit and analyse data;
- knowledge-based selection of models, when more than one is available, and
- processes for undertaking and recording peer reviewing of models.

Protocols

The task of developing draft protocols for model documentation was commenced and many hours were spent on the WWW searching for models, environments and architectures currently in use. We were also trying to find what documentation, if any, was used for model design and model use. The findings have been included in a paper titled 'Land and Water Resource Model Integration - Beyond Software Engineering' that Robert Argent and I have submitted to the International Symposia on Environmental Software Systems' Integration Workshop, to be held in June 2000.

Metadata, help systems

Other aspects of documentation, including metadata and help systems, were also researched as part of my work. I found some interesting Help systems that are currently in use. An HTML type Help system seems attractive as a help documentation system for model detail and theory, and program use. I also researched metadata standards for data and found that there are not too many out there, except for geographic and spatial data. The International Standards Organisation (ISO) is working on a new standard for geographic metadata, in close consultation with ANZLIC and the US Federal Geographic Data Committee.

Initial survey, analysis of models in use

Currently Rob Vertessy is undertaking an initial analysis to identify which models are being used by CRC Parties and why. Some of my time was spent searching seminar and symposia proceedings for details of models people are using and what problems they are using them for. Rob Vertessy will be able to use these findings in his analysis.

Conclusions

Hopefully my work at the CRC will have helped kick-start some of the tasks in Project 1.1 and make life a bit easier for the project members. My time at the CRC has been quite enjoyable and I have learnt about the many aspects of a research project and research organisation. Activities such as sitting in on budget and planning meetings with Rob Argent and Rob Vertessy, searching the WWW (which at many times proved both fruitless and frustrating), and by having an office with air conditioning that at times I think may have gone below zero and a computer that crashed anywhere between 1-5 times a day have been part of this learning.

I'd like to thank Rob Argent for the opportunity, and his time and helpfulness with my many questions.

Brad Houghton (Summer Student)

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Email: r.argent@civag.unimelb.edu.au

CANBERRA TECHNICAL SEMINAR

PROGRESS WITH THE INTEGRATED CATCHMENT MANAGEMENT SYSTEM (ICMS)

by

Dr Sue Cuddy
Researcher
CSIRO Land and Water
CRC for Catchment Hydrology

Wednesday 31 May 2000
TIME:
10.45am for 11.00am start

Tea/coffee on arrival

at the Conference Room
C.S. Christian Laboratory
CSIRO Land and Water
Black Mountain Laboratory
Canberra,
Clunies Ross Street, Acton.

Contact Tanya Jacobson on 02 6246 5746 for further details.

RECENT INDUSTRY SEMINAR VIDEO

MANAGING SEDIMENT SOURCES AND MOVEMENT IN FORESTS: THE FOREST INDUSTRY AND WATER QUALITY.

Presented by

Dr Jacky Croke
CSIRO Land and Water

Dr Peter Wallbrink
CSIRO Land and Water

Mr Peter Fogarty
Soil and Land Conservation Consulting

CRC VIDEO 00/1

This video was recorded in Melbourne last year; the first of the three seminars held in Victoria and NSW during November.

It will be of interest to anyone involved in forest and catchment management.

PROGRAM 2

LAND-USE IMPACTS ON RIVERS

Program Leader
PETER HAIRSINE

Report by Peter Hairsine

What are we doing in the area of salinity research?

Initial CRC salinity research

In the initial CRC for Catchment Hydrology we had a salinity program. This program was very successful in producing much quality research and research products (see the Centre's web site http://www.catchment.crc.org.au/ for details).

In our new centre our programs are organised around themes so that issues such as salinity are distributed across programs and projects. So where are we now doing salinity research and development?

Current CRC activities

In the "Land-use impacts on rivers" program we have some salinity research in the core projects 2.2 and 2.3. There is also salinity research in some externally funded activities which we are in the process of adding to our list of associate projects.

Project 2.2 work

Project 2.2 "Managing pollutant delivery in dryland upland catchments" is concerned with the washoff of pollutants, including sediment, nutrients and salt from the land surface. Salt wash off is now recognised as an important mechanism linking land salinisation to in-stream salt loads. This project will have a PhD student investigating salt washoff. We are finalising the arrangements for a student to work with us in this area. This activity should form a link between the NSW Department of Land and Water Conservation's CATSALT project and CSIRO's expertise in this area.

Project 2.3 aspects

Project 2.3 "Predicting the effects of land use changes on catchment water yield and stream salinity" is led by Dr Lu Zhang in Canberra. This project, as currently approved, will research changes to water yield as a result of land use changes including afforestation and conversion of pasture types. Changes in water yield are strongly related to recharge and surface runoff, the drivers of dryland salinity. We are seeking to extend this project to consider the salinity consequences of such changes to catchment water balances. We have approached the Murray Darling Basin Commission to support some of the existing projects and the proposed extension.

Associate projects

As with all our programs, this program aims to meet some of its goals through externally funded associate projects. Some of the proposals for associate projects concerning salinity at this time are: the MDBC-funded catchment categorisation for dryland salinity project led by Glen Walker, and Lu Zhang's proposal to the second phase of the LWRRDC's National Dryland Salinity Program.

Lu Zhang's project concerns the impact of rising groundwater and salinity on the magnitude of floods.

The catchment categorisation project is a multi-agency effort to use knowledge concerning catchment types to extend findings in research catchments into all other catchments within the Murray Darling Basin.

If you have any questions about this work, please do not hesitate to contact me.

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PROGRAM 3
SUSTAINABLE WATER ALLOCATION

Program Leader:
JOHN TISDELL

Report by John Tisdell

A socioeconomic approach to land and water research

Water markets in focus catchments

Socioeconomics is a new area of research within the CRC. This article outlines some of the main features of socioeconomic research.

A socioeconomic approach to land and water research brings together disciplines from social sciences and economics. It a multidisciplinary framework with a body of knowledge, theories dealing with human activities, and combines well-established methodologies.

Research questions vary greatly, but generally concern people and the expression of their preference sets to land and water resources: as individuals, and in aggregate. Expression of those preferences depends on interactions within and between key pressure points.

These key pressure points are largely economic, institutional and social rather than biophysical (see *Fig. 2.1).*

Data requirements in socioeconomic research

In analysing these pressure points, typical data requirements deal with the "drivers" or critical aspects in institutional approaches, water demand, water supply, land use and social factors. Examples of water demand data requirements include yield and gross margin data (models of crop markets), crop water requirement data, rainfall data and weather prediction model output, farm management practices, and attitudes to risk (perceived and realised), as well as demographic and regional economic statistics.

Examples of social data requirements include attitudes to the river and land environment, knowledge regarding water and land management reform, community willingness to embrace change and perceptions of social and procedural justice.

Data Sources, Analysis and Models

Secondary sources of data for researchers in the field of socioeconomics include State Departments of Primary Industries, Water Authorities, the Australian Bureau of Statistics and other data collection organisations. Where primary data on specific issues is required, surveys are common. In the case of social data, surveys may derive information on attitudes and perceptions of equitable or just dealings and institutional procedures, as well as water policy impacts on individual rights and regional communities.

In analysing socioeconomic data, analysts tend to use operational research and statistical methods. Regression and multivariate analysis, and linear and dynamic programming models are among the approaches used. In essence the output is linked to its objective, namely, to analyse the way people manage land and water resources. The research tends to produce models of how rights are defined and obligations are distributed, models to explain the impact of community attitudes and behavior, and most importantly models and theories concerning the social and economic consequences of land and water use changes.

Conclusion

Socioeconomic research explores processes involving people within the catchment. Research in the field offers a new aspect to the CRC and will complement the biophysical research into land and water processes.

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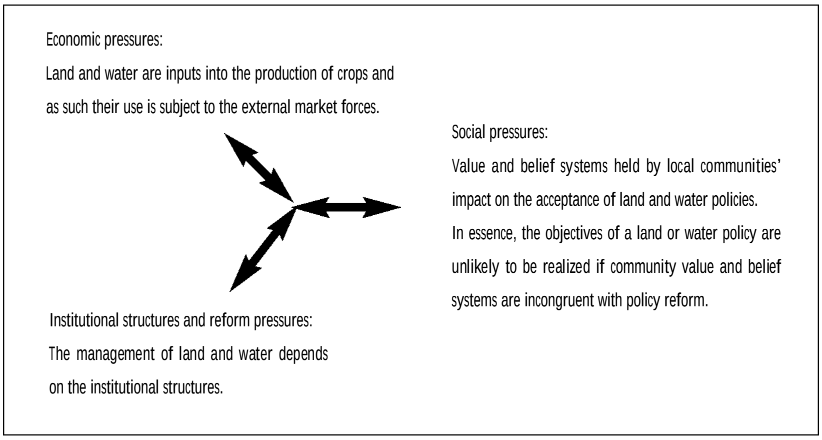

Figure 2.1 Key pressure points

CANBERRA TECHNICAL SEMINAR

AN INTRODUCTION TO THE TARSIER CATCHMENT MODELLING FRAMEWORK

SPEAKER:

Dr Fred Watson
Postdoctoral Research Fellow
California State University Monterey Bay

Wednesday 24 May 2000
TIME:
10.45am for 11.00am start

Tea/coffee on arrival

at the Conference Room
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CSIRO Land and Water
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Canberra
Clunies Ross Street, Acton.

Contact Tanya Jacobson on 02 6246 5746 for further details.

RECENT INDUSTRY REPORT

THE REUSE POTENTIAL OF URBAN STORMWATER AND WASTEWATER

by
Grace Mitchell
Russell Mein
Tom McMahon

Report No. 99/14

This report deals with the feasibility of reusing stormwater and wastewater to reduce the demand on the potable water supplies in Australian cities. It also describe 'Aquacycle' - a model developed by the CRC to assist in this process.

Copies available for $25 from the Centre Office.

Please contact Virginia Verrelli on tel 03 9905 2704 or email virginia.verrelli@eng.monash.edu.au.

PROGRAM 4
URBAN STORMWATER QUALITY

Program Leader
TONY WONG

Report by Jai Vaze

Estimation of event stormwater pollutant loads

Diffuse pollution

Diffuse pollution is a major environmental problem. This is particularly the case in urban areas where the runoff volumes and pollutant concentrations are typically much greater than in undisturbed catchments.

Estimating pollutant loads

Estimates of diffuse source pollution loads over different time and spatial scales are required to evaluate the severity of the pollution problems and to determine appropriate management measures. Estimates of pollutant loads generated over storm events are required for the following purposes:

- to evaluate the impacts of alleviated runoff and pollutant concentrations on macroinvertebrates and ecology of urban waterways
- to investigate short-term toxicity problems
- to study the effectiveness of various pollution control measures
- to design storage/treatment facilities where first flush mechanisms are influential.

Pollutant buildup and washoff

Existing stormwater quality models typically view stormwater contamination as a two stage process – pollutant accumulation on the surface during dry weather (buildup) and subsequent washoff during storm events (washoff).

Recently completed CRC studies suggest that buildup is less important than what is often thought. This is because there is often an unlimited source of pollutants available on the surface. Storm events typically remove only a small proportion of available surface pollutant load. The surface pollutant load increases relatively quickly after a storm event and redistribution ensures that the surface pollutant load remains at a roughly constant level (see Duncan, 1995b; Chiew et al., 1997a, 1997b).

This study thus concentrates on understanding the washoff mechanism to improve the estimation of pollutant loads for a storm event.

Pollutant washoff

Washoff is the removal of accumulated pollutants by rainfall and runoff. The apparent diversity of opinions for explaining the washoff process of particulate pollutants centres around four explanatory variables (rainfall intensity, rainfall volume, runoff rate, and runoff volume) and four main processes (pollutant detachment by raindrop impact, transport by raindrop splash, detachment by runoff, and transport by runoff). It is difficult to distinguish between these explanatory variables because they are correlated to each other.

Empirical equations

An assessment has been made of the use of simple power functions of rainfall intensity, runoff rate, rainfall volume and runoff volume to estimate event pollutant loads using data from three Australian catchments.

$$\text{Load} = a \sum_{i=1}^{n} (\text{explanatory variable})^{b}$$

Cross validation results from our studies indicate that the calibrated parameters can be used to successfully estimate pollutant loads for independent events in the same catchment, particularly where both the rainfall intensity and runoff rate are used as the explanatory variables. We concluded that where there are sufficient data to calibrate the parameters, washoff of particulate pollutants from impervious surfaces for individual storm events could be estimated reasonably accurately using simple power functions of rainfall intensity and runoff rate. The accuracy of the estimates was similar or better than those obtained using the more complex water quality models. The results have been published in Chiew and Vaze (1998) and Vaze and Chiew (1999).

Experiment to improve understanding of pollutant washoff process

An experimental study is presently underway to identify the importance of raindrop energy (rainfall intensity) and flow energy (runoff rate) in pollutant washoff.

(i) Field set-up

Figures 4.1 and *4.2* show the experimental field setup. As shown, an area of 3m x 3m was separated out from the surrounding area using a plywood framework. Petroleum jelly was used to seal the gaps so that there is no water flow across the plywood sides. On test surface I (see *Figure 4.1*), 3 layers of very fine insect screens were placed at a height of 2 to 5 cm from the surface. These screens absorbed almost all the raindrop impact energy and so the only energy available for pollutant detachment and transport was the flow energy. Test

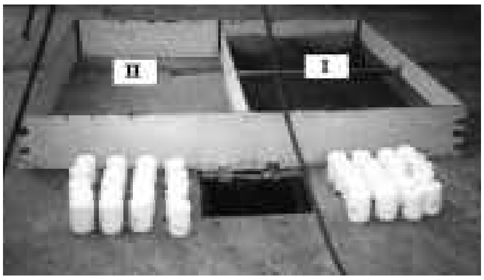

Figure 4.1. Test surfaces

surface II was without screens and so have full raindrop impact energy plus the flow energy available for pollutant washoff. Other than this, both the surfaces had the same initial pollutant load, surface roughness, slope, rainfall rate and volume and the same total runoff.

(ii) Sprinkler selected

After testing a number of sprinklers, a 1/2 HH 40 W (wide angle) square nozzle marketed by Spraying Systems Company Pty. Ltd, USA was selected. A single nozzle placed at a height of 4m from the ground surface was able to cover the area of 9 sq meters with a uniformity coefficient of more than 0.90. This nozzle was capable of producing the complete range of typical rainfall intensities using a normal tap water supply. The drop size distribution for this nozzle was determined using the flour pellet method (Laws and Parsons, 1943) and was found almost similar to natural rainfall events. [Thanks to Jim Brophy (CSIRO Land and Water Canberra) for all his help regarding the simulator design.]

(iii) Experimental runs

Five experimental runs have been conducted so far in the field. For each run, rainfall intensity, runoff rate, raindrop size and distribution and fall velocity were measured. Runoff samples were also collected at regular intervals and tested for total phosphorus, total nitrogen (using a MERCK Photometer, SQ 200) and total suspended solids. Several more experimental runs will be made. A more detailed study will be also undertaken in the laboratory to obtain more data to adequately develop a washoff equation.

(iv) Conclusion from initial results

The initial results clearly indicate that raindrop impact energy is a very important factor in generating washoff of the particulate pollutants (suspended solids and phosphorus).

References

Chiew, F.H.S., Duncan, H.P. and Smith, W. (1997a). Modelling pollutant buildup and washoff: keep it simple. Proceedings of the 24th International Hydrology and

Figure 4.2. Sprinkler rig

Water Resources Symposium, November 1997, Auckland, New Zealand Hydrological Society, pp. 131-136.

Chiew, F.H.S., Mudgway, L.B., Duncan, H.P. and McMahon, T.A. (1997b). *Urban Stormwater Pollution.* Cooperative Research Centre for Catchment Hydrology, Melbourne, Australia, Industry Report 97/5.

Chiew, F. H. S. and Vaze, J. (1998). 'Estimation of Event Diffuse Pollution Loads Using Simple Equations' *Proceedings of the 4th International Conference on Developments in Urban Drainage Modelling*, September 1998, London, United Kingdom

Duncan, H.P. 1995b, A Review of Urban Stormwater Quality Processes, Cooperative Research Centre for Catchment Hydrology, Melbourne, Australia, Report 95/9

Laws, J and Parsons, D. (1943). The relation of raindrop-size to intensity. *Trans. Amer. Geophysics Union* (Hydrology Papers), 452-460.

Vaze, J. and Chiew, F. H. S. (1999). Investigation of the Relationship between Event Pollutant Load and Rainfall and Runoff Characteristics. *The 25th Hydrology and Water resources Symposium*, July 1999, Brisbane, Australia

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NEW TECHNICAL REPORT

EFFECTIVENESS OF STREET SWEEPING FOR STORMWATER POLLUTION CONTROL

by
Tracey Walker
Tony Wong

Report 99/8

This report investigates the effectiveness of street sweeping as a stormwater pollution source control measure. It describes a scoping study to assess the efficiency of Australian street sweeping practices in the removal of pollutants from street surfaces.

Copies of this report are available from the Centre Office for $25.

RECENT TECHNICAL REPORT

BLACKBURN LAKE DISCHARGE AND WATER QUALITY MONITORING PROGRAM: DATA SUMMARY AND INTERPRETATION

by
Sharyn RossRakesh
Chris Gippel
Francis Chiew
Peter Breen

Report 99/13

The 100 page report documents work undertaken by the CRC for Catchment Hydrology and the CRC for Freshwater Ecology on the performance of an urban pollution control pond in Melbourne.

Copies of this report are available from the Centre Office for $25.

PROGRAM 5
CLIMATE VARIABILITY

Program Leader
TOM McMAHON

Report by Alan Seed

Modelling and forecasting the space and time characteristics of rainfall - the nowcasting problem.

Types of rainfall models

Rainfall prediction models can be divided into two main categories, stochastic and deterministic, where the deterministic models are based on solving the dynamic and thermodynamic equations used to describe the atmosphere. Stochastic models are generally able to provide forecasts out to 6 hours of lead time, but the variability of the precipitation traces is quite large. Thus forecasts from stochasic models cannot be regarded as quantitative but can be used to give the probability of exceeding certain thresholds.

Lead times for weather prediction models

Conventional numerical weather prediction (NWP) models can only represent the larger scales explicitly and are best suited to more general forecasts for periods beyond 12 hours. Mesoscale dynamic models are based on solving the equations over smaller domains and at higher resolution; they are able to give better details for the 6-18h ahead period. For forecasts up to a few hours ahead, the optimum forecast method is to extrapolate the observed rainfield forwards in time. This situation is represented in *Figure 5.1* as a schematic taken from Collier (1991).

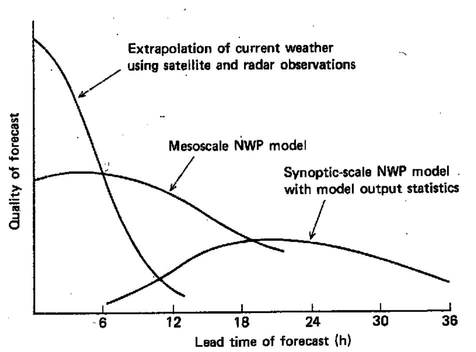

Figure 5.1. The quality of rainfall forecasts as a function of lead time. Taken from Collier, 1991.

Short term forecast systems

Short term quantitative rainfall forecast systems based on field advection can vary in complexity from simple methods based on the advection of the entire field, to complex cell-tracking algorithms that allow cell mergers and splits. The first stage in the generation of a forecast based on global field advection is to identify the area in the field containing significant rainfall and thereafter use a pattern recognition algorithm to identify the same region in a subsequent image and hence the field advection. The forecast is based on advecting the field at the observed velocity assuming no dynamic development. A very early example of an operational system of this type is the SHARP system (Austin and Bellon, 1974) and more recently the system used to generate forecasts over London (Moore et al, 1992). All cell tracking algorithms depend on a definition of what constitutes a cell, thereby implying that they are designed to follow small convective elements in the field. As a result, they do not generally perform well in widespread rainfall situations.

Scaling aspects of modelling rainfields

Considerable empirical evidence accumulated over the past decade suggests that rainfields can be modelled as self similar multifractal fields (Lovejoy and Schertzer, 1995). This implies that the rainfield is not organised as a collection of individual cells, each with a characteristic scale, but rather as a continuum or hierarchy of structures over all scales from 100 m to 200 km at least. Recent research has been conducted on methods to exploit this scaling behaviour in nowcasting applications. The fundamental observation is the fact that the lifetime of a turbulent structure has a power law dependence on the scale of the structure. The promise of these new methods is their ability to recognise the rate at which the field is evolving as a function of scale and to use this in an optimal way so as to produce forecasts where the small-scale detail is allowed to dissipate in a structured way.

Model from initial CRC work

A multiplicative cascade model for characterising the spatial and temporal properties of rainfall has been developed in the Flood Hydrology Program of the initial CRC for Catchment Hydrology (Seed *et al*, 1999). This model is able to produce scaling rainfields. The model has the potential to be used in forecast mode if methods are developed to calculate the model state variables (the fields of random numbers at each level in the cascade) based on observations over the past few hours. The most obvious approach is to use Fourier filtering techniques to filter the observed field at the scales represented by each level in the cascade, and to allow these fields to develop in time using the hierarchy of AR(1,1) temporal models. This model will allow the small scale detail to dissipate as the lifetime at each scale in the cascade is reached, thereby recognising that we know less and less about the forecast field as the lead time is increased. Alternatively, noise can be added into the model as the structures at each scale evolve thereby providing a stochastic forecasting scheme.

Results from prototype of cascade model

A prototype of the above model is in the process of being developed and the first results have proved to be very promising. *Figure 5.2* shows a rain field measured by the Melbourne weather radar on 2 March 1999. The first operation for the now casting engine is to estimate the current field advection velocity. This is done using pattern matching techniques to find the displacement between successive images. The rainfield is then converted into log rainfall and disaggregated into fields representing features of scales which decrease by a factor of two per level from the outer scale of the image to twice the pixel size. This is done using Fourier notch filtering techniques. The Lagrangian autocorrelations for the field shown in *Figure 5.2* over the preceding 30 minutes are given in Table 1. It can be seen that for this case all features at scales less than 32 km have life times that are less than 30 minutes. Therefore, no advection scheme will have much skill at forecasting the rainfall at scales below 32 km after 30 minutes.

Table 1. Lagrangian autocorrelations for the rain field in *Figure 2*.

	10 min	20 min	30 min
256 km	0.99	0.95	0.91
128 km	0.96	0.85	0.75
64 km	0.85	0.56	0.27
32 km	0.57	0.17	-0.03
16 km	0.28	-0.04	-0.08
8 km	-0.03	-0.03	0.00
4 km	-0.08	0.15	0.00

Each level in the cascade was allowed to decay to the mean using an AR(1) forecast scheme. Since the high intensity features are also generally the small scale features, this has the effect of allowing the field to become progressively smoother as less is known about the future state of the rainfield. *Figures 5.3* and *5.4* show the 30-minute and 60-minute forecasts for the field in *Figure 5.2* respectively.

Next steps

Work in the immediate future will concentrate on developing and validating the nowcasting engine using a wide range of rainfall situations. It will be then deployed in real-time as a test system at the Bureau of Meteorology.

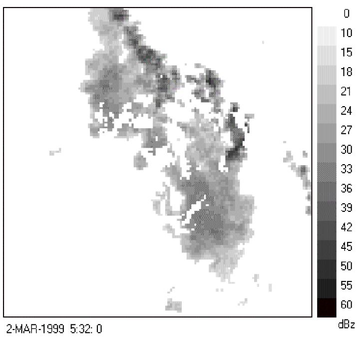

Figure 5.2. Rain field measured by the Melbourne weather radar on 2 March 1999. The domain of the field is 256 km and the spatial resolution is 2 km.

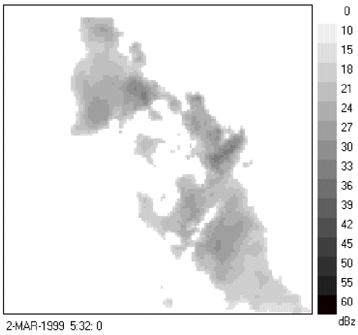

Figure 5.3 30-minute forecast of the field in Figure 2.

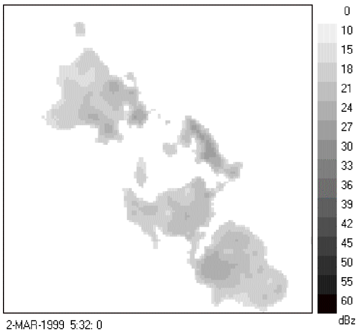

Figure 5.4 60-minute forecast of the field in Figure 2.

References

Austin, G.L., and A. Bellon, 1974, The use of digital weather radar records for short term precipitation forecasting, Q. J. of the Royal Meteorol. Soc., 100, 658-664.

Collier, C.G., 1991, The combined use of weather radar and mesoscale numerical model data for short-period rainfall forecasting, in Hydrological Applications of Weather Radar, editors Cluckie, I.D. and C.G. Collier, Ellis Horwood, London, 331-348.

Moore, R.J., D.S. Hotchkiss, D.A. Jones, and K.B. Black, 1992, London weather radar rainfall forecasting study. Final report for National Rivers Authority, Thames Region. Institute of Hydrology, pp129.

Lovejoy, S., and D. Schertzer, 1995, Multifractals and rain, in New Uncertainty Concepts in Hydrology and Hydrological Modelling, edited by A.W. Kundzewicz, p 61, Cambridge Univ. Press., New York.

Seed, A.W., R. Srikanthan, and M. Menabde, 1999, *A space and time model for design storm rainfall.* J. Geophys. Res., vol. 104 (D24) 31623-31630.

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RECENT TECHNICAL REPORT

PREDICTING THE EFFECT OF VEGETATION CHANGES ON CATCHMENT AVERAGE WATER BALANCE

by

Lu Zhang
Warwick Dawes
Glen Walker

Report 99/12

This project's aim was to estimate the effects of afforestation or deforestation on run-off that leads to recharge to some of the alluvial catchments in the upland areas of the Murray-Darling Basin. The method proved to be very successful and can be more widely used by providing a basis for making estimates of the water yield impacts of wide-scale afforestation in Murray-Darling Basin

Copies of this report are available from the Centre Office for $25.

TECHNICAL REPORT

GUIDELINES FOR STABILISING STREAMBANKS WITH RIPARIAN VEGETATION

by

Bruce Abernethy and Ian Rutherfurd

Report 99/10

The Queensland Department of Natural Resources contracted the CRC for Catchment Hydrology to write technical guidelines to help specify the width and composition of vegetated riparian zones, for bank erosion control.

This report will guide and focus the practitioner's approach to planning riverbank stability works using vegetation.

The report is available from the Centre Office for $25.

Please contact Virginia Verrelli on tel: 03 9905 2704 or email: virginia.verrelli@eng.monash.edu.au

PROGRAM 6
RIVER RESTORATION

Program Leader
IAN RUTHERFURD

Report by Ian Rutherfurd

River Restoration Evaluation workshop

Workshop purpose and sponsor

Project 6.1 of the River Restoration program is concerned with the evaluation of rehabilitation projects. To kick off this project entitled "Stream restoration procedures and evaluation", we conducted a workshop on 12 March as part of the International Water 2000 Congress held in Melbourne. The workshop was entitled "Did we make a difference: evaluation approaches for stream restoration projects", and was fully sponsored by the Land and Water Resources Research and Development Corporation (LWRRDC). Thirty participants from many states and countries attended the workshop (instead of attending the Grand Prix!).

Monitoring for rehabilitation projects

After designing an evaluation plan for some hypothetical restoration projects, the participants heard talks by leading evaluation workers. We were fortunate to have Professor Jay O'Keefe from Rhodes University speaking about the monitoring program at the Kruger National Park in South Africa. Jay emphasised the importance of embedding monitoring (a cornerstone of evaluation) into a full rehabilitation plan that includes clear objectives. The South Africans have developed a very neat procedure where the goals and objectives can be linked right through to the on-ground monitoring. This process includes triggers for action called 'Thresholds For Concern'.

Evaluating biological inputs

Professor Sam Lake from Monash University presented a talk on the issues involved in designing a project that aims to evaluate the biological impacts of restoration. Here are a few of the key points that Sam made:

The larger the stream that is treated, the more likely you are to run out of reference sites or controls for the experiment.

Stream systems are likely to recover from disturbance much more slowly than the rate at which they were damaged. We need to think in terms of decades before we might see much change in biological communities in restored streams.

Experiments can involve many different measures ranging from the presence and abundance of organisms, through to the ecosystem functions such as respiration or photosynthesis. The only way we will do successful evaluation is to be very smart about the way the measures are designed.

Pitfalls of evaluation

Finally, Dr Mike Stewardson of The University of Melbourne presented a talk about some dangers of evaluation projects. A very real danger is being either too optimistic, or too pessimistic in our expectations. If we are too optimistic about the effects of evaluation, then we could find ourselves endorsing projects that are actually ineffective. An equal danger is that if we are too pessimistic about the outcome (eg. The number of extra fish), we will find that various treatments are seen to be ineffective, when in fact they may have been effective in some way. For example, imagine that we set a 95% confidence limit for the effect of an environmental flow regime, but find that the effect was only significant to 80% confidence limit. This suggests that the environmental flow is ineffective (by the strict 95% criterion), and there is a strong possibility that it would be taken back from the environment for other uses. Perhaps we need to explore more flexible ways of setting evaluation targets.

Main messages

- Need to define evaluation

Two very clear messages came out of the day. The first message is that we need to define very clearly what we mean by evaluation! There was some initial confusion in the workshop about what we were talking about. The scientists defined 'evaluation' in the very narrow sense of determining whether an intervention in a stream led to some change in physical and biological variables. Others in the audience saw evaluation much more in terms of program delivery: did a major program or project deliver what it said it would (eg. NHT). This evaluation is couched in terms of "appropriateness, effectiveness, and efficiency". There are some good Federal Government documents on this type of evaluation (see below).

- Ranking evaluation methodologies

Another clear conclusion from the extensive discussions on the day, is the need for a hierarchy of methodologies for evaluation. The reality is that Australia can only afford the time and money to do a few rigorous, scientific evaluations of major long-term, longitudinal rehabilitation projects at multi-reach or catchment scales (such as some of the projects planned in Project 6.1). We need robust evaluation procedures that provide useful information about the thousands of more modest rehabilitation projects that are already being carried out all over Australia.

Designing such procedures may be a task for the Restoration Program, and certainly for LWRRDC.

Thanks

There were many other good ideas that came out of the day, and these are being consolidated into a short report for LWRRDC. Many thanks for the people who attended the workshop, and special thanks to Dr Nick Schofield of LWRRDC and the corporation itself who initiated and paid for the workshop, and provided sponsorship for Professor Jay O'Keefe.

Reference

Department of Environment Sport and Territories, 1997. Evaluation guidelines. DEST, Canberra

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COMMUNICATION AND ADOPTION PROGRAM

Program Leader
DAVID PERRY

Report by Graham Rooney

Introducing the Yarra Catchment

About Melbourne Water

People often ask me why Melbourne Water is associated with the CRC for Catchment Hydrology, so I think it is appropriate to start at this question and explain our interest.

Melbourne Water comprises 450 people who manage sewerage, drinking water supply and drainage functions. I am part of the drainage function (Waterways and Drainage Group) where we provide everything from stormwater run-off requirements and advice on new subdivisions, through to controlling pest animal and plant species along waterways, and improving stormwater quality. The Group spends about $6 million to $8 million annually on waterway 'rehabilitation works'. Our jurisdiction covers a majority of the Port Phillip and Western Port catchments, and managed assets include waterways, channels, underground drains, retarding basins, pumping stations, levee banks, tidal gates, and wetland systems.

Then there is the Water Group, which harvests 'wholesale' drinking water, and sells it to the 'retail' water utilities. The Water Group needs information on factors affecting the yield of water supplied from catchments to reservoirs, and the means of managing water quality within reservoirs. Hence our involvement and great interest with the CRC.

About the Yarra River catchment

The Yarra River rises in the Great Dividing Range to the east of Warburton and flows 245 kilometres in a west to southwesterly direction until entering Port Phillip at Newport. Its catchment area is greater than 4,000 square kilometres and 1.5 million people live within its boundaries. Lower reaches flow through urbanised country, but a majority of the river is in rural areas.

Records over the period 1891 to 1986 have given a mean annual flow in the Yarra River (Warrandyte) at 718,000 ML (an average of 1,967 ML/day). The highest flow recorded at the city end is 1,120 cumec in 1934 (96,770 ML/day), while the lowest flow recorded is 0.2 cumec in 1968 (17 ML/day).

Unfortunately, the Yarra River has been always known as turbid – with a reputation for the river that 'flows upside-down'. This is partly unfair, since the river is turbid by

NEW WORKING DOCUMENT

DISAGGREGATION OF DAILY TO HOURLY RAINFALLS FOR FLOOD STUDIES

by
Walter Boughton

Working Document 00/2

This working document presents two models for disaggregating 9am to 9am daily rainfalls into temporal patterns of 24 hourly values. It is available from the Centre Office for $20

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NEW WORKING DOCUMENT

DEVELOPMENT OF A REAL-TIME FLOOD FORECASTING MODEL
VOLUME 4: EVALUATION OF THE XINANJIANG-URBS MODEL

by
R. Srikanthan
M.H. Khan
P. Sooriyakumaran
J.F. Elliott

Working Document 00/1

This working document and the three others in this series are available from the Centre Office for $20 each.

Please contact
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nature, picking up clay particles as it flows through an area of unstable soils in the upper Yarra Valley. Admittedly, land-use changes do exacerbate turbidity levels.

Current Yarra catchment management issues

- There has been extensive clearing through a majority of the catchment, along with the traditional conversion to agricultural land uses. A simple loss of the pre-existing tree and shrub cover is sufficient alone to affect the river detrimentally. Riparian vegetation is either poor or non-existent along many reaches. Weed invasion is rife.
- There is increasing pressure on river flows from diversions and off-stream storage with 1,319 licences and an allowed annual volume of 34,770 ML to be taken from the river. Water is also diverted into Sugarloaf reservoir from the Yering Gorge site for supply of treated drinking water.
- Melbourne is rapidly spreading, and we want to at least maintain water quality in our streams. In 1990, all urban areas accounted for 1,500 square kilometres, and it is estimated this will grow to 3,100 square kilometres by 2020. We need information and tools on how best to maintain water quality – in both 'green-field' developments, and new urban 'in-fill' developments.
- Loss of in-stream habitat is regarded as a serious problem. Some 40% of waterways are rated as 'poor' or 'very poor' in terms of habitat structure.
- Port Phillip is nitrogen limited, and catchment load reductions have been recommended in order to protect the bay's ecosystem into the future. Storm events have been identified as the key to managing nitrogen-load reductions.
- Historical willow planting along many reaches is evident today in the proliferation of mature stands. Biodiversity and channel capacity suffers, but fortunately, we know what needs to be done to rehabilitate streams from the willow menace. All we need is time and money.
- Fish navigation appears possible - even through urban inner Melbourne - however so many barriers remain. Native fish struggle with fishway designs that work overseas, so information is needed on cost-effective designs that will work in our country and jurisdiction.
- Bacterial contamination at bay beaches is a perennial public concern, and stormwater runoff is seen as a major culprit.
- Litter in streams and on bay beaches is regarded as a serious water quality issue by the public.

If in-stream ecosystem values are to be improved, we need information on the nature of land-based works, and where they should be concentrated. So many of the CRC projects will directly link with Waterways and Drainage programs. The Water Group has benefited from the initial CRC research, in both understanding catchment-vegetation influences on water yield to reservoirs, and the nature of diffuse-source contributions to poor reservoir water quality. We expect these understandings to grow, while being complemented with information for better managing in-stream flows.

Our main pursuits and philosophy

- Poor water quality is a concern, and diffuse sources have to be managed if improvements are to occur.
- We consider that improving stream health - including fish, invertebrates, and platypus – is the ultimate measure of whether waterway management programs are working.
- Waterways and Drainage is moving towards revegetation from a previous emphasis on bed and bank stabilisation – in particular, there is a focus on riparian zone rehabilitation that incorporates 'indigenous' broad vegetation types.
- Programs are being developed in order to scope the reduction of nitrogen loads to Port Phillip, and it is essential to work with other agencies if possibilities are to be achieved.
- We are encouraging the construction of wetland systems to treat urban stormwater.
- There is a greater interest in establishing if and how our waterway works affect specific animal and plant communities, and if so, how may we improve our works.

Possibilities and synergies

Melbourne Water is a participant in the CRC for Freshwater Ecology, so there are wonderful opportunities in undertaking joint research. Because we undertake a large number of capital works projects each year, it is possible to schedule research on relevant projects.

A Yarra Forum is being initiated, where researchers and managers can come together to reveal findings and gaps in our knowledge.

A number of 'friends' groups exist in the catchment. All are enthusiastic, and along with Waterwatch groups, want to provide assistance.

Waterways and Drainage is not the only body managing the drainage system. Municipal government manages the smaller systems that feed into ours. Links already exist to several municipalities due to Waterway Activity Plans and Stormwater Management Plans. These links may prove useful in the new CRC.

As Focus Catchment Coordinator, I will be preparing a regular newsletter containing information on CRC projects and other studies and research of interest in the Yarra basin. If you would like to receive copies of the newsletter, drop me a line at my e-mail address.

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CRC PROFILE

Mike Brisk

Professor Michael Brisk, Dean of Engineering at Monash University, has had a career which has spanned both industry and academia in roughly equal proportions over almost forty years.

He graduated with the University Medal in Chemical Engineering from the University of Sydney in 1960, and obtained a PhD from the same university in 1965. In the early sixties he lectured in chemical engineering at Sydney, having been appointed specifically to teach process control when Dr Charles Sinclair left Sydney to start up the Chemical Engineering Department at the then infant Monash University – a subliminal link to the Faculty where Professor Brisk was to become dean some 30 years later. He returned to Sydney in 1971 as senior lecturer in process control and process systems engineering after having worked in process control and reaction engineering with ICI in the UK for six years, very much involved in the exciting early days of applications of computers to plant control.

His academic career in the seventies included a stint as a visiting academic at Imperial College of Science and Technology in London, and extensive consulting for Australian process industries. The lure of industry proved too strong, and he joined ICI Australia in 1983, managing applied research at the manufacturing complex in Botany, Sydney. He transferred to ICI Australia Engineering in Melbourne in 1988 to establish a group which pioneered the applications of advanced process control in ICI Australia. Later, as an Engineering Associate, and International Technology Leader in advanced process control for the ICI Group worldwide, he led the development of the Group's process control strategy, working with ICI engineers in the UK, South Africa and the Asia Pacific region.

His first real contact with Monash was as an Adjunct Professor, spending one day a week teaching process control to chemical engineers in 1994. In 1995 he joined Monash full time as Dean of Engineering. He still lectures in process control to final year chemical engineering students, and has research interests in chemical reactor control, and the economic benefits of control, but has little time to pursue them. Unfortunately, his strong hobby interest in macro-photography has fallen victim to those same time constraints.

NEW WORKING DOCUMENT

An Integrated Dataset of Climate, Geomorphological and Flood Characteristics for 104 Catchments in South-East Australia

The two volumes (750+pp) consist of over 150 papers covering all aspects of stream management.

by

Ataur Rahman
Russell Mein
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Working Document 99/2

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PLEASE SEE PAGE 2 OF THIS CATCHWORD FOR DETAILS.

He chairs the University's Occupational Health and Safety Policy Committee where he attempts to apply his chemical industry experience of emphasis on safe working practices and the culture of a safety conscious environment to the academic workplace. Within the Engineering Faculty he has led a major re-structuring of the BE degree to incorporate the key recommendations of the 1996/97 Review of Australian Engineering Education, seeking to broaden students' perceptions of the context of engineering and their understanding of the profession's responsibilities to, and interactions with, the community at large. Keenly interested in and aware of the Asian region (no doubt partly due to the fact that he was born in Shanghai), he intends to retain and further develop Engineering's status as the faculty with the third largest international student enrolment at Monash.

In the context of the CRC for Catchment Hydrology, he admits that his only real prior experience related to issues of water conservation and quality has been the design of effluent control systems for chemical plant discharges to sewer. However, he did work with a group of students developing a computer model of the surface water systems at Mt Isa Mines in the seventies. An interesting challenge then was the handling of monsoonal rains with precipitation up to 100mm/h !

Professor Brisk is a Past President of the NSW Group of the Institution of Chemical Engineers, and a recipient of the tripartite IEAust/IChemE/RACI Award for Excellence in Applied Chemical Engineering for his work in process control. He is a Fellow of the Australian Academy of Technological Sciences and Engineering, and is currently the Chair of the Australian Council of Engineering Deans.

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WHERE ARE THEY NOW?

Report by Xudong Sun

Where is Xudong Sun now? He is still in Melbourne.

After submitting my PhD thesis in June 1998, I was given the opportunity of working in CRC for a short period to be involved in the CRC flood hydrology project on radar remote sensing for hydrological applications. The main objective of the project was to develop of a space-time model of rainfall suited to Australian conditions. Most of the work related to my PhD research project.

In early 1999, I was employed by Sinclair Knight Merz (SKM) in its groundwater section. Much of my work was concentrated on groundwater modelling, groundwater contamination transport, and climate change impacts on surface and ground water. I also developed some MATLAB graphical software for various model output displays.

In September 1999, I came back to the Bureau of Meteorology Research Centre (BMRC) to work on regional rainfall analyses. My current job involves of using kriging methods to analyse daily rainfall distributions over the Australian region. The main tool for measuring rainfall was the Australia raingauge network, in conjunction with satellite remote sensing. The aim of the analysis is to provide grid rainfall values at short spatial-time scales. This rainfall analysis system is important for operational weather forecasting and hydrological applications.

Over the years, I have been enjoying working and studying in various earth science disciplines. I continue to have the opportunity to be involved with CRC for Catchment Hydrology in my current work, and earlier this year attended the BMRC planning meeting on identifying possible joint activities with the CRC.

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